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Research Article

The Effect of Explicit Environmentally Oriented Metacognitive Guidance and Peer Collaboration on Students' Expressions of Environmental Literacy

Idit Adler, Michal Zion, and Zemira R. Mevarech

School of Education, Bar-Ilan University, Ramat Gan, Israel

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Abstract: The prevalence of habitat and life-threatening environmental problems has motivated environmental researchers to develop education programs to strengthen students' environmental literacy. We argue that the connection between environmental literacy and metacognition is theoretically promising. Therefore, we developed the *Meta-CIC* model, which is designed to develop students' environmental literacy, in parallel to supporting their metacognition. The core of this model is open inquiry-based learning. An explicit environmentally focused metacognitive guidance (*Meta*) was embedded within the inquiry setting. This guidance referred to the components of metacognition and the strands of environmental literacy. The model includes two levels of collaboration: the *Collaborating Inquiry* (*CI*), which refers to the interactions between a pair of students working on an inquiry project; and the *Collaborating Inquiry Community* (*CIC*), which refers to the interactions among pairs of students working on different projects. We investigated the contribution of the *Meta-CIC* model to students' expression of environmental literacy. For this purpose, 250 seventh and eight grade students, who conducted open inquiry projects throughout a full school year, participated in this research. We examined students' environmental literacy using two tools: an environmental literacy questionnaire, which adopts a positivist, outcome-based approach; and an innovative Environmental Literacy INventory (ELIN), which adopts a phenomenological process-based approach. The environmental literacy questionnaire served as pre- and post-test measurements. The ELIN was used to analyze students' reflections, following their involvement in the inquiry process. The results of this study provide supporting evidence for the theoretical relationship between metacognition and environmental literacy, and demonstrate the different effects of the *Meta* and the *CIC* components on students' expressions of environmental literacy. The results also point to the importance of providing explicit and context-based metacognitive support. This study highlights the importance of developing students' high order thinking and implementing the *Meta-CIC* model, within the framework of environmental education. © 2015 Wiley Periodicals, Inc. J Res Sci Teach 53: 620–663, 2016

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Correspondence to: M. Zion; E-mail: michal.zion@biu.ac.il
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תקציר

האתגרים הסביבתיים הרבים העומדים בפני האנושות הניעו חוקרים סביבתיים לפתח תכניות לימוד המיועדות לפיתוח אוריינות סביבתית בקרב תלמידים. במחקר זה אנו טוענים כי קשר בין אוריינות סביבתית ובין מודעות מטה-קוגניציה הינו מבטיח מבחינה תיאורטית. לכן, פיתחנו את מודל ההוראה *Meta-CIC*, שמיועד לפיתוח אוריינות סביבתית בקרב תלמידים, במקביל לתמיכה במודעות המטה-קוגניטיבית שלהם. למידת חקר פתוח מהווה את לב המודל. הכוונה מטה-קוגניטיבית מפורשת מכוונת אוריינות סביבתית (*Meta*) שולבה בתוך סביבת החקר. ההכוונה התייחסה הן לרכיבי האוריינות הסביבתית והן לרכיבי המודעות המטה-קוגניטיבית. בנוסף, המודל כולל שתי רמות של למידה משתפת: רמה אחת שמתייחסת ליחסים בין זוג תלמידים העובדים על אותה עבודת חקר *Collaborating Inquiry (CI)*; ורמה שנייה שמתייחסת ליחסים בין זוגות תלמידים העובדים על עבודות חקר שונות *Collaborating Inquiry Community (CIC)*. במחקר נבחנה השפעת המודל על ביטויי אוריינות סביבתית של התלמידים. למטרה זו השתתפו במחקר 270 תלמידים בכיתות ז׳ ו–ח׳, אשר עסקו בחקר פתוח במשך שנת לימודים מלאה. בדקנו את האוריינות הסביבתית של התלמידים באמצעות שני כלים: שאלון אוריינות סביבתית, הנוקט בגישה פוזיטיביסטית ממוקדת תוצר; ובמחוון שנבנה במיוחד עבור מחקר זה Environmental Literacy INventory (ELIN), הנוקט בגישה פנומנולוגית ממוקדת תהליך. ה-ELIN שימש לבחינת רפלקציות של תלמידים שנכתבו בעקבות מעורבותם בתהליך החקר. תוצאות המחקר תומכות בקשר התיאורטי בין אוריינות סביבתית ובין מודעות מטה-קוגניטיבית, ומציגות את ההשפעה השונה של הרכיבים של המודל *Meta* ו-*CIC* על ביטויי האוריינות הסביבתית של התלמידים. התוצאות גם מצביעות על החשיבות של תמיכה מטה-קוגניטיבית מפורשת המקושרת היטב לתחום הידע. לבסוף, המחקר מצביע על החשיבות של פיתוח חשיבה מסדר גבוה של תלמידים ויישום המודל *Meta-CIC* במסגרת החינוך הסביבתי.

Keywords: cooperative grouping; environmental education; inquiry; metacognition

The crucial role of environmental education in the face of environmental conflicts has long been acknowledged. According to the Tbilisi Declaration, the goal of environmental education (EE) is to develop a world population that is aware of, and concerned about, the environment and its associated problems (UNESCO, 1977). Specifically, EE should empower students worldwide with the knowledge, skills, attitudes, motivations, and commitment to work both individually and collectively toward solving current problems and preventing new ones (UNESCO, 1977). These goals can be achieved by developing "environmental literacy," which Roth (1992) defines as the capacity to perceive and interpret the relative health of environmental systems, and to take appropriate action to maintain, restore, or improve the health of those systems. Roth (1992) considers environmental literacy as a continuum of competencies, divided into three working levels: nominal, functional, and operational. Each of these levels is organized around four major strands: knowledge, affect, skills, and behavior. According to Roth, people tend to progress through the development of environmental literacy in stages that include several components: awareness, concern, understanding, and action (Disinger & Roth, 1992; Roth, 1992). The highest degree of environmental literacy is achieved only when these components come together and result in the implementation of environmental actions (Roth, 1992).

According to Jickling (2003), behavioral change should not be the ultimate goal of environmental educators, because such a goal presents EE as an instrumentalist and ideological tool. Consequently, EE instructs students what to think instead of how to think. In fact, EE should promote unconventional thinking and more radical ideas (Jickling, 2003; Orr, 1999), and enhance a critical stance toward the world and toward oneself by promoting discourse, debate, and reflection (Wals & van der Leij, 1997). Educators who support this approach argue that greater emphasis should be given to the development of deeper educational and learning processes, and to the development of autonomous thinking about environmental issues (Wals & van der Leij, 1997). Accordingly, Stables and Bishop (2001) proposed to consider differences among functional (the "facts"), cultural (the socially significant), and critical (the ability to critique and to reconstitute an argument) environmental literacy. The authors argued that this approach depends on a broad view of environmental literacy as an essentially semiotic relationship with the biophysical world (Stables & Bishop, 2001). Consequently, a highly environmentally literate population, according to this definition, would have the ability to engage with environmental issues at a high level (Stables & Bishop, 2001).

A central question in the field of EE is how to produce environmentally literate citizens. According to Hungerford and Volk (1990), traditional thinking asserts that humans can change behavior by becoming more knowledgeable about the environment and its associated issues. Though there is some evidence that knowledge and attitudes are positively correlated (e.g., Bradley, Waliczek, & Zajicek, 1999), a gap between knowledge about environmental problems and actions to support the environment often exists (Kollmuss & Agyeman, 2002). Kaiser and Fuhrer (2003) and Frick, Kaiser, and Wilson (2004), further argued that different forms of knowledge must work together in a convergent manner to foster environmental behavior. Today, because a new focus implies less emphasis on establishing linkage between educational interventions and behavioral outcomes (Wals, Brody, Dillon, & Stevenson, 2014), much interest focuses on the conditions and learning processes that enable citizens, young and old, to (i) develop their own capacity to think critically, ethically, and creatively in appraising environmental situations; (ii) make informed decisions about those situations; and (iii) develop the capacity and commitment to act individually and collectively in ways which sustain and enhance the environment (reviewed by Marcinkowsky et al., 2014). Accordingly, Wals and van der Leij (1997) claimed that environmental education should be a learning process which enables participants to construct, transform, critique, and emancipate their world in an existential way (e.g., Wals & Jickling, 2002). McBeth and Volk's (2010) recent large-scale survey heightened the significance of promoting deep educational processes within the framework of environmental education; their study described the students' tenuous grasp of critical thinking and the decision-making skills necessary to resolve environmental issues. Notably, Littledyke (2008) emphasized the importance of explicitly integrating cognitive and affective domains within science and environmental education to develop students' relationship with the environment. This relationship then may translate into pro-environmental behavior.

The goal of this study is to investigate a model aimed at developing students' environmental literacy. Our underlying assumption is that environmental literacy should be developed through deep educational learning processes, which would enhance students' autonomous and critical thinking about environmental issues, and result in changes in environmental knowledge attitudes, and behavior. Consequently, we argue that environmental programs aimed at fostering students' environmental literacy should in parallel support students' metacognition.

Environmental Literacy and Metacognition

Metacognition refers to the ability to reflect upon, understand, and control one's cognitive processes (Schraw & Dennison, 1994; Schraw, Crippen, & Hartley, 2006). Accounts of metacognition distinguish between two major components: *knowledge about cognition* and *regulation of cognition* (Brown, 1987; Flavell, 1976; Schraw & Dennison, 1994). *Knowledge about cognition* includes three subprocesses which facilitate the reflective aspect of metacognition: declarative knowledge ("what"), procedural knowledge ("how"), and conditional knowledge ("when" and "why"). *Regulation of cognition* includes several of subprocesses that facilitate the control aspect of learning; five subprocesses have been discussed extensively: planning, process management strategies, monitoring, debugging, and evaluation (Schraw & Dennison, 1994; Schraw & Moshman, 1995).

The argument for the importance of supporting students' metacognition is based on several aspects of metacognition and environmental literacy. First, the skills which are at the core of environmental literacy, such as: using creative thinking, searching for and organizing information, thinking and planning ahead, and evaluating the consequences of potential actions (Roth, 1992) are related to the skills which metacognition supports and scaffolds (Schraw & Dennison, 1994). Research also suggests that students' active engagement in metacognition is a key to developing deeper conceptual understanding (Nielsen, Nashon, & Anderson, 2009) and critical thinking (Halpern, 1998; Ku & Ho, 2010; Magno, 2010). Both conceptual understanding and critical thinking are crucial to environmental literacy: They enable individuals to perceive and interpret the relative health of environmental systems, tackle multivariable environmental problems, and be actively involved in the implementation of valid and applicable solutions (Mogensen, 1997; Roth, 1997; Wals et al., 2013; Wals & Jickling, 2002; Wals & van der Leij, 1997). Furthermore, critical thinking enables the individual to examine his environmental or non-environmental personal behaviors, and identify behaviors that could be changed (Heimlich & Ardoin, 2008).

As the relationship between environmental literacy and metacognition seems theoretically promising, our research aimed at developing an instructional model which would support students' metacognition within the framework of EE. Based on relevant literature, a key characteristic of the model includes inquiry-based learning.

Supporting Students' Metacognition Through Inquiry-Based Learning

According to the NRC (1996), scientific inquiry "refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world" (NRC, 1996, p. 23). Inquiry-based learning engages students in science through hands-on activities (Minner, Levy, & Century, 2010). During inquiry projects, 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). Consequently, students acquire an authentic understanding of the nature of scientific knowledge, and develop thinking strategies as well as a deep understanding of science content (Bell, Blair, Crawford, & Lederman, 2003). Engagement in inquiry also provides students with an opportunity to develop their metacognition: Inquiry promotes an active reflection of problems, and provides the students with many opportunities to monitor their learning and evaluate errors in their thinking, or gaps in their conceptual understanding (Kipnis & Hofstein, 2008; Schraw, Crippen, & Hartley, 2006).

In the field of EE, several educators have examined the instructional effects of inquiry-based programs on variables associated with environmental literacy (e.g., Culen & Volk, 2000; Hsu, 2004; Ramsey, 1993; Volk & Cheak, 2003). These programs were generally modeled after Hungerford, Peyton, and Wike's (1980) goals for curriculum development in EE. According to these goals, environmental programs should: (a) provide science and ecological foundations of environmental issues or problems; (b) develop awareness of environmental issues; (c) involve students in environmental issue-investigation and evaluation; and (d) train students in citizenship action-skills. Nevertheless, these programs did not consider the development of metacognition as an objective or as a key element, and therefore did not emphasize this aspect in the environmental curriculum.

Though metacognitive skills are promoted by inquiry learning, they are also considered as a prerequisite for the successful engagement in inquiry (e.g., Andersen & Nashon, 2007). According to this view, to optimize the inquiry process and realize its full potential, students' metacognition should be actively supported during their engagement in the inquiry process (White, Frederiksen, & Collins, 2009). Embedding an explicit metacognitive guidance within the inquiry process is a method to support students' metacognition.

Supporting Students' Metacognition Through Explicit Metacognitive Guidance

Schraw (1998) describes four ways to support students' metacognition in classroom settings. These methods include: promoting *general awareness* of the importance of metacognition, improving *knowledge about cognition*, improving *regulation of cognition*, and fostering *environments that promote* metacognitive awareness.

Students' *knowledge about cognition* can be supported through the explicit teaching of strategies (Schraw, 1998). For example, Ben-David and Zohar (2009) embedded explicit teaching about thinking strategies within the scientific inquiry-based learning. This metacognitive support included the following cognitive procedures: making generalizations about a thinking strategy; naming the strategy; explaining when, why, and how such a strategy should be or not be used; indicating the disadvantages of not using appropriate strategies; and identifying the task characteristics which call for the use of the strategy.

The *regulation of cognition* subcomponent of metacognition has been generally supported by reflective metacognitive questions or prompts embedded within the learning process (King, 1991; Lin & Lehman, 1999; Schraw, 1998; Tanner, 2012). For example, the IMPROVE method, an instructional method aimed at enhancing mathematical reasoning, includes three kinds of metacognitive questions: *comprehension,* which orients the students to articulate the main ideas in the problem, classifies the problem into an appropriate category, and elaborates the new concepts; *strategic*, which refers to strategies appropriate for solving the problem; and *connection,* which refers to the similarities and differences between the current problems and previously solved problems (Mevarech & Kramarski, 1997). Zion, Michalsky, and Mevarech (2005), expanded the IMPROVE techniques into an inquiry-based learning environment. This metacognitive guidance included two sets of metacognitive questions for regulating the learning process: question*s* which refer to knowledge about the problem-solvers, the goals of the assignment, and problem solving strategies; and questions which educate students in regulating, controlling, and criticizing the cognitive processes and products.

Recently, a growing research interest has emerged regarding the use of computer-based learning environments to support students' metacognition in a science and technology curriculum (e.g, Graesser & McNamara, 2010; Manlove, Lazonder, & De Jong, 2007; Quintana, Zhang, & Krajcik, 2005). Such environments typically provide the students with regulative tools, which support various aspects of students' metacognition. An example of such environment includes White and Frederiksen's (2005) Inquiry Island software. In Inquiry Island, students' metacognition is supported by two kinds of software advisors: *task advisors*, who serve as cognitive models for inquiry processes, and provide the students with knowledge of goals for the inquiry step, strategies for accomplishing them, and criteria for monitoring their effectiveness; and *general-purpose advisors*, who serve as models of cognitive, social and metacognitive competencies, and whose expertise may be useful throughout the inquiry process.

Jost, Kruglanski, and Nelson (1998) claim that the traditional views of metacognition as an individual and self-reflective process have restricted its focus, as they have ignored the role of metacognition about other people. To overcome this restricted focus, Goos, Galbraith, and Renshaw (2002) expanded the process of metacognition to include collaborative conversations among peers of comparable expertise who made the process of monitoring and regulation overt. Consequently, peer-learning and specifically peer-collaboration serves as an additional technique to support students' metacognition.

