Chapter 4
Metacognitive Knowledge and Field-based Science Learning in an Outdoor Environmental Education Program

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Introduction

Metacognition is an important component of learning and self-regulation at all ages (Efklides 2008; McCormick 2003). Previous research indicates that older students are more metacognitively aware than younger students, but that even students in the lower elementary grades demonstrate metacognitive awareness that is related positively to learning (Presley and Harris 2006). The goal of this chapter is to examine the relationship between different types of metacognitive knowledge, attitudes about environmental education, and learning during a half-day science intervention on a floating laboratory at Lake Mead National Recreation Area. Our chapter is arranged into seven sections. The first section presents a multi-component taxonomy of metacognition and related terms. The second section describes the development of two self-report instruments intended to measure metacognitive knowledge and regulation. Section three states five predictions of the present research. Section four describes the participants, materials, and research procedures used in our research. Section five presents results, while section six discusses these results and links them to previous research. Section seven explores several ways to improve metacognition.

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Taxonomy of Metacognition

Metacognition is a broad term that is usually interpreted as *thinking about thinking* or *demonstrating awareness and understanding of one's cognition* (McCormick 2003). The term metacognition is related to several other terms in the literature usually referred to as metamemory and metacomprehension which distinguish between knowledge about the contents of memory versus processes used to regulate and monitor memory and cognition. The term *metacomprehension* appeared later and refers to understanding at the broadest level of comprehension that is necessary for an individual to be fully self-regulated (Efklides 2008). At least two components of metacomprehension are necessary for comprehensive understanding, including metamemory and metacognition. Given current definitions, metamemory refers to knowledge and understanding of memory in general, as well as one's own memory in particular. This knowledge enables individuals to appraise memory demands and to assess available knowledge and strategies in memory. Metacognition refers to knowledge about cognition and cognitive processes (Schraw 2006). Metacognition usually is subdivided into two distinct components, including knowledge of cognition and regulation of cognition. Some researchers also refer to these two components as metacognitive knowledge and metacognitive skills.

The framework used in the present study for conceptualizing metacognition is based on the distinction between knowledge and regulation of cognition (Sperling et al. 2002). Figure 4.1 shows components of metacognition and their relationship to metacomprehension and metamemory. Knowledge of cognition refers to what we know about our cognition and usually includes three subcomponents. The first, declarative knowledge, includes knowledge about oneself as a learner and what factors influence one's performance. For example, most adult learners know the limitations of their memory system and can plan accordingly. Procedural knowledge, in contrast, refers to knowledge about strategies and other procedures. For instance, most adults possess a basic repertoire of useful strategies such as note-taking, slowing down for important information, skimming unimportant information, using mnemonics, summarizing main ideas, and periodic self-testing. Finally, conditional knowledge, includes knowledge of why and when to use a particular strategy. Individuals with a high degree of conditional knowledge are better able to assess the demands of a specific learning situation and, in turn, select strategies that are most appropriate for that situation.

Research suggests that knowledge of cognition is late developing and explicit (Efklides 2008; Kuhn 2000). Adults tend to have more knowledge about their own cognition and are better able to describe that knowledge than children and adolescents. However, many adults cannot explain their expert knowledge and performance and often fail to spontaneously transfer domain-specific knowledge to a new setting. This suggests that metacognitive knowledge need not be explicit to be useful and, in fact, may be implicit in some situations (McCormick 2003).

Regulation of cognition typically includes at least three components, planning, monitoring, and evaluation (Schraw 2006). Planning involves the selection of appropriate strategies and the allocation of resources. Planning includes goal setting,