Supporting Students' Metacognition Through Peer Collaboration

Research has demonstrated that peer learning, namely knowledge acquisition and skill building through active help and support among status equals or matched companions (Topping, 2005), can prompt metacognitive behaviors (Salonen, Vauras, & Efklides, 2005). Through social interactions, students can develop their self-regulation skills and metacognition (de Jong, Kollöffel, van der Meijden, Staarman, & Janssen, 2005; Lajoie & Lu, 2012). According to a model suggested by Topping and Ehly (2001), during engagement in peer learning, peers become more consciously aware of what is happening to them in their learning interaction, and better able to monitor and regulate the effectiveness of their own learning strategies.

Collaborative learning is a form of peer learning in which particular forms of interaction among people are expected to occur, which would then trigger learning mechanisms (Dillenbourg, 1999). Peer collaboration involves students at roughly the same levels of competence (Damon & Phelps, 1989). During collaborations, the students are engaged in mutual discovery, reciprocal feedback, and sharing of ideas. Therefore, peer collaboration emphasizes equality and mutuality (Damon & Phelps, 1989). According to Dillenbourg (1999), there are four ways to increase the probability of students' collaborative interactions: to set up initial conditions, and carefully design the collaborative situation (Lou, Abrami, & Spence, 2000); to over-specify the collaborative interactions with a *scenario* based on *roles* (e.g., King, 1997, 1998; Palincsar & Herrenkohl, 2002); to scaffold productive interaction by encompassing interaction rules in the medium (e.g., Chinn, O'Donnell, & Jinks, 2000); and to monitor and regulate the collaborative interactions (e.g., Goos, Galbraith, & Renshaw, 1999).

Research has shown that collaborative learning has the potential to develop metacognition (e.g., Larkin, 2006; Nielsen et al., 2009; Siegel, 2012). According to Frith (2012), collaboration and metacognition are mutually related. On the one hand, the social interactions enhance metacognition, as individuals improve their ability to provide a more accurate report on the reasons for actions and experiences. On the other hand, the ability to reflect and report on one's activities and experiences improves collaboration, through an optimized sharing of resources and information. During collaborative interactions, both self- and social regulatory mechanisms interrelate: Self-regulation includes the cognitive and metacognitive regulatory processes used by individuals to plan, enact, and sustain their desired course of actions (*self-regulated learning*); social-regulation includes reciprocal regulation of each other's cognitive and metacognitive processes (*co-regulated learning*), and occasional genuinely shared modes of cognitive and metacognitive regulation (*socially shared regulated learning*) (Hadwin & Oshige, 2011; Volet, Vaurus, & Salonen, 2009). Research suggests that optimally functioning groups combine all three forms of regulatory competences during collaborations (Grau & Whitebread, 2012; Järvelä & Hadwin, 2013; Järvelä, Järvenoja, Malmberg, & Hadwin, 2013; Rogat & Linnenbrink-Garcia, 2011).

Slavin (1996) claimed that an important issue concerns the conditions under which peer interactions affect achievements, and in the case of metacognition—under which conditions would peer interactions optimally develop students' metacognition. Studies which have examined the effects of interventions designed to support self-regulation and metacognition within a collaborative environment, indicate an overall positive effect of these interventions on the development of students' metacognitive awareness (e.g., Hogan, 1999; King, 2007; Sandi-Urena, Cooper, & Stevens, 2011; White & Frederiksen, 2005; Yarrow & Topping, 2001). The studies also imply that the interventions should be thoughtfully designed, in order to overcome the gap between metacognitive awareness and implementation of the metacognitive skills (Hogan, 1999; Sandi-Urena, Cooper, & Stevens, 2011).

Supporting Students' Metacognition and Developing Their Environmental Literacy Through the *Meta-CIC* Model

In this research, we developed the *Meta-CIC* model which aims to develop students' environmental literacy. This model is based on the proposed theoretical relationship between environmental literacy and metacognition. In the *Meta-CIC* model, an explicit and environmentally oriented metacognitive guidance, and an innovative collaborative learning script, serve as scaffolding for students' metacognition. Both the metacognitive guidance and the collaborative script are embedded within an open inquiry-based learning approach (see Figure 1a,b).

The core of this model is the challenging open inquiry-based learning, which is the highest level of inquiry (Schwab, 1962). In this highly student-centered instructional technique, students are active decision-making participants in all stages of the inquiry process (NRC, 2000); the students engage in scientific questions, design and conduct investigations, formulate explanations

(a) Research Goal:
To develop students' environmental literacy

(b) The *Meta-CIC* model – provides metacognitive support

Theoretical construct	Open inquiry-based learning	***Meta component*** Explicit environmentally oriented metacognitive guidance		***CIC component*** Peer collaboration	
Educational intervention	Environmental inquiry projects	*Knowledge about cognition* - Strategy Evaluation Matrix (**SEM**)	*Regulation of cognition* - Regulatory Checklist (**RC**) - Reflective Metacognitive Questions (**RMQ**)	*Collaborating Inquiry* (***CI***)	*Collaborating Inquiry Communi.* (***CIC***)

(c) Treatment conditions

	Baseline intervention		*Explicit environmentally oriented metacognitive guidance* ***Meta component***	*Collaborative Inquiry Community* ***CIC component***
	Environmental inquiry projects	***Collaborative Inquiry (CI)***		
Comparison group	+	+		
Meta group	+	+	+	
CIC group	+	+		+
Meta-CIC group	+	+	+	+

(d) Research tools

Outcome-based approach **Environmental literacy questionnaire**	Process-based approach **Environmental Literacy INventory (ELIN)**
The questionnaire examines: Environmental knowledge, attitudes, and behavior	The ELIN examines: Environmental knowledge, affect, skills, and behavior.

Figure 1. Overview of the research: (**a**) The research goal; (**b**) The *Meta-CIC* model and its implementation in the educational intervention; (**c**) The research design; and (**d**) The research tools.

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., Sadeh & Zion, 2009). In the *Meta-CIC* model, the role of inquiry-based learning is two-fold: it is a means to expand students' familiarization with their local environment (Duvall & Zint, 2007); and is a means to support students' metacognition within the framework of EE.

An explicit and environmentally oriented metacognitive guidance, represented by the word *Meta* in the model, is embedded within the inquiry-based learning approach. This metacognitive guidance combines the two major components of metacognition (*knowledge about cognition* and *regulation of cognition*) and is based on previously researched metacognitive tools (a description of the metacognitive guidance is found in the Methods section). In addition, this explicit metacognitive guidance is environmentally focused, and refers to the strands of environmental literacy (knowledge, affect, and behavior). This environmental focus was added to the "traditional" metacognitive guidance due to the debate in the literature concerning the domain-dependency of metacognition. Several researchers found evidence for general, domain-independent metacognition (e.g., Schraw, Dunkle, Bendixen, & Roedel, 1995; Schraw & Nietfeld, 1998; Veenman & Verheij, 2001; Veenman, Wilhelm, & Beishuizen, 2004); other researchers found evidence against a general metacognitive ability (e.g., Kelemen, Frost, & Weaver, 2000). In their attempt to bridge the gap between domain dependent and independent metacognition, Veenman and Spaans (2005), and van der Stel and Veenman (2008), claim that metacognition may initially develop in separate domains. Later, these domains merge into a more general repertoire of metacognitive skills which is applicable and transferable across tasks and domains. Therefore, Veenman and Spaans (2005) emphasize the importance of instructing students to acquire metacognitive skills in various specific domains.

Peer collaboration is used to further support students' metacognition. The collaborations in this model are based on **face-to-face** interactions. These interactions are important because they promote the development of social relationships, which play a major role in students' meaningful experiences (e.g., James & Bixler, 2008). In addition, these interactions are appropriate for activities such as brainstorming and visual demonstration (Meyer, 2003), and promote non-formal interactions, visual and verbal communications. These interactions encourage students with a wide range of learning abilities to participate during the collaboration (Michalsky, Zion, & Mevarech, 2007). Throughout the inquiry process, the students collaborated with each other using an innovative scheme which included 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. These *CIC* interactions expand the learning beyond the limitations of one pair by providing more opportunities for the students to exchange insights, ideas, and strategies, and to learn from each other's strengths and weaknesses (Lou, 2004; Lou & MacGregor, 2004). Furthermore, in the *CIC*, the context and progress of other working projects provide the students with both motivational support and new insights (Lou, 2004; Lou & MacGregor, 2004). The students provide feedback to each other, and in doing so, they are able to develop critical thinking, self-regulation skills, and metacognition.

Research Goals, Objectives, and Hypotheses

We are not aware of a research that has evaluated the possible contribution of supporting students' metacognition to the development of environmental literacy. This is the main objective and challenge of this research. Therefore, we developed and implemented the *Meta-CIC* model, in which an explicit environmentally oriented metacognitive guidance (*Meta*) and peer collaboration (*CIC*) are embedded within inquiry-based learning. We evaluated the contribution of the *Meta* and the *CIC* components to the development of students' environmental literacy. Specifically, we posed the following three research questions:

1. What is the contribution of the **explicit environmentally oriented metacognitive guidance (*Meta* component)** to the development of students' **environmental literacy**?
2. What is the contribution of the Collaborating Inquiry Community (*CIC* component) to the development of students' **environmental literacy**?
3. What is the combined contribution of the ***Meta-CIC*** **model** to the development of students' **environmental literacy**?

We hypothesize that both the *Meta* and the *CIC* components will each contribute to the development of students' environmental literacy: the *Meta* component, which includes the *explicit* support to students' metacognition, will encourage students' engagement in covert autonomous reflection. In contrast, the *CIC* learning environment, which includes the *implicit* support to students' metacognition, will create a supportive environment for students' engagement in the process of overt reflection through peer monitoring, evaluation, and reciprocal feedback. We further hypothesize that the combination of both components will have a synergistic effect on the development of environmental literacy, because of the reciprocity between the covert reflection, triggered by the *Meta* component, and the overt reflection, triggered during the collaborative interactions of the *CIC* component (see Frith, 2012).

Methods

We will first describe the context of the research and its participants, followed by the educational intervention which was designed according to the *Meta-CIC* model. Then, we will present the research design and the measurements that were developed and used for this research.

Research Context

The study was conducted within the framework of an environmental program supervised by the Council for a Beautiful Israel (CBI), a public organization aimed at promoting quality of life in Israel through environmental education. The program aimed to develop students' environmental literacy. The schools' decision to register with the CBI environmental program was usually driven by an enthusiastic and motivated teacher, who was willing to lead and supervise the students' inquiry projects. The program was comprised of two components. The first component included monthly visits to the CBI, in which the CBI staff introduced the students to their environment, and provided them with knowledge and awareness of environmental issues related to both their surroundings and to the principle of sustainable development. The second component included year-long open inquiry-based environmental projects, which were conducted by the students at their schools, under the supervision of their teachers. Importantly, once a school registers with the program, the inquiry projects become part of the students' mandatory science-education curriculum.

Participants

Students. At the beginning of the school year, for three consecutive years, the researchers recruited teachers and their classes, from a pool of classes that enrolled in the CBI environmental program. The participants consisted of 250 high-achieving seventh and eighth grade students

(13–14 years old) from five Israeli junior-high schools, of similar average socioeconomic status (as defined by the Israel Ministry of Education). The students were distributed across nine high-achieving homologous classes, in which students were selected according to their academic achievements.

Teachers. The teachers who participated in the research were the primary teachers of the CBI environmental program in their school. These teachers regarded environmental issues as a top priority in education; therefore, they enrolled in the CBI program, out of a wide range of school-based enrichment programs. Overall, five experienced female teachers from five different schools participated in this study. All the teachers held a bachelor's degree in science education, and a teaching certificate. They all had at least 3 years of experience with open inquiry-based teaching. The teachers participated in a professional development program, which included a 4 hour individual in-service training session. In addition, throughout the entire inquiry process, the researcher closely assisted the teachers, and maintained ongoing contact with them through weekly 1 hour sessions. These weekly meetings had two goals: (a) to supervise teachers' implementation of the educational intervention in their classes (described herein); and (b) to facilitate the teachers' role in guiding the students throughout the inquiry process.

Educational Intervention

The educational intervention was designed according to the *Meta-CIC* model. Consequently, it included three major components: (a) a *baseline curriculum*; (b) the *Meta* component; and (c) the *CIC* component. The following sections describe each of these components (see Figure 1b).

(a) **The *baseline curriculum*—engagement in environmental inquiry projects.** Instructed by their teachers, the students studied their nearby environment, identified and selected real-life environmental issues related to their surroundings, and were then engaged in challenging year-long socio-environmental open inquiry projects. Because the students were engaged in open inquiry in which they studied self-derived questions, their inquiry projects embraced a wide range of environmental topics, such as: recycling, consumption, environmental education, environmental hazards or nuisances, factories and industries, animals in urban environments (see Supplementary Table S1 for examples of specific inquiry questions).

The students worked in pairs of their own selection (*CI* component), and conducted the inquiry projects after school hours. The inquiry projects followed the scientific inquiry process, and were divided into three phases which comprised a total of seven stages: (a) *framing the inquiry*, which included choosing a socio-environmental issue and formulating the inquiry question; and generating the hypothesis; (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; organizing a discussion and drawing conclusions. The students were required to complete each stage of the inquiry process within approximately 1 month, except for the 2-month requirement to develop the research tools. The students managed the inquiry process, provided they submitted their assignments at each stage of the inquiry process according to the project submission schedule.

Throughout the process, the students documented their inquiry in a structured report which resembled a scientific article. In this report, the students articulated the inquiry question, the theoretical background, the hypothesis, research tools, data analysis, the discussion, and the conclusions. In addition to writing the structured chapters of the reports, the students were instructed to include an introduction and a summary chapter. In these chapters, students were prompted to reflect and describe their personal perspectives on their inquiry process. In the introduction, the students indicated the reasons and importance for choosing their topic, their inquiry question, and the conclusions. In the summary chapter, students reflected upon their process of inquiry, addressed the conflicts, difficulties, and strategies they implemented, and elaborated on any new insights they learned about either the environment or themselves (see Supplementary Table S2 for a complete description of the prompts).

Supporting Students' Inquiry Process. Though open inquiry is a highly student-centered process in which students take responsibility for their learning (Herron, 1971; NRC, 2000; Schwab, 1962), researchers have underscored the importance of providing students with extensive scaffolding (Hmelo-Silver, Duncan, & Chinn, 2007; Kirschner, Sweller, & Clark, 2006; Sweller, Kirschner, & Clark, 2007). Therefore, we developed a course syllabus for each of the inquiry stages, which included theoretical and practical explanations concerning the procedural aspect of the inquiry process. Each syllabus was based on central themes from the field of science education and inquiry-based learning, such as: scientific practices (Osborne, 2014), Nature of Science (Abd-El-Khalick, Bell, & Lederman, 1998), and Concepts of Evidence and procedural understanding (Roberts, 2001).

The teachers who participated in this research were instructed to closely guide the students' inquiry throughout the inquiry process. During school hours, the teachers conducted both collective class sessions and individual meetings with each pair of students; after school hours, students received further help and feedback from the teacher through an online asynchronous forum. The teachers followed the syllabuses, instructed the students about the various aspects of inquiry, addressed procedural problems, and provided individual feedback on each student's progress.

(b) **The *Meta* component—supporting students' metacognition through explicit environmentally oriented metacognitive guidance.** The environmentally oriented metacognitive guidance was designed to support the two major components of metacognition, *knowledge about cognition* and *regulation of cognition*. The metacognitive guidance included both a general, domain-independent orientation, and a specific, domain-dependent environmental orientation. The domain-dependent environmental orientation was constructed by consolidating the strands of environmental literacy (environmental knowledge, affect, and behavior) into the metacognitive support.

Supporting Students' Knowledge About Cognition. Students' *knowledge about cognition* was supported using a S*trategy 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 each strategy (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 strategies to each stage of the inquiry process. The information about each strategy included both a general and a specific component: the general component included an overall description of the strategy; whereas the specific component provided an environmental context for the use of the strategy (see e.g., in Table 1). The SEM was taught by the teachers during class sessions. Thereafter, the students received a brief summary of the strategies through the online forum. They were required to implement the strategies to complete the tasks throughout the various stages of the inquiry process. The teachers examined the students' use of the strategies, and provided critical and constructive feedback.

Supporting Students' Regulation of Cognition. Students' regulation of cognition was supported using a combination of the *Regulatory Checklist* (RC) suggested by Schraw (1998), and

Table 1
Explicit environmentally oriented metacognitive guidance—Examples of learning strategies that were taught by the teachers and implemented by the students during the inquiry process, using the Strategy Evaluation Matrix (SEM)

Strategy	How to Use	Why	When to Use
Brainstorming	Make a list of spontaneous ideas which are associated with a specific topic. Focus on quantity, withhold criticism, welcome unusual and wild ideas and combine and improve ideas Osborne (1963).	Facilitates creative problem solving and generation of ideas.	When searching for new, creative and unusual ideas. For example, in search of an inquiry topic.
	STOP & THINK! What do I know about the environment? About which environmental issue would I like to know more? Which environmental issues interest me? Do I have a personal connection to an environmental issue? With which environmental actions am I familiar? In which environmental actions do I want to get involved?		
Flowchart	Present the process as a diagram – the steps are presented in boxes of various kinds connected by arrows which represent their order Gilbreth and Gilbreth (1921).	Visualizes the process as a means of understanding and improving it.	(1) When composing the literature review, a flowchart organizes the logical sequence of the review. (2) To understand and follow procedural aspects of the inquiry process.
	STOP & THINK! Which environmental concepts should the reader be familiar with to understand my inquiry project? What should be the order of these environmental concepts in my literature review, so that the reader understands my claims?		

the *Reflective Metacognitive Questions* (RMQ) suggested by Mevarech and Kramarski (1997) and Zion et al., 2005.

Regulatory Checklist (RC). 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 students to implement a systematic regulatory sequence to help them control their performance through a set of explicit prompts. Adapted to an inquiry process, the RC was administered to the students at each stage of the inquiry process. The prompts in the RC refer to the components of *regulation of cognition* (planning, process management, monitoring, and debugging) and to the strands of *environmental literacy* (environmental knowledge, affects, and behavior). Table 2 provides examples of the prompts that were included in the RC. The teachers discussed the RC with the students in the class, at the beginning of each stage of the inquiry process and during their individual meetings.

Reflective Metacognitive Questions (RMQ). The RMQ serves 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). Students' reflections following a task have been shown to have positive effects on learning outcomes (Mevarech & Kramarski, 1997;

Table 2
Explicit environmentally oriented metacognitive guidance—Examples of prompts that were included in the Regulatory Checklist (RC)

Planning
1. What goal is the task expected to achieve?
2. How much time do I need in order to accomplish my goal?

Process management
1. Which strategies are needed to accomplish my goal?

Monitoring
1. Am I reaching my goal?
2. Do my strategies 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?

Environmental Literacy
1. How can my environmental knowledge help me to complete the task?
2. How can my environmental attitudes help me to complete the task?

Michalsky, Mevarech, & Haibi, 2009). Once adapted to an inquiry process, the RMQ was used in this study to support students' regulation of cognition. Similarly to the RC, the RMQ addressed the components of *regulation of cognition* (planning, process management, monitoring, debugging, and evaluation) and the strands of *environmental literacy* (environmental knowledge, attitudes, and behavior). The RMQ included Likert questions in which students were required to indicate their level of agreement with a specific statement, and open questions in which they were asked to detail their experience. 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 issue and generated the 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 completing the required tasks at each stage of the inquiry process (six times in total throughout the entire inquiry process), and submitted them to their teachers.

(c) **The *CIC* component—supporting students' metacognition through peer collaborations in the *Collaborating Inquiry Community* (*CIC* component).** Peer collaborations were structured through the *Collaborating Inquiry Community* (CIC). In this environment, three pairs of students working on *different projects* joined together for a *CIC* meeting at each stage of the inquiry process. During each stage, students followed a macro script (see Dillenbourg & Hong, 2008), aimed at structuring the collaborative learning, developing rich interactions, and hence increasing the probability that metacognitive processes would occur (e.g., Iiskala, Vauras, & Lehtinen, 2004; Iiskala, Vauras, Lehtinen, & Salonen, 2011). The collaborative script assigned a specific *scenario* which students were required to follow throughout their *CIC* meeting. The scenario included: (a) teachers' instruction; (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 session by introducing and explaining procedural aspects of the inquiry process. Thereafter, the "peer-feedback" round took place in which each pair of students

Table 3
Explicit environmentally oriented metacognitive guidance—Examples of reflective questions that were used in the Reflective Metacognitive Questions (RMQ)

Evaluation

1. To what extent have you reached your goals?

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

Explain:____

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

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

Which learning strategy was the most effective? Why? ______________________________

Did you use your own original learning strategy? Explain: ______________________________

Environmental literacy

1. To what extent did your environmental knowledge help you to complete the task?

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

Explain and demonstrate:____

2. To what extent has your environmental knowledge changed?

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

Explain and demonstrate:____

in the *CIC* presented their inquiry project according to their progress, while the other members of the *CIC* group provided feedback, evaluation, social support, 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 presenter. The pairs continued onto a second round aimed at modeling the subsequent stage of the inquiry process. In this round, all the pairs addressed one inquiry project at a time, and modeled together the next stage of the inquiry process according to the teachers' instructions. This modeling round served as a second opportunity for the participants to exchange ideas, thoughts, strategies, and insights.

Throughout the collaborative discussions in the *CIC* sessions, the teachers facilitated groups' discussions by *implicitly* emphasizing aspects of metacognition. For example, the teachers urged the students to *plan* the session to allow time for all pairs to participate; encouraged students to *monitor* and *evaluate* each other's projects; and exposed the groups' difficulties and coping *strategies*. The teachers did not *explicitly* refer to the theoretical construct of metacognition, and did not raise students' awareness of their engagement in metacognitive processes. In addition, the teachers encouraged the students to think overtly, and supervised the students' social interactions to ensure a positive social atmosphere.

Research Design

To examine the effect of the *Meta-CIC* model and its components, we employed a research design based on the interplay among the three components of the educational intervention, namely: the *baseline curriculum*, the *Meta*, and the *CIC* components. The research groups differed by the addition or absence of the *Meta* or the *CIC* components to the *baseline curriculum*. Consequently, the research consisted of the following four research groups:

- *Comparison group*: The instructional scheme of the students in this group included the *baseline curriculum* only.
- *Meta group*: The *Meta* component was added to the *baseline curriculum*; the teachers embedded the *SEM*, *RC*, and *RMQ* within their instruction.
- *CIC group*: The *CIC* component was added to the *baseline curriculum*; each three pairs of students were assigned by their teacher to a *CIC* group; the *CIC* groups joined and collaborated at each stage of the inquiry process (approximately once each month).
- *Meta-CIC group*: both the *Meta* and the *CIC* components were added to the *baseline curriculum*: the teachers embedded the *SEM*, *RC*, and *RMQ* within their instruction; each one of the three pairs of students was assigned by their teacher to a *CIC* group; the *CIC* groups joined and collaborated at each stage of the inquiry process.

Upon obtaining permission from the school administration, teachers, and parents, the teachers and their classes were randomly assigned to one of the four research groups (see Figure 1c). Notably, all the teachers who participated in the study were introduced to the *baseline curriculum* during their training program. However, the *Meta* and the *CIC* components were only introduced to the teachers designated to implement these components in their classes. Consequently, the teachers were exposed to only one treatment condition.

Data Collection and Analysis

According to Wals and van der Leij (1997), two approaches dominate the field of environmental education: the first, an outcome-based approach, which aims at producing desired behavioral changes; the second is a process-based approach, quantifying the quality of the program through the students' perception of the experience, and their internalization of the learning process. Roth (1997) argues that both approaches should be integrated into the assessments of environmental programs. Accordingly, to assess the contribution of the *Meta-CIC* model to the development of students' environmental literacy, we used research tools that combined these two approaches: (a) an *environmental literacy questionnaire*, which is consistent with the outcome-based approach, and examines specific desirable changes in students' environmental knowledge, attitudes, and behaviors; (b) the *Environmental Literacy INventory (ELIN),* which was specially developed as part of this research; the ELIN is consistent with the process-based approach, and adopts a phenomenological approach (see also Knapp & Poff, 2001) (see Figure 1d).

The Environmental Literacy Questionnaire. Numerous attempts have been made to develop valid tools to measure levels of environmental literacy (e.g., Bluhm, Hungerford, McBeth, & Volk, 1995; Leeming & Dwyer, 1995; McBeth & Volk, 2010; Morrone, Mancl, & Carr, 2001; Negev, Sagy, Garb, Salzberg, & Tal, 2008). In our research, we adapted an environmental questionnaire from an Israeli research (Peled & Tal, 2011; Tal & Peled, 2011; Tal, Peled, & Abramovich, 2010), which assessed three components of environmental literacy (knowledge, attitudes, and behavior). The developers of this questionnaire emphasized its validity and reliability, and developed it according to the Israeli school curriculum.

The environmental questionnaire includes 57 items composed of three subscales: *knowledge*, *attitudes*, and *behavior*. The *knowledge* subscale includes 16 multiple-choice questions, which examine students' environmental knowledge in various environmental topics. These questions refer to various forms of environmental knowledge, as suggested by Kaiser and Fuhrer (2003), namely: *system*, *action-related*, and *effectiveness* knowledge. The *attitudes* subscale includes 21 Likert-scaled items which address both the personal and social aspects of diverse environmental issues. The students were required to indicate the degree to which they agree with each of these items (scale range of 1–5). The *behavior* subscale includes 20 Likert-scaled items describing various environmental behaviors, such as: saving natural resources and recycling, eco-friendly consumption, leisure activities, and environmental activism. The students were required to indicate the extent to which they perform the specified environmental behaviors (scale range of 1–5) (see Supplementary Table S3 for examples of items in each subscale).

We used a pre-post research design: students completed the pre-test questionnaire upon their enrollment in the CBI environmental program, prior to the onset of the inquiry process. In addition, students completed the questionnaire a second time at the end of the inquiry process. The *knowledge* subscale score was comprised of the sum of all correct responses, ranging from 0 to 16. The scores for the *attitudes* and *behavior* subscales were defined as the means of the items which composed them; the higher the score the more pro-environmental attitudes were expressed or more pro-environmental behaviors were reported. The internal consistencies of the questionnaire were: pre Cronbach $\alpha = 0.81$ and post Cronbach $\alpha = 0.82$ for attitudes; pre Cronbach $\alpha = 0.87$ and post Cronbach $\alpha = 0.87$ for behavior.

The Environmental Literacy INventory (ELIN). The Environmental Literacy INventory (ELIN) was used to analyze the students' individual experiences, using a phenomenological approach. The ELIN examines variables associated with environmental literacy using content analysis methods within a quantitative framework. A similar approach was applied by Erdoğan, Bahar, Özel, Erdaş, and Uşak, 2012; Erdoğan, Kostova, and Marcinkowski (2009a) and Erdoğan, Marcinkowski, and Ok (2009b): The framework for environmental literacy used in these studies included six main components (ecological knowledge, socio-political knowledge, knowledge of environmental issues, affect, cognitive skills, and environmentally responsible behaviors), and was used to analyze national socio-political issues, such as childhood curricula (Erdoğan et al., 2009a), and environmental education research (Erdoğan et al., 2009b). The data analysis occurred through a series of steps, which included: (a) selecting data for the qualitative analysis; (b) developing the ELIN; (c) using the ELIN to conduct a content analysis of students' inquiry reports; and (d) performing data analysis.

Selecting Data for Qualitative Analysis. As this research represents one part of a large study, a wide variety of data were collected throughout the inquiry process, and was made available to the researchers. This data included students' transcripts of meetings with the teachers; interactions during *CIC* sessions; messages from the online forum; final inquiry reports; and interviews. Initially, the first two researchers of this manuscript familiarized themselves with this wide variety of data. Throughout this comprehensive process, the researchers identified the possibility of measuring students' environmental literacy through students' personal reflections, as described in the introduction and summary chapters of the scientific inquiry reports. Consequently, the qualitative analysis data are based on 131 student inquiry reports from the four research groups. For these groups, the distribution of the inquiry reports were as follows: *Meta-CIC* group ($N = 36$) 27.5%; *CIC* group ($N = 40$) 30.5%; *Meta* group ($N = 28$) 21.4%; *Comparison* group ($N = 27$) 20.6%.

Developing the ELIN. Using a thematic analysis approach, in which the text serves as an opportunity to capture the human experience (Shkedi, 2003), Adler and Zion acknowledged that common themes in students reflections are associated with the four strands of environmental literacy following Roth (1992). Consequently, these strands served as the four main criteria of the ELIN (see Table 4). To improve the ELIN's ability to define and explain the themes discovered, further categorization was made within each criterion according to relevant literature. The *knowledge strand* was further categorized into four different types of knowledge associated with environmental literacy: *system*, *action-related*, *effectiveness*, and *social knowledge* (Frick et al., 2004; Kaiser & Fuhrer, 2003). Categories within the *affect strand* included: *general* or *specific responsibility*, *general or specific attitudes*, *external or internal locus of control*, and *economic orientation* (Hines, Hungerford, & Tomera, 1987); *conventional or moral responsibility feelings* (Kaiser & Shimoda, 1999); *emotional involvement* (Chawla, 1998, 1999; Kollmuss & Agyeman, 2002)*; and social (altruistic)*, *egocentric or biospheric orientation* (Kollmuss & Agyeman, 2002; Stern, 2000). The following categories were included in the *skills strand*: *using critical and creative thinking, finding and organizing information, displaying skepticism in a healthy way, thinking and planning ahead, identifying connections between events, looking for the seeds of change, evaluating the consequences of potential actions, examining alternatives and making choices among them,* and *making choices among alternatives that have a minimum negative impact on natural systems* (Roth, 1992). The *behavior* strand included: *verbal commitment* (Hines et al., 1987); *pro-social behavior* (Granzin & Olsen, 1991; Kaiser, 1998; Van Liere & Dunlap, 1978); *impact* or *intent oriented behavior*, *environmental activism, non-activism behaviors in the public sphere, private sphere environmentalism,* and *other environmentally significant behaviors* (Stern, 2000) (See the categorization and the theoretical definitions in Table 4). For an updated meta-analysis of psych-social determinants of pro-environmental behavior, see Bamberg and Möser (2008).

Thereafter, Adler and Zion re-examined students' reflections and assigned indicators to each of the categories. Through discussions on the coding scheme and indicators, the researchers formulated an operationalized definition, which adapted the theoretical concepts according to the students' reflections (see the operationalization of the concepts in Table 4). Subsequently, the two researchers independently coded 25 reflections, and κ values for inter-rater agreement were calculated: $\kappa = 0.87$ ($p < 0.001$) for the *knowledge*; $\kappa = 0.89$ ($p < 0.001$) for *affect*; $\kappa = 0.93$ ($p < 0.001$) for *skills*; and $\kappa = 0.95$ ($p < 0.001$) for the *behavior.*

Using the ELIN to Conduct a Content Analysis of Students' Inquiry Reports. The first researcher of this manuscript coded the students' reflections according to the ELIN's indices. For each inquiry report, the introduction and summary chapters served as the unit of analysis. Following coding, a personal report was developed for each pair of students, detailing their references to the various categories of the ELIN. Each variable was coded as a binary variable (i.e., 0,1) representing whether or not the category was mentioned by the students.