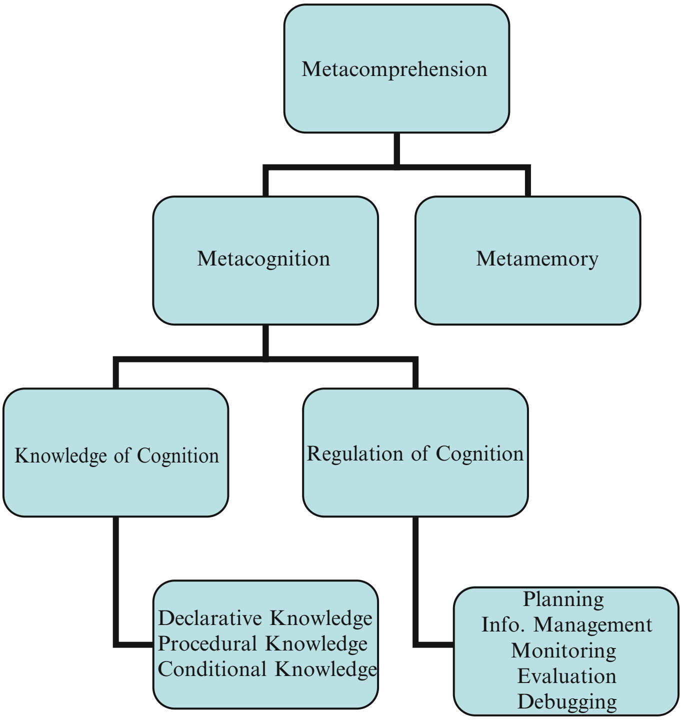


Fig. 4.1 The relationship of metacomprehension, metacognition, and metamemory

activating relevant background knowledge, and budgeting time. Previous research suggests that experts are more self-regulated compared to novices largely due to effective planning, particularly global planning that occurs prior to beginning a task. Monitoring includes the self-testing skills necessary to control learning. Research indicates that adults monitor at both the local (i.e., an individual test item) and global levels (i.e., all items on a test). Research also suggests that even skilled adult learners may be poor monitors under certain conditions (Pressley and Harris 2006). Evaluation refers to appraising the learning and self-regulation of one's learning. Typical examples include re-evaluating one's goals, revising predictions, and consolidating intellectual gains.

Some researchers and theorists believe that self-regulatory processes, including planning, monitoring, and evaluation, may not be conscious or explicit in many learning situations. One reason is that many of these processes are highly automated, at least among adults. A second reason is that some of these processes may develop without any conscious reflection and therefore are difficult to report to others. Some science educators believe that science education should reduce the amount of instructional time devoted to conceptual understanding and increase the amount of time devoted to procedural understanding. The rationale for this claim is that procedural competence in the form of expert problem-solving and critical thinking becomes increasingly more important at higher levels of science education.

Development of the Metacognitive Awareness Inventory

Schraw and Dennison (1994) created an instrument designed to assess metacognitive awareness. The metacognitive awareness inventory (MAI) included 52 statements that measured awareness about knowledge and regulation of cognition (see Table 4.1). Schraw and Dennison (1994) conducted two experiments as part of an initial validation study. Experiment 1 piloted the instrument on 179 college undergraduates and reported a two-factor structure based on exploratory factor analyses. Results supported a reliable two-factor solution. Experiment 2 replicated the exploratory factor analysis reported in Experiment 1 using 100 college undergraduates and added several additional variables, including reading comprehension scores on a 16-item test and calibration judgments for each test item. The knowledge of cognition variable was significantly correlated with test performance and ratings of confidence for test items, but was not related to calibration accuracy. A number of subsequent studies replicated the two-factor structure of the MAI and extended the findings reported above (Mevarech and Amrany 2008).

More recently, Sperling et al. (2002) created a parallel 12-item version of the MAI called the Jr. MAI that was intended for students in 3rd through 8th grade that could be used to assess incoming metacognitive knowledge or changes in knowledge after an intervention to improve metacognitive skills. Sperling et al. (2002) conducted two experiments. Both experiments replicated the knowledge and regulation of cognition factors reported in the MAI. In addition, scores on the Jr. MAI were correlated significantly with scores on the metacomprehension ($r = .30$) and strategic problem-solving ($r = .72$) inventories, as well as teacher ratings ($r = .21$).

Table 4.1 Types of metacognition described by Schraw and Dennison (1994)

Type of metacognition	Skills within each domain of metacognition	Definition
Knowledge of cognition		
	Declarative knowledge (8 items)	Knowledge about one's skills, intellectual resources, and abilities as a learner
	Procedural knowledge (4 items)	Knowledge about *how* to implement learning procedures (e.g., strategies)
	Conditional knowledge (5 items)	Knowledge about *when* and *why* to use learning procedures
Regulation of cognition		
	Planning (7 items)	Planning, goal setting, and allocating resources prior to learning
	Information management (10 items)	Skills and strategy sequences used on-line to process information more efficiently
	Monitoring (7 items)	Ongoing appraisal of one's learning or strategy use
	Debugging (5 items)	Strategies used during learning to correct comprehension and performance errors
	Evaluation (6 items)	Analysis of performance and strategy effectiveness after a learning episode