Performing Data Analysis. Chi square tests were first conducted for each category, to examine frequency differences by group. Thereafter, MANOVA tests were run for each environmental literacy strand, and the summary scores of the four research groups were compared. For the *knowledge strand*, a summary score was computed for the types of environmental knowledge mentioned, the sum of the four binary variables (ranging 0–4). For the *skills strand*, a summary score was computed for the total types of skills mentioned with sufficient variance, namely the sum of the five binary variables (ranging 0–5). For the *affect* and the *behavior strand*s, a hierarchical cluster analysis was conducted to examine the manner in which categories may be

Table 4
The Environmental Literacy INventory (ELIN)—(A) Knowledge strand, (B) Affect strand, (C) Skills strand, and (D) Behavior strand

Categories	Theoretical concept	Operationalization of concept	Example
(A) Main criteria—knowledge strand			
System knowledge	*System knowledge* relates to the question of how ecosystems operate or to knowledge about environmental problems Frick et al. (2004).	"Knowing what" – the student specifies or refers to scientific facts about an ecosystem or about the environment.	*We learned about '**ecosystems**' and their components; we were exposed to **types of flowers, plants, and trees** that grow in the limestone hills* (Imbar & Stav, *Meta*).
Action-related knowledge	*Action-related knowledge* is "knowing how," or knowledge of behavioral options and possible courses of action. This knowledge refers to information that either has direct or indirect relevance for action Frick et al. (2004).	The student describes behavioral options that should or should not be undertaken to protect the environment or prevent environmental damage.	*We learned a lot from our inquiry: We learned about the physiological damage to humans due to noise, which we were not aware of before conducting our inquiry, **and about the laws and regulations intended to prevent or regulate noise*** (Sapir & Ophir, *Meta*).
Effectiveness knowledge	*Environmental effectiveness knowledge* addresses the relative gain or benefit associated with a particular behavior Frick et al. (2004).	The student describes the environmental effect (gain or loss) of a particular behavior.	*Even if each person **throws away a small amount of waste,** and even if it is degradable, there is a danger of **damaging the food chain**, the **ecosystem,** and the **quality of other visitors' experiences**... **a person handling his vessel in a shipyard (i.e., cleaning or painting) without appropriate safeguards, endangers his health, and the health of the people around him*** (Oded, *Meta-CIC*).
Social knowledge	The first type of *social knowledge* refers to the motives and intentions of others, and is derived from the observation of others' behavior. The second type is socially shared knowledge, and depends on socialization. This knowledge consists of normative beliefs about how people think they should act Kaiser and Fuhrer (2003).	The student refers to other peoples' environmental literacy.	*I learned that **age and gender** as well as many other factors **can influence environmental awareness**. I learned about the environment in Holon and the **environmental awareness of its residents*** (Inbal & Sophie, *CIC*).

continued

Table 4. (Continued)

Categories	Theoretical concept	Operationalization of concept	Example
(B) Main criteria—affect strand			
General or specific responsibility	*Personal responsibility* represents an individual's feelings of duty or obligation. These may be expressed in reference to the *environment as a whole*, or in reference to only *one facet of the environment* Hines et al. (1987).	(a) The student expresses a feeling of obligation and responsibility towards the environment in **general**.	*The results of the project helped us see the grim reality of youths' environmental behavior,* ***which we must change, both personally and in wider circles, passing on the insights*** (Noa & Noa, *Meta*).
		(b) The student expresses a feeling of obligation and responsibility towards **specific aspects** of the environment.	*Since obviously we cannot replace our world,* ***we should think*** *of original and creative ideas that will* ***cause everyone to recycle, save the environment, buy environmentally friendly products****... and especially* ***not pollute*** *(*Romi & Ariel, *Comparison group).*
Conventional* or moral responsibility	Feelings of *conventional responsibility* depend on the social expectations a person is aware of and his or her readiness to fulfill these expectations.	(a) The student's expressions of responsibility towards the environment are reasoned by the need to follow **social environmental expectations**.	*NE*[a]
	Feelings of *moral responsibility* depend on a person's self-ascribed responsibility and guilt feelings Kaiser and Shimoda (1999).	(b) The student's expressions of responsibility towards the environment are supported by **moral arguments**.	***If we don't start caring for our environment*** *by recycling and protecting it, within a few years* ***the condition of the earth will be irreversible****. The earth will be polluted and depleted. If we continue to pollute the planet as much as we do today,* ***the entire human race will become extinct*** *(*Linoy & Noa, *CIC).*
General or specific attitudes	*General attitudes* refer to ecology and the environment as a whole. *Specific attitudes* refer to taking specific environmental action Hines et al. (1987).	(a) The student expresses attitudes towards ecology and the environment **as a whole**.	*We reached the conclusion that* ***if we contribute to improving the environment even in a small way, we can achieve good results, because every change begins small. If everyone contributes a little, it will add up to something great.*** (Noam, Tali & Sara, *Meta-CIC*).

continued

Table 4. (Continued)

Categories	Theoretical concept	Operationalization of concept	Example
		(b) The student expresses attitudes towards a **specific aspect** of the environment. **In this category, the students do not explicitly express a feeling of obligation or responsibility.	*We believe that we are on the threshold of a new era in* ***which the consumption habits that we are familiar with today will change****. In the future, the average consumer will* ***consume many green products*** (Inbal & Rotem, *Meta*).
External* or internal locus of control	*External locus of control* refers to the attribution of change to external factors (e.g., God, parents, government).	(a) The student attributes the ability to succeed to chance, circumstances, or to other people.	*When we were asked to choose an inquiry question, we discovered that we have difficult work ahead of us, and that* ***we need an adult to help and support us*** *throughout the process* (Noa & Shai, *Meta*).
	Internal locus of control refers to the belief that one's activities are likely to bring about change Hines et al. (1987).	(b) The student attributes the ability to succeed to oneself.	*We encountered difficulties from the beginning of the inquiry process in selecting an inquiry topic. We thought and thought. . ..and then we realized that* ***we cannot give up, and that are determined to finish what we started!*** (Adam & Sandra, *Meta-CIC*).
Economic orientation	*Economic orientation* refers to an individual's cost consciousness and concern about the economic impact of certain responsible environmental behaviors and regulations Hines et al. (1987).	The student refers to economic aspects of environmental acts or behaviors.	*We learned that a lack of environmental awareness among consumers* ***results in a waste of money and a polluted environment*** (Inbal & Rotem, *Meta*).
Emotional involvement	*Emotional involvement* is the extent to which a person has an affective relationship to the natural world, involving one's emotional investment in the problem Chawla (1998, 1999); Kollomus and Agyeman (2002).	The student describes a personal involvement with the inquiry process.	*Two years ago, my family took a trip to the U.S., where I was introduced to* ***environmental issues in general, and recycling in particular****. . . In the beginning of the year, during* ***family conversations*** *aimed at finding an inquiry topic****, my father told us about his friend's tire recycling plant.*** *Thus we discovered an interesting industrial sector, and set out to explore it.* (Aviv & Amit, *Meta-CIC*).

continued

Table 4. (Continued)

Categories	Theoretical concept	Operationalization of concept	Example
Social (altruistic) orientation*	The *social orientation* concerns the removal of suffering of other people Kollomus and Agyeman (2002); Stern (2000).	The student views environmental protection as a means to ensure the welfare of other people.	***As part of the youth community***, which is one of the main sources of noise in the city, **we wanted to learn how to reduce noise and how to consider the elder residents.** For example, to inform them in advance, or not to make noise during designated afternoon or evening hours (Sapir & Ofir, *Meta*).
Egocentric orientation*	The *egoistic orientation* concerns the removal of suffering and harm from oneself Kollomus and Agyeman (2002); Stern (2000).	The student views environmental protection as a means to ensure his own welfare.	*Now answer this question sincerely:* ***Would you like to spend your leisure time in a park, amusement park, or in nature with the scent of garbage everywhere??*** (Dan & Daniel, *Meta-CIC*).
Biospheric orientation*	The *biospheric orientation* concerns the removal of destruction and suffering in the non-human world Kollomus and Agyeman (2002); Stern (2000).	The student views environmental protection as a means to ensure the welfare of the non-human world.	*Driving ATVs in the sand dunes negatively influences the animals and plants in the area,* ***and we should take appropriate actions to save them from extinction!*** *Our study can help* ***protect of the flora and fauna against human interference*** (Shai & Lior, *CIC*).
(C) Main criteria—skills strand			
Environmental associatedskills Roth (1992)	Using critical and creative thinking	The student presents a critical reflection upon the inquiry process or final report, and provides insights for the future.	*I look at my* ***inquiry report and I am happy****. It was difficult at times - to organize my time, explore, and formulate an interesting discussion. But when I look at the final project, I take a deep breath and say,* ***"Wow, something good came out of all this investment; it was not in vain."*** (Tomer, *Meta*).

continued

Table 4. (Continued)

Categories	Theoretical concept	Operationalization of concept	Example
	Finding and organizing information	The student describes the process of investigation and data collection.	*The main difficulty we had was* ***finding someone to interview****. We* ***called*** *many people from the Ministry of Environment, but no one knew the answers to our questions.* ***We sent many emails****, but nobody answered. Finally, with the help of our teacher,* ***we interviewed an air-conditioning technician****, and found the answers* (Lior & Shani, *Meta-CIC*).
	Displaying skepticism in a healthy way	The student raises doubts concerning their inquiry topic or inquiry question.	*We are exposed in many cases to companies that* ***label themselves as 'green'*** *companies. This aroused our curiosity:* ***Do these companies really act environmentally? Or is this just a sophisticated marketing campaign?*** (Tami & Nitzan, *Comparison group*).
	Thinking and planning ahead	The student demonstrates an understanding of the importance of planning.	*The* ***damage to open landscapes is almost always irreversible****. It is possible, for example, to stop emission of pollutants, to lower noise levels, to clean dirty areas; however, damage to open landscapes which have turned into a developed area are irreparable.* ***Proper planning can prevent damage to open landscapes*** (Dan & Ofek, *Meta-CIC*).
	Identifying connections between events*	The student explicitly defines connections between events that occurred during the inquiry process.	*NE*[a]
	Looking for the seeds of change*	The student expresses an environmental issue that should be examined.	*If people were more interested in the environmental hazards around them, the* ***municipality would be obligated to supply special bins for garbage and encourage recycling*** (Yuni & Liel, *CIC*).

continued

Table 4. (Continued)

Categories	Theoretical concept	Operationalization of concept	Example
	Evaluating the consequences of potential actions*	The student evaluates the consequences of a potential environmental action.	***A residential complex without open green areas such as gardens or parks will be an urban area with a poor quality of life*** (Dan & Ofek, *Meta-CIC*).
	Examining alternatives and making choices among them	The student describes dilemmas that arose during the inquiry process, and details the resolution and the decision making process.	*We* ***faced many difficulties*** *while choosing our inquiry question - many issues concerned and interested us. Finally,* ***we selected a subject that was the closest to us*** *- the effect of the reduction in urban green open spaces on the lifestyle and habits of the youth – us!* (Rinat & Tal, *Meta*).
	Making choices among alternatives that have a minimum negative impact on natural systems*	The student describes an environmental dilemma, and details the resolution and the decision making process.	*We hope that as the consumers' awareness to the environmental and health impacts of meat production increases, they will* ***purchase products wisely and minimize the environmental damage*** (Itai & Itai, *Meta-CIC*).
	Acting responsibly as one species among many diverse, interactive, and interrelated species[b]		
(D) Main criteria—behavior strand			
Verbal commitment	*Verbal commitment* refers to an expressed intention to act upon a specific environmental problem Hines et al. (1987).	The student explicitly expresses intentions to be involved or act upon environmental problems.	*I have also discovered an interesting topic, and* ***I'm sure I will be involved with this issue later in life*** *(*Aviv, *Meta).*
Pro-social behavior	*Pro-social behaviors* include helpfulness and a concern for the well-being of others Granzin and Olsen (1991); Kaiser (1998); Van Liere and Dunlap (1978), and include behaviors which demonstrate proper conduct towards others within society.	The student refers to the social aspects of the inquiry process.	*The inquiry process was full of team work and collaboration among all of us. We were given* ***help and support from our classmates*** *and* ***helped other groups****. We discovered the* ***warm, responsible, and mature side of our friends*** *and our desire to succeed. The inquiry process revealed the* ***affective characteristic*** *of our classmates (*Or, Shir & Gil, *Meta-CIC).*

continued

Table 4. (Continued)

Categories	Theoretical concept	Operationalization of concept	Example
Impact or intent-oriented behavior	*Impact behavior* is the extent to which the behavior changes the availability of materials or energy from the environment, or alters the structure and dynamics of ecosystems or the biosphere itself.	(a) The student expresses a willingness to adopt environmental behaviors which have a **direct impact** on the environment.	*We are both only speaking and doing. For example, our science teacher assigned us many pages of homework for the Passover vacation, and asked us to print them at home. A deep debate arose in class, and finally* ***we all decided not to print the pages, but to send them to her*** **via** ***e-mail*** (Maya & Gal, Meta-CIC).
	Intent-oriented behavior is defined from the actor's standpoint as behavior that is undertaken with the intention to change (normally, to benefit) the environment Stern (2000).	(b) The student expresses a willingness to adopt behaviors that **have an indirect impact on the environment**, by shaping the context in which choices are made that directly cause environmental change.	***We will continue to fight against battery cages and animal abusers. We promised each other that we will continue to fight the damage to the environment and animals and to develop awareness in others of this topic*** *(Itai & Itai, Meta-CIC).*
Environmental activism	Environmental activism refers to active involvement in environmental organizations and demonstrations Stern (2000).	The student describes adopted, strengthened, or intended environmental behaviors within in public domain (e.g., school or city).	*Our main goal was* ***to change the way the city looks; improve the municipal employees' awareness of environmental issues; and create a good and healthier atmosphere in our city*** (Tal & Shoval, *Meta-CIC*).
Non-activism behaviors in the public sphere[*]	*Non activism behaviors in the public sphere* refer to the support or acceptance of public policies, e.g., stated approval of environmental regulations, and willingness to pay higher taxes for environmental protection Stern (2000).	The student expresses support of environmental policy.	*NE*[a]
Private sphere environmentalism	*Private sphere environmentalism* refers to the purchase, use, and disposal of personal and household products that have an environmental impact Stern (2000).	The student describes adopted, strengthened, or intended environmental behaviors within the private domain (e.g., home or family).	*From now on,* ***we will not enter a supermarket like ordinary consumers;*** *we will be aware of the manipulations that the supermarket activates {to encourage consumption}, and* ***we will know how to manage and ignore them*** (Inbal & Rotem, *Meta*).

continued

Table 4. (Continued)

Categories	Theoretical concept	Operationalization of concept	Example
			We tried to reduce the amount of meat we eat, read articles and reports on the topic, and convince our parents to consume organic meat. *Our efforts were not very successful, but at least we tried (*Itai & Itai, *Meta-CIC*).
Other environmentally significant behaviors	Individuals may significantly affect the environment through *other behaviors*, such as influencing the actions of organizations to which they belong Stern (2000).	The student describes adopted, strengthened, or intended environmental behaviors which are intended to influence the actions of organizations.	*We will be able* ***to show to anyone who reads our inquiry report*** *that a company can advertise and market its products without using marketing techniques that are harmful to our environment* (Shai & Niv, *Comparison group*).

*Indicates that this category was excluded from the statistical analysis due to lack of variance.

[a]NE - No example for this category was found in students' reflections.

[b]This category originally appears in Roth's (1992) description of environmental literacy's associated skills. This category was omitted from the ELIN because it is similar to the categories concerning environmental responsibility in the *affect* strand.

grouped while taking into consideration both the theoretical background and Cronbach's α. The hierarchical cluster analysis uses a stepwise algorithm to merge similar variables into a cluster. Within the *affect* and *behavior* strands, variables which lacked sufficient variance were excluded from the hierarchical cluster analysis. Three dimensions were derived from this analysis in the *affect strand*; and consequently, three summary scores were computed: (a) *values and attitudes* mentioned, the sum of the six binary variables (ranging 0–6); (b) *internal locus of control*, which was either mentioned or not mentioned (ranging 0–1); (c) and *emotional involvement*, which was either mentioned or not mentioned (ranging 0–1). In the *behavior strand*, the hierarchical cluster analysis yielded two dimensions; and consequently, two summary scores were computed: (a) *pro-social behavior* which was either mentioned or not mentioned (ranging 0–1); (b) and *environment-related behaviors*, the sum of the six binary variables (ranging 0–6).

Results

Assessing Students' Environmental Literacy Using an Environmental Literacy Questionnaire

Pre-study differences in students' environmental literacy were examined with a two way MANOVA. No significant pre-study differences were found among the research groups on *knowledge*, *attitudes*, and *behavior* [*Meta*: $F(3,273) = 2.37$, $p = 0.071$, $\eta^2 = 0.025$; *CIC*: $F(3,273) = 0.46$, $p = 0.714$, $\eta^2 = 0.005$; *Meta* by *CIC*: $F(3,273) = 0.11$, $p = 0.952$, $\eta^2 = 0.001$]. Table 5 presents the means, standard deviations, and *F* values of the MANOVA for environmental literacy by research group and time.

Table 5 shows rather moderate means for *knowledge* (scale range 0–16), high means for *attitudes* (scale range 1–5), and moderate means for *behavior* (scale range 1–5). Significant differences were found for time: $F(3,263) = 17.81$, $p < 0.001$, $\eta^2 = 0.169$; but not for *Meta* by time: $F(3,263) = 0.95$, $p = 0.418$, $\eta^2 = 0.011$; *CIC* by time: $F(3,263) = 0.67$, $p = 0.573$, $\eta^2 = 0.008$; or *Meta* by *CIC* by time: $F(3,263) = 0.25$, $p = 0.858$, $\eta^2 = 0.003$. Univariate analyses revealed two main effects for time: *knowledge*, beyond group, increased from $M = 9.83$ (SD = 2.16) to $M = 10.69$ (SD = 1.98), yet *attitudes* decreased, beyond group, from $M = 4.17$ (SD = 0.39) to $M = 4.10$ (SD = 0.47). Namely, students' environmental knowledge increased overtime while students' environmental attitudes decreased overtime. No significant group differences were found for both these processes.

Characterizing Students' Environmental Literacy Using the Environmental Literacy INventory (ELIN)

Knowledge Strand. Table 6 presents the distribution of types of knowledge mentioned in the students' inquiry reports. The table shows that *system knowledge* was mentioned in about 40% of the reports, *action-related knowledge* was mentioned in about 67% of the reports, and *effectiveness-knowledge* was mentioned in about 87% of the reports, with no significant difference among the research groups. *Social knowledge* was mentioned in about 53% of the reports, and a significant group difference was found, showing that this type of knowledge was mentioned fewer times in the projects of the group which received only the *Meta* component. Furthermore, a significant difference was found among the types of knowledge mentioned in the reports, beyond group: $\chi^2(3) = 64.56$, $p < 0.001$, showing that *effectiveness-knowledge* was mentioned the most, *action-related knowledge* was mentioned less, *social-knowledge* was mentioned fewer times than these two types, and *system knowledge* was mentioned the least.

Table 5
Environmental literacy questionnaire—Means, standard deviations, and F values for environmental literacy by group and time ($N = 269$)

	Meta-CIC M (SD)		*Meta* M (SD)		*CIC* M (SD)		*Comparison group* M (SD)					
Dimension	Pre ($n = 101$)	Post ($n = 98$)	Pre ($n = 54$)	Post ($n = 53$)	Pre ($n = 74$)	Post ($n = 71$)	Pre ($n = 50$)	Post ($n = 47$)	F_{time} (1,296) (η^2)	$F_{time \times Meta}$ (1,296) (η^2)	$F_{time \times CIC}$ (1,296) (η^2)	$F_{time \times Meta \times CIC}$ (1,296) (η^2)
Knowledge	9.81	10.79	10.02	10.96	9.54	10.13	9.86	11.04	42.46***	0.12	0.97	0.41
(0–16)	(2.43)	(2.05)	(1.94)	(1.94)	(1.78)	(1.91)	(2.44)	(1.83)	(0.138)	(0.001)	(0.004)	(.002)
Attitudes	4.13	4.11	4.13	4.11	4.21	4.08	4.16	4.11	8.66**	2.66	0.01	0.04
(1–5)	(0.44)	(0.54)	(0.39)	(0.44)	(0.33)	(0.44)	(0.47)	(0.39)	(0.032)	(0.010)	(0.001)	(.001)
Behavior	2.56	2.60	2.60	2.56	2.74	2.68	2.72	2.68	2.24	0.99	0.78	0.41
(1–5)	(0.53)	(0.57)	(0.44)	(0.42)	(0.44)	(0.49)	(0.51)	(0.59)	(0.008)	(0.004)	(0.003)	(.002)

** $p < 0.01$.
*** $p < 0.001$.

Table 6
The ELIN knowledge strand—Distribution of types of knowledge mentioned in the students' inquiry reports (N = 131)

Categories of the ELIN	*Meta-CIC* ($n = 36$)	*Meta* ($n = 28$)	*CIC* ($n = 40$)	*Comparison group* ($n = 27$)	$\chi^2(3)$
Knowledge strand					
System knowledge	11 (30.6)	16 (57.1)	13 (32.5)	13 (48.1)	6.37
Action-related knowledge	25 (69.4)	15 (53.6)	29 (72.5)	19 (70.4)	3.05
Effectiveness knowledge	35 (97.2)	23 (82.1)	32 (80.0)	24 (88.9)	5.69
Social knowledge	25 (69.4)	5 (17.9)	26 (65.0)	13 (48.1)	20.18*** Meta < all other groups

***$p < 0.001$.

A total score for the types of knowledge mentioned was composed of the sum of types of knowledge mentioned, ranging from 0 to 4. About 2.5 types of knowledge were mentioned per inquiry report (grand mean = 2.47, SD = 0.92), with no group difference. ($F_{\text{Meta}}(1,127) = 0.76$, $F_{\text{CIC}}(1,127) = 2.44$, $F_{\text{MetaxCIC}}(1,127) = 3.63$, n.s.).

Affect Strand. Table 7 presents the distribution of types of affective characteristics expressed in the students' reports. Group differences were found for *moral*, *general*, and *specific responsibility*, showing a higher percentage in reports of the *Meta-CIC* research group (39%, 22%, and 28%, respectively) than in the other groups. No group differences were found for *general* and *specific attitudes*; *general attitudes* were expressed in about 24% of the reports, and *specific attitudes* in about 50%. Expressions indicating *internal locus of control* were found in about 82% of the reports of the group that received only the *Meta* component, compared with about 50% in the other groups, a difference that was found significant. No group difference was found for *economic orientation*, expressed in about 13% of the reports. Finally, a significant group difference was found for *emotional involvement*. This category was expressed in all the reports of the three experimental groups more than in the *comparison* group, and more in the reports of the *Meta-CIC* group than in the reports of the *CIC* group. The following categories were generally missing or seldom mentioned in the students' inquiry reports: *conventional responsibility*, *external locus of control*, *social (altruistic) orientation*, *egocentric orientation*, and *biospheric orientation*. Due to lack of variance, these categories were excluded from Table 7 and from further statistical analysis.

Hierarchical cluster analysis revealed three clusters: (a) *values and attitudes* (including *moral responsibility*, *general responsibility*, *specific responsibility*, *general attitudes*, *specific attitudes*, and *economic orientation*—Cronbach $\alpha = 0.59$); (b) *internal locus of control*; (c) and *emotional involvement*. A total score for *values and attitudes* mentioned was composed of the sum of its components, ranging from 0 to 6. The total scores for each *internal locus of control* and *emotional involvement* ranged from 0 to 1. Group differences in *values and attitudes*, *internal locus of control*, and *emotional involvement*, were analyzed with a MANOVA (see Table 8).

The MANOVA was found significant for *Meta* $F(3,125) = 9.95$, $p < 0.001$, $\eta^2 = 0.193$, significant for *CIC* $F(3,125) = 4.12$, $p = 0.008$, $\eta^2 = 0.090$, and significant for the interaction of *Meta* and *CIC* $F(3,125) = 3.31$, $p = 0.022$, $\eta^2 = 0.074$.

Table 7
The ELIN affect strand—Distribution of affective characteristics expressed in the students' inquiry reports (N = 131)

Categories of the ELIN	*Meta-CIC* ($n = 36$)	*Meta* ($n = 28$)	*CIC* ($n = 40$)	*Comparison Group* ($n = 27$)	$\chi^2(3)$
Affect strand					
Moral responsibility	14 (38.9)	3 (10.7)	5 (12.5)	2 (7.4)	14.21** *Meta-CIC*> others
General responsibility	8 (22.2)	1 (3.6)	2 (5.0)	1 (3.7)	10.15* *Meta-CIC*> others
Specific responsibility	10 (27.8)	2 (7.1)	3 (7.5)	2 (7.4)	9.56* *Meta-CIC*> others
General attitudes	7 (19.4)	6 (21.4)	9 (22.5)	10 (37.0)	3.00
Specific attitudes	23 (63.9)	11 (39.3)	20 (50.0)	11 (40.7)	4.94
Internal locus of control	21 (58.3)	23 (82.1)	20 (50.0)	13 (48.1)	8.78* *Meta*> others
Economic orientation	7 (19.4)	3 (10.7)	4 (10.0)	3 (11.1)	1.84
Emotional involvement	26 (72.2)	19 (67.9)	20 (50.0)	4 (14.8)	23.57*** *CI* < all other groups; *Meta-CIC* > *CIC*

*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.

Results in Table 8 reveal a significant interaction for *values and attitudes*. Significantly, more *types of values and attitudes* were mentioned in the reports of students from the *Meta-CIC* group, than in the reports of students from the other three research groups ($p < 0.05$). Expressions indicating *internal locus of control* were more predominant in the reports of students who received the *Meta* component ($M = 0.69$, SD = 0.47) than in the reports of students who did not receive this component ($M = 0.49$, SD = 0.50) ($p < 0.05$). Likewise, *emotional involvement* was expressed

Table 8
The ELIN affect strand—Means, standard deviations, and F values for types of affective characteristics

Group: Dimension:	*Meta-CIC* M (SD)	*Meta* M (SD)	*CIC* M (SD)	*Comparison group* M (SD)	F_{Meta} (η^2)	F_{CIC} (η^2)	$F_{\text{Meta} \times \text{CIC}}$ (η^2)
Types of values and attitudes expressed (0–6)	1.92 (1.66) ($n = 36$)	0.93 (1.21) ($n = 28$)	1.08 (1.05) ($n = 40$)	1.07 (1.07) ($n = 27$)	$F(1,127) = 2.34$ (0.018)	$F(1,127) = 4.73^*$ (0.036)	$F(1,127) = 4.71^*$ (0.036)
Expressions of internal locus of control (0–1)	0.58 (0.50) ($n = 36$)	0.82 (0.39) ($n = 28$)	0.50 (0.51) ($n = 40$)	0.48 (0.51) ($n = 27$)	$F(1,127) = 6.12^*$ (0.046)	$F(1,127) = 1.65$ (0.013)	$F(1,127) = 2.25$ (0.017)
Expressions of emotional involvement (0–1)	0.72 (0.45) ($n = 36$)	0.68 (0.48) ($n = 28$)	0.50 (0.51) ($n = 40$)	0.15 (0.36) ($n = 27$)	$F(1,127) = 21.44^{***}$ (0.144)	$F(1,127) = 5.92^*$ (0.045)	$F(1,127) = 3.59$ (0.028)

*$p < 0.05$.
***$p < 0.001$.

more in the reports of students who received the *Meta* component ($M = 0.70$, SD = 0.46) than in the reports of students who did not receive this component ($M = 0.36$, SD = 0.48) ($p < 0.001$). *Emotional involvement* was also expressed more in the reports of students who received the *CIC* component ($M = 0.61$, SD = 0.49) than in the reports of students who did not receive this component ($M = 0.42$, SD = 0.50) ($p < 0.05$).

Skills Strand. Table 9 presents the distribution of the types of skills expressed in the students' reports. Five skills were expressed with sufficient variance: *Using critical and creative thinking*, *finding and organizing information*, *displaying skepticism in a healthy way*, *thinking and planning ahead,* and *examining alternatives and making choices among them*. Group differences were found for *using critical and creative thinking*, which was expressed in a higher percentage in groups that received the *Meta* component (81%, and 100%) than in the groups that did not receive the *Meta* component (47%, and 59%). No group difference was found for *finding and organizing information*, expressed in about 66% of the reports. Similarly, no group difference was found for *displaying skepticism in a healthy way*, expressed in 16% of the reports. *Thinking and planning ahead* was expressed in about 68% of the reports of the *Meta* group, compared with about 36–37% in the *Meta-CI*C and the *Comparison* groups, and all were higher than the *CIC* group (10%). No group difference was found for *examining alternatives and making choices among them*, mentioned in about 55% of the reports. The following categories were generally missing or seldom mentioned in the students' inquiry reports: *identifying connections between events, looking for the seeds of change*, *evaluating the consequences of potential actions*, and *making choices among alternatives that have a minimum negative impact on natural systems*. Due to the lack of variance, these categories were excluded from Table 9 and from further statistical analysis.

A total score for the types of skills expressed was composed of: *using critical and creative thinking*, *finding and organizing information*, *displaying skepticism in a healthy way*, *thinking and planning ahead*, and *examining alternatives and making choices among them*, ranging from 0 to 5. A significant group difference was found for the *Meta* component ($F(1,127) = 14.49$, $p < 0.001$, $\eta^2 = 0.102$), showing that more types of skills were expressed in the reports of students who received the *Meta* component ($M = 2.83$, SD = 1.16) than in the reports of students who did not receive this component ($M = 2.03$, SD = 1.23). Other differences were not significant ($F_{\text{CIC}}(1,127) = 2.22, F_{\text{MetaxCIC}}(1,127) = 0.31$, n.s.).