Metacognition and Science Education

The present study examined the relationship between metacognitive knowledge, attitudes about a field-based science program, and student learning in an environmental education program among 4th and 5th grade students. One important question was the extent to which metacognitive knowledge facilitates science learning. Previous research suggests that metacognition is an extremely important component of science learning for students of all ages (Linn and Bat-Sheva 2006). This literature identified six general instructional strategies that improved learning, including inquiry, student collaboration, use of regulatory learning strategies such as planning and organization, constructing conceptual mental models, use of technology to search and represent information, and incorporating positive personal beliefs such as mastery goal orientations and self-efficacy. Each of these had a positive effect on learning and contributed uniquely to student learning and achievement. In addition, Zohar (2006) found that teachers' metacognitive knowledge and instruction of metacognitive skills increased learning among high school students. Blank (2000) also reported that infusing metacognitive skills into a science learning program improved self-regulation and learning among middle school students. However, the vast majority of these studies were conducted on high school or middle school students; whereas few studies examined the metacognitive knowledge or self-regulation skills of younger students. Similarly, Annevirta and Vaurus (2006) reported that metacognitive knowledge among students aged 6–8 was related to more knowledge about problem-solving and improved learning.

The Present Research

The purpose of the present research was to examine the relationship among self-reported metacognition, attitudes about an outdoor learning program, and field-based learning in an environmental education program. Previous research has not examined the relationship of metacognitive knowledge to field-based learning in an environmental education setting. Questions also arise from a developmental perspective whether students in grades 3 and 5 possess the metacognitive knowledge and skills to support learning. The main research question was whether knowledge and regulation of cognition scores were related to attitudes and learning before and after completing a half-day field-based science curriculum. We measured metacognitive knowledge among students in the 4th and 5th grades in their daily classroom setting prior to a field-based learning experience using the Jr. MAI. We also measured attitudes about the experience before and after their participation, as well as pre- and posttest knowledge given the day long science intervention using assessments developed by the authors.

We made five predictions. Our first prediction was that the Jr. MAI would yield two reliable factors corresponding to knowledge of cognition (KOC) and regulation of cognition (ROC) scores. We expected these factors to explain approximately

35% of total sample variation, consistent with Sperling et al. (2002). Our second prediction was that the knowledge and regulation of cognition factors would be correlated in the .35 range, consistent with Sperling et al. (2002). Our third prediction was that there would be a significant increase from pretest to posttest attitudes as a result of the Forever Earth intervention. Fourth, we predicted that there would be a significant increase from pretest to posttest knowledge scores as a result of the Forever Earth intervention. Our fifth prediction was that KOC and ROC would be correlated with posttest knowledge scores. We expected students with higher self-reported metacognitive knowledge to score higher on the posttest knowledge assessment.

Methods

Participants

One hundred and thirty-four 4th and 5th grade students from a large school district in the Southwestern United States participated in the study. All 134 students completed the Jr. MAI, pretest attitudes, and pretest knowledge test in their classrooms approximately 3 weeks prior to the Forever Earth learning experience. Two 4th grade classrooms ($N=53$) and two 5th grade classrooms ($N=52$) visited the floating laboratory and completed the intervention which resulted in posttest attitude and knowledge scores.

The Forever Earth Learning Program

The Forever Earth program was brought about through the efforts of numerous partners including Forever Resorts, a division of Forever Learning, LLC; the National Park Service; Lake Mead National Recreation Area; Outside Las Vegas Foundation; and UNLV's Public Lands Institute. In 2005, a formal written agreement was reached between Fun Country Marine Industries and UNLV's Public Lands Institute to operate and manage the Forever Earth vessel for the purpose of enhancing outdoor environmental education efforts in Southern Nevada.

A development team consisting of science educators from the school district and educators from UNLV's Public Lands Institute (PLI) and Lake Mead National Recreation Area was formed to create the Forever Earth curriculum. The four member *On-Site Experience Development Team* consisted of program staff from the PLI and Lake Mead National Recreation Area. This team created the programming that was delivered aboard the Forever Earth vessel and on land at Lake Mead National Recreation Area and focused on creating engaging activities and ensuring that the mission and vision of the National Park Service and Lake Mead National Recreation

Area were accurately presented. The *Classroom Experience Development Team* authored the pre-visit and post-visit lessons. This team, consisting of four members (two from PLI and two from the school district), ensured that grade-appropriate science standards were met and that the science educator's perspective was carefully considered.