Behavior Strand. Table 10 presents the distribution of types of behaviors expressed in the students' reports. No group difference was found for *verbal commitment*s, which were present in

Table 9
The ELIN skills strand—Distribution of types of skills expressed in the students' inquiry reports (N = 131)

Categories of the ELIN	*Meta-CIC* ($n = 36$)	*Meta* ($n = 28$)	*CIC* ($n = 40$)	*Comparison group* ($n = 27$)	$\chi^2(3)$
Skills strand					
Using critical and creative thinking	29 (80.6)	28 (100.0)	19 (47.5)	16 (59.3)	24.95***
Finding and organizing information	25 (69.4)	15 (53.6)	31 (77.5)	15 (55.6)	5.71
Displaying skepticism in a healthy way	8 (22.2)	6 (21.4)	3 (7.5)	4 (14.8)	3.79
Thinking and planning ahead	13 (36.1)	19 (67.9)	4 (10.0)	10 (37.0)	24.12***
Examining alternatives and making choices among them	20 (55.6)	18 (64.3)	21 (52.5)	13 (48.1)	1.58

***$p < 0.001$.

Table 10
The ELIN behavior strand—Distribution of types of behaviors mentioned in the students' inquiry reports (N = 131)

Categories of the ELIN	*Meta-CIC* ($n = 36$)	*Meta* ($n = 28$)	*CIC* ($n = 40$)	*Comparison group* ($n = 27$)	$\chi^2(3)$
Behavior strand					
Verbal commitment	6 (16.7)	7 (25.0)	3 (7.5)	2 (7.4)	5.44
Pro-social behavior	23 (63.9)	14 (50.0)	10 (25.0)	10 (37.0)	12.50**
Impact—behaviors	7 (19.4)	3 (10.7)	5 (12.5)	0	5.77
Intent-orient-behaviors	18 (50.0)	8 (28.6)	11 (27.5)	9 (33.3)	5.04
Environmental activism	7 (19.4)	5 (17.9)	7 (17.5)	1 (3.7)	3.55
Private sphere environmentalism	10 (27.8)	2 (7.1)	10 (25.0)	2 (7.4)	7.77*
Other behaviors	17 (47.2)	7 (25.0)	9 (22.5)	7 (25.9)	6.57

*$p < 0.05$.
**$p < 0.01$.

about 14% of the reports. A group difference was found for expressions of *pro-social behavior*s, which were present in a higher percentage in the reports groups that received the *Meta* component (64%, and 50%) than in the reports of the two other groups (37% and 25%). No group differences were found for *impact–behaviors*, *intent-orient-behaviors*, *environmental activism*, and *other behaviors*, mentioned in 11%, 35%, 15%, and 30% of the reports, respectively. *Private sphere environmentalism* was expressed in about 26% of the reports of groups who received the *CIC* component, compared with about 7% in the groups that did not receive the *CIC* component. *Non activism behavior in the public sphere* was missing from the students' works. This category was therefore excluded from Table 10 and from further statistical analysis.

An examination of the inter-relationships among the behavior strand items and a hierarchical cluster that was conducted revealed two clusters: (a) *Pro-social behavior*s; (b) *Environment-related behaviors* (including *verbal commitment*, *impact–behaviors*, *intent-oriented-behaviors*, *environmental activism*, *private sphere environmentalism*, and *other behaviors*—Cronbach $\alpha = .73$). A total score for the two variables was composed, ranging 0–1 for *pro-social behavior*, and 0–6 for *environment-related behaviors*. A MANOVA for the two behavior dimensions was significant for the *Meta* component $F(2,126) = 6.33$, $p = 0.002$, $\eta^2 = 0.091$, but non-significant for *CIC* $F(2,126) = 1.72$, $p = 0.183$, $\eta^2 = 0.027$, and non-significant for the interaction of *Meta* and *CIC* $F(2,126) = 1.30$, $p = 0.275$, $\eta^2 = 0.020$.

Further analysis revealed that *pro-social behaviors* were expressed more often in the reports of students who received the *Meta* component ($M = 0.58$, SD = 0.50) than in the reports of students who did not receive this component ($M = 0.30$, SD = 0.46) ($F(1,127) = 9.35$, $p = 0.003$, $\eta^2 = 0.069$). Similarly, more types of *environment related behaviors* were expressed in the reports of students who received the *Meta* component ($M = 1.52$, SD = 1.72) than in the reports of students who did not receive this component ($M = 0.99$, SD = 1.35) ($F(1,127) = 3.71$, $p = 0.049$, $\eta^2 = 0.028$).

Table 11 summarizes the results of the effects of the *Meta* and the *CIC* components on the strands and clusters of students' environmental literacy.

In sum: the *Meta* component had a positive significant effect on students' expressions which indicate *internal locus of control*, *expressions of emotional involvement*, types of environmental associated *skills*, *pro-social behaviors* and types *of environmental related behaviors*; the *CIC* component had a positive significant effect on the on students' *expressions of emotional*

Table 11
Summary of the results—The effects of the Meta and CIC components on students' environmental literacy

Environmental literacy strands and clusters	*Meta*	*CIC*	Synergism Between *Meta* and *CIC*
Knowledge strand—types of knowledge	−	−	−
Affect strand			
Types of values and attitudes	−	−	+
Expressions of internal locus of control	+	−	−
Expressions of emotional involvement	+	+	−
Skills strand—types of skills	+	−	−
Behavior strand			
Pro-social behaviors	+	−	−
Types of environmental-related behaviors	+	−	−

involvement; and a synergistic effect between the two components was found for the types of *values and attitudes* expressed by the students.

Discussion

The Contribution of the Meta Component to Students' Environmental Literacy

The results of this study demonstrate that significantly more types of *environmental-related behaviors* and *pro-social behaviors* were mentioned by students who received the *Meta* component, than by students who did not. We attribute this difference to the reflective aspects of the *Meta* component. Students who received the explicit environmentally oriented metacognitive guidance were prompted to critically reflect upon their environmental behavior, and social interactions; this critical reflection raised students' awareness of various types of environmental-related behaviors, and their collaborations with their partners. These results demonstrate that a cognitive intervention which supports deep learning processes also promotes expressions associated with the *behavior strand* of environmental literacy, and highlight the importance of promoting critical thinking within the field of environmental education (Jickling, 2003; Orr, 1999; Wals & van der Leij, 1997). Similarly, the *Meta* component affected students' expressions which indicate an *internal locus of control;* such expressions were more predominant in the inquiry reports of students who received the *Meta* component, than in the inquiry reports of students who did not. We hypothesize that students' introspection of the inquiry process led them to realize their significant role in this process, and their responsibility for its success.

The positive effect of the *Meta* component on students' expression of environmental-associated *skills* supports the crucial role of explicit teaching (Pintrich, 2002); *using critical and creative thinking* was expressed in a higher percentage by the groups that received the *Meta* component (i.e., *Meta-CIC* group and *Meta* group) and *thinking and planning ahead* was mostly expressed by students in the *Meta* group. In addition, more types of environmental literacy-associated *skills* were mentioned by students who received the *Meta* component, than by students who did not. We hypothesize that the explicit reference to various environmental-associated skills within the metacognitive guidance (see Table 2, and Table 3), positively affected students' expressions of these skills.

The Contribution of the CIC Component to Students' Environmental Literacy

The social environment, in which both self- and social regulatory processes occur, is a key feature of the *CIC* component. Consequently, we hypothesized that this component will affect students' environmental behaviors, through the process of personal, reciprocal, and shared metacognitive processes (Hadwin & Oshige, 2011; Volet et al., 2009). Indeed, significantly more expressions of *private sphere environmentalism* were mentioned by students who received the *CIC* component, than by the students who did not. We propose that the unique setting provided by the *CIC* environment triggered a process of self-examination, followed by identification of personal environmental behaviors that can be changed. These results are in line with social learning theories, which suggest that behaviors are learned from others in the situated context in which the behaviors can be implemented (Heimlich & Ardoin, 2008).

In contrast to our expectations, the results indicate that the *CIC* component did not make a significant contribution to students' references to types of *environment-related behaviors*. Perhaps in contrast to the *private sphere environmentalism*, which includes a set of behaviors well known to the students (such as reducing, re-using, and recycling), describing types of *environment-related behaviors* requires the students to acquire new sets of behaviors. Therefore, to achieve this goal, the students should explicitly discuss environmental issues and decide upon various types of *environmental-related behaviors* which might affect them. However, such discussions were not regarded as a goal of the *CIC* environment, and were rapidly dismissed. Hence, we propose a future dual goal for the *CIC* component: a means to support students' metacognition within a social context; and as a platform in which lively thoughtful discussions concerning environmental issues would take place, and in which various types of *environmental-related behaviors* could be explicitly discussed and internalized. We hypothesize that the addition of such environmental focus to the *CIC* component would greatly improve its effect on students' environmental literacy.

A major feature of the *CIC* environment is its implicitness. Consequently, although the collaborative sessions offer numerous opportunities for the development of metacognitive skills, its implicit nature may impede students' awareness to the development of these skills. This may explain the lack of significant effect of the *CIC* component on students' expressions of environmental-associated skills. Similarly, despite the vast social interactions experienced by students who received the *CIC* component (e.g., Salomon & Globerson, 1989; Van den Bossche, Gijselaers, Segers & Kirschner, 2006), this collaborative environment did not significantly affect students' expressions of *pro-social* behaviors. We postulate that requiring the student to explicitly reflect upon the *CIC* sessions, and specifically consider the metacognitive skills which they have developed, and the social interactions with their peers, will improve the effect of the *CIC* component. These results emphasize the importance of explicitly teaching and supporting students' metacognition (Pintrich, 2002).

In sum, to fulfill the potential of the *CIC* component, and improve its effect on students' environmental literacy, we suggest: (a) adding an environmental focus to this component; and (b) enhancing this component's explicitness.

The Interplay of the Meta and CIC Components on Students' Environmental Literacy

The results indicate interplay between the *Meta* and the *CIC* components within the affect strand. Each component separately had a significant positive affect on students' expressions indicating *emotional involvement* within the inquiry process. Possibly, both components improved students' inquiry skills (Zion et al., 2005), critical thinking (Magno, 2010), and meaningful learning (Nielsen et al., 2009), and therefore fostered students' engagement and *emotional involvement* in their environmental inquiry process. In addition, a synergistic effect of both components was found for *types of values and attitudes* expressed by the students: students from the *Meta-CIC* group mentioned significantly more types of environmental *values and attitudes* than students from the other research groups. We assume that this synergism evolved as reciprocity between the two components: the *Meta* component triggered students' awareness to their environmental values and attitudes; and the *CIC* component enabled the students to express their environmental opinions, compare their values and attitudes to those of others, and form holistic perspectives on environmental issues (Wright, 2008). Wals and van der Leij (1997) argued that environmental education must provide situations in which participants freely discuss their environmental values; such discourse engages the participants in values verification, through self-reflection on the relationship between their own guiding assumptions and interpretations and those of others. Our research supports their call, and demonstrates the importance of combining both the *Meta* and the *CIC* components to promote such an environment.

Outcome-Versus Process-Based Approaches to Measuring Environmental Literacy

In several instances, the results indicated a gap between students' environmental literacy as measured by the environmental literacy questionnaire in comparison to the literacy measured by the ELIN. Regarding the affect strand, students from all the research groups scored high means in the pre-test measurements of attitudes using the questionnaire. Such high scores reduced the likelihood of an observable increase in the post-test measurement. Indeed, the questionnaire indicated that students' environmental attitudes decreased from the pre to post-test, regardless of the research group to which they belonged. We assume that the high scores on students' self-reported attitudes in the pre-test were triggered by Social Desirability Bias (SDB). The SDB implies that respondents reply according to a "socially acceptable" response, and provide overly positive self-descriptions (Paulhus, 2002). Research has demonstrated that SDB causes a major problem concerning the validity of self-reporting measures of environmental attitudes, because eco-friendly attitudes are considered a social norm (e.g., Bogner & Wiseman, 2006; Ewert & Baker, 2001; Oerke & Bogner, 2013). We maintain that the examination of students' self-generated reflections using the ELIN is an effective method to overcome this entanglement. Unlike the environmental literacy questionnaire, which relies on multiple-choice questions in which students can appraise the socially accepted response, the ELIN's theory-driven categories are latent and less apparent to the students. Therefore, the ELIN is less subject to SDB, and may provide the researchers with a comprehensive understanding of students' attitudes towards the environment. Indeed, the content analysis we performed using the ELIN revealed a high variance in students' expressions and references to the various categories. This variance strengthens our assumption regarding the ELIN's resistibility to SDB.

A second discrepancy was found in the behavior strand: in contrast to the between-group differences observed by the ELIN, the results of the questionnaire did not indicate significant temporal or between-group differences regarding students' reported environmental behavior. This discrepancy between the results of the two research tools may be due to the nature of the intervention employed, in which students performed inquiry projects on *specific* environmental issues. Boyes and Stanisstreet (2012) argued that the likelihood of undertaking a particular pro-environmental action is the result of an interaction between two factors: the *degree of willingness to act*, which is influenced by a general feeling of benefiting the environment, coupled with more concrete personal incentives, disincentives, and concerns; and the *believed usefulness of action*, the degree of environmental effect a person attributes to various environmental actions. Actions differ from each other in degree of association between a belief in the efficacy of an action and a willingness to undertake it (Boyes & Stanisstreet, 2012). Hence, the *potential effectiveness of education* is a measure of the association between belief in the effectiveness of an action and the willingness to undertake it (Boyes & Stanisstreet, 2012). Accordingly, students' engagement in the inquiry process possibly increased students' *degree of willingness to act* and *believed usefulness of action* regarding the *specific* topics they investigated. These changes led the students to describe various types of *environmental-related behaviors* in their reflections, related to the context of their inquiry projects, which were analyzed by the ELIN. However, due to the specificity of the intervention, the students' *degree of willingness to act* and *believed usefulness of action* did not significantly improve for other environmental behaviors, which were measured by the questionnaire. These results demonstrate the usefulness of the ELIN in examining the outcomes of environmental programs designed to foster students' environmental literacy around particular issues.

General Consideration Regarding the Environmental Education Program

We hypothesized that supporting students' metacognition, will positively affect students' environmental knowledge. In contrast to our expectations, the results of the environmental literacy questionnaire revealed that the students' environmental knowledge increased over time, with no significant differences in gains in students' knowledge among the four research groups. Similarly, the analysis of students' reflections using the ELIN revealed no significant difference in students' references to the various types of knowledge associated with environmental literacy, among the four research groups. On the one hand, these results support findings from previous studies which employed inquiry-based learning techniques to develop environmental knowledge (e.g., Culen & Volk, 2000; Hsu, 2004; Ramsey, 1993; Volk & Cheak, 2003; Zion et al., 2011). On the other hand, the absence of significant differences reveals some possible weaknesses of the *Meta* and the *CIC* components. Regarding the *Meta* component, the metacognitive guidance was environmentally oriented and addressed the knowledge strand; nonetheless, this guidance did not explicitly reference the various types of environmental knowledge associated with environmental literacy. To overcome this limitation, we recommend that future implementations of the *Meta* components clearly distinguish among the various types of environmental knowledge, and specifically address each type of knowledge within the metacognitive guidance. Regarding the *CIC* component, we assume that enabling students to discuss environmental issues during the collaborative sessions, and reflecting upon their acquired environmental knowledge would have improved this component's influence on students' environmental literacy. Therefore, we propose assigning an environmental focus to the *CIC* component and enhancing its explicitness for future implementations.

The results indicate that *system knowledge*, namely knowledge about environmental problems (Frick et al., 2004), was mentioned least by all students, regardless of their research group. This result raises concern because this type of knowledge is at the core of environmental literacy (Roth, 1992). Furthermore, Kaiser and Fuhrer (2003) and Frick et al. (2004), claimed that different forms of knowledge must work together jointly and convergently to foster ecological behavior, and that both *system knowledge* and *procedural knowledge* are needed before *effectiveness knowledge* can be acquired. A possible explanation for this phenomenon concerns the topics which students chose for their inquiry. Because the core of the *Meta-CIC* model involves open-inquiry, students were not restricted to specific topics, provided they were related to their environment. Consequently, the inquiry topics varied greatly in their respect to scientific-environmental content knowledge. One possible recommendation could be to limit students' options only to inquiry topics which have a clear affinity to scientific-environmental knowledge. However, implementing such a limitation may impede students' autonomy; a major characteristic of open-inquiry based learning (Chinn & Malhotra, 2002), and consequently impair students' enjoyment, satisfaction, creativity, and curiosity during the inquiry process (Zion & Sadeh, 2007). Therefore, an alternative recommendation is to emphasize the ecological and scientific affinity of the student-selected environmental topics within the teachers' guidance and the students' inquiry process, so that they are expressed more clearly within the section of the "literature review" in students' inquiry reports. Another suggestion is to integrate a "pre-inquiry" in which the teacher exposes the students to various environmental issues and conflicts, and emphasizes aspects of system knowledge. Upon completion of this "pre-inquiry" stage, students will possess a broader basic knowledge of various environmental issues and topics, and will be able to make informed decisions regarding the topic of their own inquiry project.

Regarding students' expressions of environmental-associated *skills*, the results of the descriptive analysis show that the students' expressions of these skills varied. Interestingly, skills which were expressed by a higher percentage of the students (e.g., *using critical and creative thinking*, *finding and organizing information*, *displaying skepticism in a healthy way*, *thinking and planning ahead*, and *examining alternatives and making choices among them*), can be regarded as domain-independent metacognitive skills: general skills which are required during the inquiry process, and lack an environmental affinity (Veenman & Spaans, 2005). In contrast, skills which were not extensively expressed (e.g., *looking for seeds of change*, *evaluating the consequence of potential actions*, and *making choices among alternatives that have a minimum negative impact on natural systems*), incorporated in their operationalized definitions both metacognitive and environmental aspects, and may be regarded as domain-dependent metacognitive skills (Veenman & Spaans, 2005). Taken together, the results indicate that while the metacognitive support provided to the students succeeded in increasing students' expression of domain-independent skills, it failed in increasing their reference to domain-dependent skills. Consequently, these results underscore the importance of organically integrating aspects of the knowledge domain within the metacognitive support, thus providing the students with context-based and explicit metacognitive support (see also Veenman, Van Hout-Wolters, & Afflerbach, 2006).

Regarding students' environmental behavior, we did not find expressions associated with *non-activism behaviors in the public sphere* in students' reflections. According to its theoretical definition, these types of behaviors refer to the support or acceptance of public policies and willingness to pay higher taxes for environmental protection (Stern, 2000). Although these behaviors affect the environment indirectly, the effects may be large, because public policies can change the behavior of many people and organizations at once (Stern, 2000). The absence of expressions associated with *non-activism behaviors in the public sphere* may indicate that students failed to realize the potential of this environmental behavior. Therefore, it is important that future environmental curriculum place a higher emphasis on this aspect behavior. Such emphasis could be embedded during students' engagement in the inquiry process, or during a "pre-inquiry" stage, in which aspects of effective environmental behaviors, such as *non-activism behaviors in the public sphere*, would be explicitly discussed.

Limitations and Future Studies

The participants in this study were high-achieving students who studied in homologous classes. Consequently, the generalization of the findings to a heterologous class, and to average or under-achieving students should be made with caution. Previous studies demonstrated that metacognitive guidance enhances metacognition and learning in a broad range of students (e.g., Veenman, Elshout, & Busato, 1994), but has particular relevance to low-achieving students (e.g., Pressley & Gaskins, 2006). Therefore, we suggest a study which investigates the *Meta-CIC* model in these populations. Such an investigation immediately raises two questions: (1) What is the effect of the *Meta-CIC* model on the environmental literacy of these students? and (2) What are the requirements for successful implementation of the *Meta-CIC* model in these populations?

Research indicates that students' metacognition becomes more sophisticated and academically oriented whenever formal educational requires the explicit utilization of a metacognitive repertoire (Veenman et al., 2006). Consequently, supporting students' metacognition, and ensuring their active engagement in metacognitive processes were at the core of the educational intervention we designed. For example, the students were required implement learning strategies, and to perform a reflection at each stage of the inquiry process. The teachers further supported students' metacognition through explicit teaching, continuous feedback, and facilitation of group discussions during the *CIC* sessions. The extensive data which were collected provides support for students' engagement in metacognition (e.g., Zion, Adler, & Mevarech, 2015). Despite all of these activities in support of students' metacognition, we recognize that the lack of pre and post assessments of students' metacognition is a limitation of this study.

Previous studies demonstrated that teachers play a crucial role in teaching inquiry (Crawford, 2000; Crawford, Krajcik, & Marx, 1999). In addition to the "regular" difficulties imposed by teaching inquiry, the *Meta-CIC* model requires the teachers to be highly skilled in orchestrating metacognitive support and collaborative learning. In this study, the teachers were closely supported by the researchers during the entire inquiry process. This situation raises several concerns regarding the feasibility of implementing the *Meta-CIC* model on a wider scale. At least two questions should be addressed: (1) Would novice teachers be able to effectively implement this model in their classes? (2) What preparations can be made in pre or in-service teachers' training to assist teachers to implement this model?

Designing an efficient and applicable metacognitive support is a challenging task. While the individual aspect of metacognition has been widely researched, resulting in numerous research-based techniques to support this self-directed aspect, research on the social aspect of metacognition and interventional techniques to support this aspect are still in their infancy. Consequently, the *CIC* component was designed as an innovative means to support students' metacognition throughout the inquiry process. However, the results suggest that several modifications are needed to improve the effect of this component: first, we recommend integrating an environmental focus into the *CIC* collaboration script; second, principles of social learning theories should be incorporated into this component to a greater extent; and finally, the addition of joined or individual reflections on the social interactions and knowledge gains from the *CIC* sessions, could further improve this component's efficiency. Finding the right balance among all these elements is certainly a challenging but worthwhile task for future studies.

Social Desirably Bias (SDB) is regarded as a major problem concerning the validity of self-reporting measures of (Oerke & Bogner, 2013). Consequently, SDB may prompt students to provide overly positive self-descriptions of their environmental attitudes and behaviors in their reflections, and result in an overly positive measurement of students' environmental literacy using the ELIN. We maintain that because the ELIN's categories are latent to the students, the ELIN is less subject to SDB. However, to further overcome the limitation of SDB, we suggest expanding the measuring capability of the ELIN to include two aspects of each measured characteristic: (a) the presence or absence of the characteristic; and (b) an evaluation of the quality of the students' statements. Such a modification will improve the ELIN's evaluation of students' environmental literacy, and provide further insights into the effect of environmental educational programs.

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References

Abd-El-Khalick, F., Bell, R. L., & Lederman, N. G. (1998). The nature of science and instructional practice: Making the unnatural natural. Science Education, 82(4), 417–436.

Anderson, D., & Nashon, S. (2007). Predators of knowledge construction: Interpreting students' metacognition in an amusement park physics program. Science Education, 91(2), 298–320.

Bamberg, S., & Möser, G. (2007). Twenty years after Hines, Hungerford, and Tomera: A new meta-analysis of psycho-social determinants of pro-environmental behaviour. Journal of Environmental Psychology, 27(1), 14–25.

Bell, R. L., Blair, L. M., Crawford, B. A., & Lederman, N. G. (2003). Just do it? Impact of a science apprenticeship program on high school students' understandings of the nature of science and scientific inquiry. Journal of Research in Science Teaching, 40(5), 487–509.

Ben-David, A., & Zohar, A. (2009). Contribution of meta-strategic knowledge to scientific inquiry learning. International Journal of Science Education, 31(12), 1657–1682.

Bluhm, W. J., Hungerford, H. R., McBeth, W. C., & Volk, T. L. (1995). The middle school report: A final report on the development and pilot assessment of the middle school environmental literacy instrument. Unpublished research paper. Southern Illimois University at Carbondale.

Bogner, F., & Wiseman, M. (2006). Adolescents' attitudes towards nature and environment: Quantifying the 2-MEV model. Environmentalist, 26(4), 247–254.

Boyes, E., & Stanisstreet, M. (2012). Environmental education for behaviour change: Which actions should be targeted? International Journal of Science Education, 34(10), 1591–1614.

Bradley, J. C., Waliczek, T. M., & Zajicek, J. M. (1999). Relationship between environmental knowledge and environmental attitude of high school students. The Journal of Environmental Education, 30(3), 17–21.

Brown, A. L. (1987). Metacognition, executive control, self-regulation, and other more mysterious mechanisms. In F. E. Weinert & R. H. Kluwe (Eds.), Metacognition, motivation, and understanding (pp. 65–116). Hillsdale, NJ: Lawrence Erlbaum Associates.

Chawla, L. (1998). Significant life experiences revisited: A review of research on sources of environmental sensitivity. The Journal of Environmental Education, 29(3), 11–21.

Chawla, L. (1999). Life paths into effective environmental action. The Journal of Environmental Education, 31(1), 15–26.

Chinn, C. A., & Malhotra, B. A. (2002). Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks. Science Education, 86(2), 175–218.

Chinn, C. A., O'Donnell, A. M., & Jinks, T. S. (2000). The structure of discourse in collaborative learning. The Journal of Experimental Education, 69(1), 77–97.

Crawford, B. A. (2000). Embracing the essence of inquiry: New roles for science teachers. Journal of Research in Science Teaching, 37(9), 916–937.

Crawford, B. A., Krajcik, J. S., & Marx, R. W. (1999). Elements of a community of learners in a middle school science classroom [Eléments d'une communauté d'apprenants dans une classe de science au collège.]. Science Education (Saleem. Mass.), 83(6), 701–723.

Culen, G. R., & Volk, T. L. (2000). Effects of an extended case study on environmental behavior and associated variables in seventh-and eighth-grade students. The Journal of Environmental Education, 31(2), 9–15.

Damon, W., & Phelps, E (1989). Critical distinctions among three approaches to peer education. International Journal of Educational Research, 13(1), 9–19.

de Jong, F., Kollöffel, B., van der Meijden, H., Staarman, J. K, & Janssen, J. (2005). Regulative processes in individual, 3D and computer supported cooperative learning contexts. Computers in Human Behavior, 21(4), 645–670.

Dillenbourg, P. (1999). What do you mean by collaborative learning. In P. Dillenbourg (Ed.), Collaborative-learning: Cognitive and computational approaches (pp.1–19). Oxford: Elsevier.

Dillenbourg, P., & Hong, F. (2008). The mechanics of CSCL macro scripts. International Journal of Computer-Supported Collaborative Learning, 3(1), 5–23.

Disinger, J. F., & Roth, C. E. (1992). Environmental literacy. Columbus, OH: ERIC Clearinghouse for Science Mathematics and Environmental Education. (ERIC/CSMREE Digest No. ED351201).

Duvall, J., & Zint, M. (2007). A review of research on the effectiveness of environmental education in promoting intergenerational learning. The Journal of Environmental Education, 38(4), 14–24.

Erdoğan, M., Bahar, M., Özel, R., Erdaş, E., & Uşak, M. (2012). Environmental education in 2002 and 2006 early childhood curriculum. Educational Sciences: Theory & Practice, 12, 3259–3272.

Erdoğan, M., Kostova, Z., & Marcinkowski, T. (2009a). Components of environmental literacy in elementary science education curriculum in Bulgaria and Turkey. Eurasia Journal of Mathematics Science and Technology Education, 5(1), 15–26.

Erdoğan, M., Marcinkowski, T., & Ok, A. (2009b). Content analysis of selected features of K-8 environmental education research studies in Turkey, 1997–2007. Environmental Education Research, 15(5), 525–548.

Ewert, A., & Baker, D. (2001). Standing for where you sit: An exploratory analysis of the relationship between academics major and environment beliefs. Environment and Behaviour, 33, 687–707.

Flavell, J. (1976). Metacognitive aspects of problem solving. In L. Resnick (Ed.), The nature of intelligence (pp. 231–236). Hillsdale, NJ: Erlbaum.

Frick, J., Kaiser, F. G., & Wilson, M. (2004). Environmental knowledge and conservation behavior: Exploring prevalence and structure in a representative sample. Personality and Individual Differences, 37(8), 1597–1613.

Frith, C. D. (2012). The role of metacognition in human social interactions. Philosophical Transactions of the Royal Society B: Biological Sciences, 367, 2213–2223.

Gilbreth, F. B., & Gilbreth, L. M. (1921). Process Charts. American Society of Mechanical Engineers, New York.

Goos, M., Galbraith, P., & Renshaw, P. (1999). Establishing a community of practice in a secondary mathematics classroom. In L. Burton (Ed.), Learning mathematics: From hierarchies to networks (pp. 36–41). London: Falmer Press.

Goos, M., Galbraith, P., & Renshaw, P. (2002). Socially mediated metacognition: Creating collaborative zones of proximal development in small group problem solving. Educational Studies in Mathematics, 49(2), 193–223.

Graesser, A., & McNamara, D. (2010). Self-regulated learning in learning environments with pedagogical agents that interact in natural language. Educational Psychologist, 45(4), 234–244.

Granzin, K. L., & Olsen, J. E. (1991). Characterizing participants in activities protecting the environment: A focus on donating, recycling, and conservation behaviors. Journal of Public Policy & Marketing, 10(2), 1–27.

Grau, V., & Whitebread, D. (2012). Self and social regulation of learning during collaborative activities in the classroom: The interplay of individual and group cognition. Learning and Instruction, 22(6), 401–412.

Hadwin, A., & Oshige, M. (2011). Self-regulation, coregulation, and socially shared regulation: Exploring perspectives of social in self-regulated learning theory. Teachers College Record, 113(2), 240–264.

Halpern, D. F. (1998). Teaching critical thinking for transfer across domains: Disposition, skills, structure training, and metacognitive monitoring. American Psychologist, 53(4), 449–455.

Heimlich, J. E., & Ardoin, N. M. (2008). Understanding behavior to understand behavior change: A literature review. Environmental Education Research, 14(3), 215–237.

Herron, M. D. (1971). The nature of scientific enquiry. The School Review, 79 (2), 171–212.

Hines, J. M., Hungerford, H. R., & Tomera, A. N. (1987). Analysis and synthesis of research on responsible environmental behavior: A meta-analysis. The Journal of Environmental Education, 18(2), 1–8.

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). Educational Psychologist, 42(2), 99–107.

Hogan, K. (1999). Thinking aloud together: A test of an intervention to foster students' collaborative scientific reasoning. Journal of Research in Science Teaching, 36(10), 1085–1109.

Hsu, S. J. (2004). The effects of an environmental education program on responsible environmental behavior and associated environmental literacy variables in Taiwanese college students. The Journal of Environmental Education, 35(2), 37–48.

Hungerford, H., Peyton, R. B., & Wilke, R. J. (1980). Goals for curriculum development in environmental education. The Journal of Environmental Education, 11(3), 42–47.

Hungerford, H. R., & Volk, T. L. (1990). Changing learner behavior through environmental education. The Journal of Environmental Education, 21(3), 8–22.

Iiskala, T., Vauras, M., & Lehtinen, E. (2004). Socially-shared metacognition in peer learning? Hellenic Journal of Psychology, 1(2), 147–178.

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

James, J. J., & Bixler, R. D. (2008). Children's role in meaning making through their participation in an environmental education program. The Journal of Environmental Education, 39(4), 44–59.

Järvelä, S., & Hadwin, A. F. (2013). New frontiers: Regulating learning in CSCL. Educational Psychologist, 48(1), 25–39.

Järvelä, S., Järvenoja, H., Malmberg, J., & Hadwin, A. F. (2013). Exploring socially shared regulation in the context of collaboration. Journal of Cognitive Education and Psychology, 12(3), 267–286.

Jickling, B. (2003). Environmental education and environmental advocacy: Revisited. The Journal of Environmental Education, 34(2), 20–20.

Jost, J. T., Kruglanski, A. W., & Nelson, T. O. (1998). Social metacognition: An expansionist review. Personality and Social Psychology Review, 2(2), 137–154.

Kaiser, F. G. (1998). A general measure of ecological behavior. Journal of Applied Social Psychology, 28(5), 395–422.