The curriculum for each grade level was developed to complement traditional classroom studies in grades four through seven with engaging, participatory, on-site activities and support lessons based upon a solid framework for inquiry and discovery. In the present study, 4th and 5th grade students participated in activities, performed investigations, and used scientific equipment to discover the answers to key questions while on the Forever Earth vessel (i.e., floating classroom and research laboratory).

Curriculum and Materials Used in the Research

Participants in Forever Earth programs explored the Lake Mead aquatic environment and its interrelationships with the surrounding area through their participation in two different curricula. Students in 4th grade completed the *The Water Cycle!* Curriculum in which they learned about Lake Mead's water use cycle by following one drop of water and then diagramming this important cycle on a magnet board. Working as scientists, students determined if water is the same in all parts of the lake by comparing water samples from the middle of the lake and from Las Vegas Bay.

Students in 5th grade completed the *Finicky Fish Finish Last!* Curriculum in which they explored what has happened to the Colorado River and the reasons why it is so difficult for a native fish species, the razorback sucker, to thrive in this changed environment. Students collected water quality data to determine whether habitat conditions are sufficient for the survival of young razorback suckers.

Two different types of student assessments were completed, including attitude and knowledge pre- and posttests.

Attitude Items

Two types of attitudes were assessed. The first included four questions administered prior to the Forever Earth intervention and immediately after the intervention that addressed attitudes about participating in the FE program, which we refer to as *intervention attitudes* because they focus on attitudes about the Forever Earth intervention before and after their participation. These questions are included as questions 1–4 in Appendix 1. The second type of attitudes addressed the extent to which participants felt they learned important information during the Forever Earth intervention, which we refer to as *learning attitudes* because they focus on the student's attitudes about his or her learning during the intervention. The questions are included as questions 5–8 of Appendix 2. Both questionnaires were developed for this research based on assessments used by (Metzger and McEwen 1999).

Knowledge Items

Assessments for each of the 4th and 5th grade curricula included four to five knowledge questions related to the specific activity. The 4th grade curriculum focused on *the water cycle* while the fifth grade focused on *native fish.* These knowledge questions consisted of constructed response items, where students were required to generate answers in response to a prompt rather than choose from a set of alternatives. Knowledge questions were developed to assess the instructional objectives outlined in each of the curricula. For example, one of the stated knowledge objectives for Water Cycle curriculum was "Students will identify how water in Las Vegas wash differs from water in Lake Mead." The corresponding knowledge item on the pre- and posttest was *How is the water from Las Vegas Wash different from water in the middle of Lake Mead?* Developing items for each knowledge objective help to ensure content validity of the assessment. See Appendix 3 for an example of the 4th grade knowledge assessment.

Procedures

The assessments were conducted over a 3-week period (i.e., pre- and post-intervention) to determine the effectiveness of the curriculum in having an impact on student attitudes and knowledge about the environment related to the curriculum content at each grade level. Pretests occurred one week prior to the study during a pre-intervention visit from the project facilitator for the FE intervention program. Students completed the pretests attitudes and knowledge scales as well as the Jr. MAI.

The curriculum was implemented on four separate occasions in December, 2008, involving 103 students from four schools. Two 4th grade classes and two 5th grade classes participated. All participants completed the attitude and knowledge assessments after the half-day curriculum on the Forever Earth vessel.

Procedures were identical for the four groups with the exception that content differed for 4th and 5th grade students. Students arrived at the Forever Earth vessel via school bus. They participated in a powerPoint introduction to the day's content (i.e., water cycle/finicky fish). The facilitator discussed activities, answered questions, and provided relevant background knowledge to students. Students then were given a research question (4th grade: Is the water in the middle of Lake Mead the same as the water in the Las Vegas wash) that served as a guide for the upcoming activities. Hands-on water measurements were made to answer the question posed to students by the facilitator. The central research question was answered by the whole group as part of collaborative discussion and inquiry. The final activity was to review the content and apply the knowledge to a real-life situation (e.g., ways the student can decrease water usage). Following these activities, students completed posttest attitude and knowledge scales, were debriefed, and returned to their school via bus.

Scoring

Scoring was completed by two of the authors who have extensive training in the scoring process. Constructed responses were scored as a 2, 1, or 0. Scores of 2 corresponded to more complete answers (see Appendix 3 for examples). Scores of 1 corresponded to partial answers. Scores of 0 corresponded to no answer or incorrect responses. The scores evaluated each knowledge protocol concurrently and resolved any differences during the scoring process, referring when necessary to a detailed scoring guide prepared prior to the study (see Appendix 3 for examples). The two scorers reached 100% percent agreement on all knowledge protocols.

Results

Four different types of data analyses were conducted. The first examined means and standard deviations for each critical variable at each grade level. Scores in Table 4.2 are based on composite scores using four pretest intervention attitude questions, four posttest intervention questions, four posttest learning questions, the 12 items from the Jr. MAI, four pretest knowledge questions, and four posttest knowledge questions that ranged from 0 to 8. The second set of analyses included several exploratory factor analyses with different rotations to examine the latent structure of the Jr. MAI. The third set consisted of correlations among critical variables. The fourth set of analyses examined dependent *t*-tests between posttest and pretest scores for attitudes and knowledge. These tests assessed whether there was significant change attributable to the Forever Earth curriculum.

Factor Analyses

A variety of exploratory solutions were used to examine the factor structure of the Jr. MAI. Consistent with Sperling et al. (2002), the most parsimonious solution

Table 4.2 Means and standard deviations for 4th and 5th grade variables

	4th grade		5th grade	
Variable	Mean	SD		
Pretest attitudes	16.40	2.51	16.12	2.70
Posttest attitudes	17.79	2.50	18.78	1.76
Intervention attitudes	17.44	2.75	18.52	1.78
Knowledge of cognition	21.22	2.65	20.83	2.92
Regulation of cognition	26.13	4.98	25.80	4.39
Pretest knowledge	2.58	1.32	1.84	1.00
Posttest knowledge	4.68	1.39	4.90	1.97

Table 4.3 Factor loadings, eigenvalues, and scale reliabilities

Item	Factor 1	Factor 2	Eigenvalue
Knowledge of cognition			
I can make myself learn when I need to		.74	
I learn best when I already know something about the topic		.72	
I really pay attention to important information		.55	
I know when I understand something		.53	
I know what the teacher expects me to learn		.40	1.46
Regulation of cognition			
When I am done with my schoolwork, I ask myself if I learned what I wanted to learn	.73		
I think of several ways to solve a problem and then choose the best one	.64		
I think about what I need to learn before I start working	.63		
I try to use ways of studying that have worked for me before	.62		
I draw pictures or diagrams to help me understand while learning	.47		
I ask myself how well I am doing while I am learning something new	.44		
I learn more when I am interested in the topic	.36		3.05

consisted of a principal components extraction with a varimax rotation (see Table 4.3). This analysis yielded two factors which explained 35% of the total sample variation. Factor 1 corresponded to the regulation of cognition factor described earlier and explained 25% of sample variation with an eigenvalue of 3.05. The regulation factor included seven items and was reliable at .78 using Cronbach's alpha. Item 7 (i.e., When I am done with my schoolwork, I ask myself if I learned what I wanted to learn) had the highest item-to-factor loading at .73. The regulation of cognition variable included items that focused on skills and strategies such as checking and monitoring that enable effective learners to regulate their learning. Factor 2 corresponded to the knowledge of cognition factor described earlier and explained an additional 12% of total sample variation with an eigenvalue of 1.46. The knowledge factor included five items and was reliable at .68 using Cronbach's alpha. Item 1 (i.e., I can make myself learn when I need to) had the highest item-to-factor loading at .74. The knowledge of cognition variable included items that focused on declarative, procedural, and conditional knowledge such as understanding optimal study conditions that facilitate effective learning.

The two-factor solution is quite consistent with our hypothesized factor structure and the empirical results reported by Sperling et al. (2002), who found two factors that explained 35% of sample variation. Sperling et al. (2002) reported similar item-to-factor loadings with the exception of item 12 (i.e., I learn more when I am interested in the topic), which loaded on the regulation of cognition factor in the present study rather than the knowledge of cognition factor.