Kaiser, F. G., & Fuhrer, U. (2003). Ecological behavior's dependency on different forms of knowledge. Applied Psychology, 52(4), 598–613.

Kaiser, F. G., & Shimoda, T. A. (1999). Responsibility as a predictor of ecological behaviour. Journal of Environmental Psychology, 19(3), 243–253.

Kelemen, W. L., Frost, P. J., & Weaver, C. A., III. (2000). Individual differences in metacognition: Evidence against a general metacognitive ability. Memory & Cognition, 28(1), 92–107.

King, A. (1991). Effects of training in strategic questioning on children's problem-solving performance. Journal of Educational Psychology, 83(3), 307–317.

King, A. (1997). ASK to THINK-TEL WHY: A model of transactive peer tutoring for scaffolding higher level complex learning. Educational Psychologis, 32(4), 221–235.

King, A. (1998). Transactive peer tutoring: Distributing cognition and metacognition. Educational Psychology Review. 10(1), 57–74.

King, A. (2007). Scripting collaborative learning processes: A cognitive perspective. In F. Fischer, I. Kollar, H. Mandl, & J.M. Haake (Eds.), Scripting computer-supported collaborative learning: Cognitive, computational, and educational perspectives (pp. 13–37). New York: Springer.

Kipnis, M., & Hofstein, A. (2008). The inquiry laboratory as a source for development of metacognitive skills. International Journal of Science and Mathematics Education, 6(3), 601–627.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. Educational Psychologist, 41(2), 75–86.

Knapp, D., & Poff, R. (2001). A qualitative analysis of the immediate and short-term impact of an environmental interpretive program. Environmental Education Research, 7(1), 55–65.

Kollmuss, A., & Agyeman, J. (2002). Mind the gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? Environmental Education Research, 8(3), 239–260.

Ku, K. Y., & Ho, I. T. (2010). Metacognitive strategies that enhance critical thinking. Metacognition and Learning, 5(3), 251–267.

Lajoie, S. P., & Lu, J. (2012). Supporting collaboration with technology: Does shared cognition lead to co-regulation in medicine? Metacognition and Learning, 7(1), 45–62.

Larkin, S. (2006). Collaborative group work and individual development of metacognition in the early years. Research in Science Education, 36(1–2), 7–27.

Leeming, F. C., & Dwyer, W. O. (1995). Children's environmental attitude and knowledge scale: Construction and validation. Journal of Environmental Education, 26(3), 22–31.

Lin, X., & Lehman, J. D. (1999). Supporting learning of variable control in a computer-based biology environment: Effects of prompting college students to reflect on their own thinking. Journal of Research in Science Teaching, 36(7), 837–858.

Littledyke, M. (2008). Science education for environmental awareness: Approaches to integrating cognitive and affective domains. Environmental Education Research, 14(1), 1–17.

Lou, Y. (2004). Learning to solve complex problems through between-group collaboration in project-based online courses. Distance Education, 25(1), 49–66.

Lou, Y., Abrami, P. C., & Spence, J. C. (2000). Effects of within-class grouping on student achievement: An exploratory model. The Journal of Educational Research, 94(2), 101–112.

Lou, Y., & MacGregor, S. K. (2004). Enhancing project-based learning through online between-group collaboration. Educational Research and Evaluation, 10(4–6), 419–440.

Magno, C. (2010). The role of metacognitive skills in developing critical thinking. Metacognition and Learning, 5(2), 137–156.

Manlove, S., Lazonder, A. W., & de Jong, T. (2007). Software scaffolds to promote regulation during scientific inquiry learning. Metacognition and Learning, 2(2–3), 141–155.

Marcinkowsky, T., Bucheit, J., Spero-Swingle, V., Lisenbardt, C., Engelhardt, J., Stadel, M., & Guzmon, K. (2013). Selected trends in thirty years of doctoral reserchin environmental education in dissertation abstracts international from collections prepared in the United States of America. In R. B. Stevenson, M. Brody, J. Dillon, & A. E. J. Wals (Eds.), International handbook of research on environmental education. (pp. 45–62). New York: Routledge.

McBeth, W., & Volk, T. L. (2010). The national environmental literacy project: A baseline study of middle grade students in the United States. Journal of Environmental Education, 41(1), 55–67.

Mevarech, Z. R., & Kramarski, B. (1997). Improve: A multidimensional method for teaching mathematics in heterogeneous classrooms. American Educational Research Journal, 34(2), 365–394.

Meyer, K. (2003). Face- to-face versus threaded discussions: The role of time and higher-order thinking. Journal of Asynchronous Learning Networks, 7(3), 55–65.

Michalsky, T., Mevarech, Z. R., & Haibi, L. (2009). Elementary school children reading scientific texts: Effects of metacognitive instruction. The Journal of Educational Research, 102(5), 363–374.

Michalsky, T., Zion, M., & Mevarech, Z. R. (2007). Developing students' metacognitive awareness in asynchronous learning networks in comparison to face-to-face discussion groups. Journal of Educational Computing Research, 36(4), 395–424.

Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction-What is it and does it matter? Results from a research synthesis years 1984 to 2002. Journal of Research in Science Teaching, 47(4), 474–496.

Mogensen, F. (1997). Critical thinking: A central element in developing action competence in health and environmental education. Health Education Research, 12(4), 429–436.

Morrone, M., Mancl, K., & Carr, K. (2001). Development of a metric to test group differences in ecological knowledge as one component of environmental literacy. Journal of Environmental Education, 32(4), 33.

National Research Council (NRC). (1996). National science education standards. Washington, DC: National Academy Press.

National Research Council (NRC). (2000). Inquiry and the national science education standards. Washington, DC: National Academy Press.

Negev, M., Sagy, G., Garb, Y., Salzberg, A., & Tal, A. (2008). Evaluating the environmental literacy of Israeli elementary and high school students. The Journal of Environmental Education, 39(2), 3–20.

Nielsen, W. S., Nashon, S., & Anderson, D. (2009). Metacognitive engagement during field-trip experiences: A case study of students in an amusement park physics program. Journal of Research in Science Teaching, 46(3), 265–288.

Oerke, B., & Bogner, F. X. (2013). Social desirability, environmental attitudes, and general ecological behaviour in children. International Journal of Science Education, 35(5), 713–730.

Orr, D. (1999). Rethinking education. The Ecologist, 29, 232–234.

Osborne, A. F. (1963). Applied imagination: Principles and procedure of creative problem solving. New York: Scribner.

Osborne, J. (2014). Teaching scientific practices: Meeting the challenge of change. Journal of Science Teacher Education 25(2), 177–196.

Palincsar, A. S., & Herrenkohl, L. R. (2002). Designing collaborative learning contexts. Theory Into Practice, 41(1), 26–32.

Paulhus, D. L. (2002). Measurement and control of response bias. In J. P. Robinson, P. Shaver, & L. S. Wrightsman (Eds.), Measures of personality and social psychological attitudes (pp. 17–59). San Diego, CA: Academic Press.

Peled, E., & Tal., T. (2011). Environmental literacy in Israeli schools: Students' knowledge, attitude and behavior. The Biannual Conference of the European Science Education Research Association (ESERA), Lyon, FR.

Pressley, M., & Gaskins, I. W. (2006). Metacognitively competent reading comprehension is constructively responsive reading: How can such reading be developed in students? Metacognition and Learning, 1(1), 99–113.

Quintana, C., Meilan, Z., & Krajcik, J. (2005). A framework for supporting metacognitive sspects of online inquiry through software-based scaffolding. Educational Psychologist, 40(4), 235–244.

Ramsey, J. M. (1993). The effects of issue investigation and action training on eighth-grade students' environmental behavior. The Journal of Environmental Education, 24(3), 31–36.

Roberts, R. (2001). Procedural understanding in biology: The 'thinking behind the doing'. Journal of Biological Education, 35(3), 113–117.

Rogat, T. K., & Linnenbrink-Garcia, L. (2011). Socially shared regulation in collaborative groups: An analysis of the interplay between quality of social regulation and group processes. Cognition and Instructio, 29(4), 375–415.

Roth, R. E. (1992). Environmental literacy: Its roots, evolution and directions in the 1990s. Columbus, OH: ERIC/CSM Environmental Education.

Roth, R. E. (1997). A critique of "alternatives to national standards for environmental education: Process-based quality assessment". Canadian Journal of Environmental Education (CJEE), 2(1), 28–34.

Sadeh, I., & Zion, M. (2009). The development of dynamic inquiry performances within an open inquiry setting: A comparison to guided inquiry setting. Journal of Research in Science Teaching, 46(10), 1137–1160.

Salomon, G., & Globerson, T. (1989). When teams do not function the way they ought to. International Journal of Educational Research, 13(1), 89–99.

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

Sandi-Urena, S., Cooper, M. M., & Stevens, R. H. (2011). Enhancement of metacognition use and awareness by means of a collaborative intervention. International Journal of Science Education, 33(3), 323–340.

Schraw, G. (1998). Promoting general metacognitive awareness. Instructional Science, 26(1–2), 113–125.

Schraw, G., Crippen, K., & Hartley, K. (2006). Promoting self-regulation in science education: Metacognition as part of a broader perspective on learning. Research in Science Education, 36(1-2), 111–139.

Schraw, G., & Dennison, R. S. (1994). Assessing metacognitive awareness. Contemporary Educational Psychology 19(4), 460.

Schraw, G., Dunkle, M. E., Bendixen, L. D., & Roedel, T. D (1995). Does a general monitoring skill exist? Journal of Educational Psychology, 87(3), 433–444.

Schraw, G., & Moshman, D. (1995). Metacognitive theories. Educational Psychology Review, 7(4), 351–371.

Schraw, G., & Nietfeld, J. (1998). A further test of the general monitoring skill hypothesis. Journal of Educational Psychology, 90(2), 236–248.

Schwab, J. J. (1962). The teaching of science as inquiry. In J. J. Schwab & P. E. Brandweine (Eds.), The teaching of science (pp. 3–103). Cambridge, MA: Harvard University Press.

Shkedi, A. (2003). Words of meaning: Qualitative research-theory and practice. Tel-Aviv: Tel-Aviv university Ramot. (Hebrew).

Siegel, M. A. (2012). Filling in the distance between us: Group metacognition during problem solving in a secondary education course. Journal of Science Education and Technology, 21(3), 325–341.

Slavin, R. E. (1996). Research on cooperative learning and achievement: What we know, what we need to know. Contemporary Educational Psychology, 21(1), 43–69.

Stables, A., & Bishop, K (2001). Weak and strong conceptions of environmental literacy: Implications for environmental education. Environmental Education Research, 7(1), 89–97.

Stern, P. C. (2000). New environmental theories: Toward a coherent theory of environmentally significant behavior. Journal of Social Issues, 56(3), 407–424.

Sweller, J., Kirschner, P. A., & Clark, R. E. (2007). Why minimally guided teaching techniques do not work: A reply to commentaries. Educational Psychologist, 42(2), 115–121.

Tal, T., & Peled, E. (2011). Indicators for environmental literacy: Local vs. global knowledge. The annual meeting NARST, Orlando, FL.

Tal, T., Peled, E., & Abramovich, A. (2010). Developing indicators to the influence of environmental education on students' environmental awareness and behavior. The Ministry Environmental Protection.

Tanner, K. D. (2012). Promoting student metacognition. CBE-Life Sciences Education, 11(2), 113–120.

Topping, K. J. (2005). Trends in peer learning. Educational Psychology, 25(6), 631–645.

Topping, K. J., & Ehly, S. W. (2001). Peer assisted learning: A framework for consultation. Journal of Educational & Psychological Consultation, 12(2), 113–132.

UNESCO. (1977). First intergovernmental conference on environmental education final report. Tbilisi, USSR. Paris: UNESCO.

Van den Bossche, P., Gijselaers, W. H., Segers, M., & Kirschner, P. A. (2006). Social and cognitive factors driving teamwork in collaborative learning environments: Team learning beliefs and behaviors. Small Group Research, 37(5), 490–521.

van der Stel, M., & Veenman, M. V. J. (2008). Relation between intellectual ability and metacognitive skillfulness as predictors of learning performance of young students performing tasks in different domains. Learning and Individual Differences, 18(1), 128–134.

Van Liere, K. D., & Dunlap, R. E. (1978). Moral norms and environmental behavior: An application of Schwartz's norm-activation model to yard burning. Journal of Applied Social Psychology, 8(2), 174–188.

Veenman, M. V. J., Elshout, J. J., & Busato, V. V. (1994). Metacognitive mediation in learning with computer-based simulations. Computers in Human Behavior, 10(1), 93–106.

Veenman, M. V. J., Hout-Wolters, B. A. M., & Afflerbach, P. (2006). Metacognition and learning: Conceptual and methodological considerations. Metacognition and Learning, 1(1), 3–14.

Veenman, M. V. J., & Spaans, M. A. (2005). Relation between intellectual and metacognitive skills: Age and task differences. Learning and Individual Differences, 15(2), 159–176.

Veenman, M. V. J., & Verheij, J. (2001). Technical students' metacognitive skills: Relating general vs. specific metacognitive skills to study success. Learning and Individual Differences, 13(3), 259–272.

Veenman, M. V. J., Wilhelm, P., & Beishuizen, J. J. (2004). The relation between intellectual and metacognitive skills from a developmental perspective. Learning and Instruction, 14(1), 89–109.

Volet, S., Vauras, M., & Salonen, P. (2009). Self- and social regulation in learning contexts: An integrative perspective. Educational Psychologist, 44(4), 215–226.

Volk, T. L., & Cheak, M. J. (2003). The effects of an environmental education program on students, parents, and community. The Journal of Environmental Education, 34(4), 12–25.

Wals, A. E., Brody, M., Dillon, J., & Stevenson, R. B. (2014). Convergence between science and environmental education. Science, 344, 583–584.

Wals, A. E. J., & Jickling, B. (2002). "Sustainability" in higher education: From doublethink and newspeak to critical thinking and meaningful learning. International Journal of Sustainability in Higher Education, 3(3), 221–232.

Wals, A. E., & van der Leij, T. (1997). Alternatives to national standards for environmental education: Process-based quality assessment. Canadian Journal of Environmental Education, 2(1), 7–27.

White, B., & Frederiksen, J. (2005). A theoretical framework and approach for fostering metacognitive development. Educational Psychologist, 40(4), 211–223.

White, B., Frederiksen, J., & Collins, A. (2009). The interplay of scientific inquiry and metacognition: More than a marriage of convenience. In D. Hacker, J. Dunlosky, & A. Graesser (Eds.), Handbook of metacognition in e ducation (pp. 175–205). New York: Routledge.

Wright, J. M. (2008). Web-based versus in-class: An exploration of how instructional methods influence postsecondary students' environmental literacy. The Journal of Environmental Education, 39(2), 33–45.

Yarrow, F., & Topping, K. J. (2001). Collaborative writing: The effects of metacognitive prompting and structured peer interaction. British Journal of Educational Psychology, 71, 261–282.

Zion, M., Adler, I., & Mevarech, Z. (2015). The effect of individual and social metacognitive support on students' metacognitive performances in an online discussion. Journal of Educational Computing Research, 52(1), 50–87.

Zion, M., Michalsky, T., & Mevarech, Z. (2005). The effects of metacognitive instruction embedded within an asynchronous learning network on scientific inquiry skills. International Journal of Science Education, 27(8), 957–983.

Zion, M., & Sadeh, I. (2007). Curiosity and open inquiry learning. Journal of Biological Education, 41(4), 162–169.

Zion, M., Spektor-Levy, O., Orchan, Y., Shwartz, A., Sadeh, I., & Kark, S. (2011). Tracking invasive birds: A programme for implementing dynamic open inquiry learning and conservation education. Journal of Biological Education, 45(1), 3–12.

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