Table 4.4 Correlations

	Pretest Int. attitudes	Posttest Int. attitudes	Learning attitudes	KOC	ROC	Pretest know	Posttest know
Pretest intervention attitudes		.69**	.58**	.38**	.09	.36**	.23*
Posttest intervention attitudes	.54**		.76**	.44**	.10	.22	.30*
Learning attitudes	.37**	.63**		.41**	.04	.44**	.36**
Knowledge of cognition	.54**	.41**	.45**		.38**	.14	.23*
Regulation of cognition	.56**	.50**	.31*	.39**		.06	.25*
Pretest knowledge	.06	.31*	.10	.10	.05		.53**
Posttest knowledge	.16	.38**	.32*	.24*	.39**	.13	

Note: 4th grade correlations appear above the main diagonal; 5th grade correlations appear below
*$p<.05$; **$p<.01$

Correlations

Correlations between all critical variables are shown in Table 4.4. Correlations using the 4th grade data are shown above the main diagonal; whereas correlations using 5th grade data are shown below the main diagonal. All tests of significance were made using a one-tail directional test in which correlations were expected to be positive and significantly different from the null hypothesis of zero correlation.

Three results were of special importance. The first is that all variables are correlated significantly with the posttest knowledge scores. This finding suggests that positive attitudes and both metacognitive factors are related positively to performance on the knowledge posttest. This finding is consistent with the data reported by Sperling et al. (2002) in with the Jr. MAI was correlated significantly with strategic knowledge, problem-solving, and academic achievement. Our second finding was that the knowledge and regulation of cognition factors were correlated, .38 and .39, respectively. This suggested that the knowledge and regulation aspects of metacognition are related to a moderate extent, which is consistent with the correlation of .35 reported by Sperling et al. (2002), as well as the .50 correlation reported by Schraw and Dennison (1994) using the MAI. Our third finding is that all variables were correlated positively and significantly with the knowledge of cognition factor; whereas variables at the 4th grade were not correlated with the regulation of cognition factor. This finding suggested that knowledge about oneself as a learner is related to attitudes and performance more strongly than self-regulatory aspects of metacognition.

Overall, the correlations shown in Table 4.4 indicated that the knowledge and regulation of cognition variables were correlated with themselves and other variables in the predicted direction and relative size of the correlation. Our findings were quite similar to Sperling et al. (2002) and Schraw and Dennison (1994). These findings strongly supported the concurrent and predictive validity of the Jr. MAI in that it was correlated significantly with attitudes and a future test of knowledge.

Table 4.5 Attitude and knowledge change scores by grade level

	Sample size	Mean	Standard deviation	*t*-Value	Significance
Grade					
4th					
Intervention attitude change score	53	1.18	1.97	4.16	.001
Knowledge change score	53	2.09	1.32	11.56	.001
5th					
Intervention attitude change score	52	2.69	2.32	8.04	.001
Knowledge change score	52	3.06	2.90	10.59	.001

Attitude and Knowledge Scores

Table 4.5 shown the means and standard deviations based on the difference between post-intervention and pre-intervention attitude and knowledge scores. Both the attitude, $t\ (52) = 4.16$, $p < .001$, and knowledge scores, $t\ (52) = 11.56$, $p < .001$, were highly significant at the 4th grade. These results were replicated at the 5th grade as well, where both the attitude, $t\ (51) = 8.04$, $p < .001$, and knowledge scores, $t\ (52) = 10.59$, $p < .001$, were highly significant. These findings revealed that the Forever Earth intervention significantly increased attitudes and knowledge from pretest to posttest. In addition, the learning attitudes scale differed significantly from zero at the 4th, $t\ (52) = 44.34$, $p < .001$, and 5th grades, $t\ (51) = 74.27$, $p < .001$.

A comparison of effect sizes indicated that the differences between pre- and posttest were quite robust. The differences for the pre- versus posttest attitudes ranged from .50 to 1.00, which are considered moderate to large effect sizes. The differences for the pre- versus posttest knowledge scores ranged from 1.0 to 1.60, which are considered large. Collectively, these effect sizes revealed that the Forever Earth intervention produced large post-intervention gains among students.

Discussion

The main goal of the present research was to examine the relationship among self-reported metacognition, attitudes about an outdoor learning program, and field-based learning in an environmental education program. We made five predictions about the factor structure of the Jr. MAI, the relationship between the two hypothesized factors, and their relationships to other variables. In addition, we predicted that the Forever Earth intervention would lead to significant increases in student attitudes and knowledge.

Our first prediction was that the Jr. MAI would yield two reliable factors corresponding to knowledge of cognition (KOC) and regulation of cognition (ROC) constructs described by Schraw and Dennison (1994) and Sperling et al. (2002). We expected these factors to explain approximately 35% of total sample variation, consistent with Sperling et al. (2002). A principal components analysis with varimax rotation yielded two factors that corresponded very closely to the hypothesized factors. Together, the two factors explained 35% of sample variation and were reliable using Cronbach's alpha. These findings replicated Sperling et al. (2002) and suggest that the knowledge and regulation of cognition factors are consistent across younger and older students and that these constructs can be measured in a reliable and valid manner.

Our second prediction was that the KOC and ROC factors would be correlated in the .35 range, consistent with Sperling et al. (2002). Data from 4th grade students revealed a correlation of .39 while data from 5th grade students found a correlation of .38. These values were very close to those reported by Sperling et al. (2002) and similar to values reported by Schraw and Dennison (1994) using the MAI. Collectively, these findings suggest that knowledge of cognition and regulation of cognition factors are correlated moderately. Indeed, previous research suggests that the two factors most likely co-develop as children become more metacognitively aware (Annevirta and Vaurus 2006).

Our third prediction was that there would be a significant increase from pretest to posttest attitudes as a result of the Forever Earth intervention. Pretest attitudes increased significantly at both 4th and 5th grades due to the intervention (see Table 4.2). This result indicated that students enjoyed the floating laboratory experience and would be willing to participate again. In particular, the composite mean for posttest attitudes for 4th (17.79) and 5th (18.78) grades using a 20-point scale revealed very highly favorable ratings. In addition, ratings for posttest learning attitudes for 4th (17.44) and 5th (18.52) grades using a 20-point scale revealed very favorable ratings about the degree of learning due to the Forever Earth intervention.

Our fourth prediction was that there would be a significant increase from pretest to posttest knowledge scores as a result of the Forever Earth intervention. Knowledge gain scores increased significantly at both 4th and 5th grades due to the intervention (see Table 4.5).

Our final prediction was that knowledge of cognition and regulation of cognition scores would be correlated with posttest knowledge scores. We expected students with higher self-reported metacognitive knowledge to score higher on the posttest knowledge assessment. Correlational data from Table 4.4 supported this claim, indicating that students who reported higher levels of knowledge and regulation of cognition scored higher on the knowledge posttest. Table 4.4 also reveals that knowledge and regulation scores were not correlated with pretest knowledge scores. This suggested that the gains in knowledge due to the Forever Earth intervention were related, in part, to the use of metacognitive knowledge to help students identify important information and learn that information more effectively.

The results of the present study support three main conclusions. The first is that the Jr. MAI assessed the knowledge and regulation of cognition factors in a reliable and valid manner. The factor analyses supported the claim that the 12 items on the Jr. MAI assess appropriate types of metacognitive knowledge. The correlations with other variables such as posttest attitudes and knowledge scores supported the predictive validity of the Jr. MAI in that KOC and ROC scores predicted future performance significantly.

A second conclusion is that metacognitive knowledge is related positively to increases learning and attitude change (Efklides 2008). One explanation is that students with higher levels of metacognition are more aware of what is important to learn and what strategies to use to learn this information (Pressley and Harris 2006). These students are better able to select information, organize, and elaborate critical information into an integrated conceptual understanding of the material. Indeed, this argument was supported by the positive correlation between metacognition and posttest knowledge scores. In addition, metacognition may enhance the value of learning, make the information more interesting, and increase students' satisfaction with the learning experience.

This finding is important as well from a developmental perspective. Previous research suggests that metacognition is late developing (i.e., age 11 and older) and that younger students, especially those in grades 1–6, usually possess limited metacognitive skills (Kuhn 2000). Nevertheless, research indicates that younger students benefit from metacognitive instruction as early as grade 1 (Blank 2000; Annevirta and Vaurus 2006). Metacognition appears to develop faster due to direct instruction, dialogue and reciprocal discussion, and collaboration and peer assistance (Pressley and Harris 2006). Our findings support the claim that a field-based program that includes interactive instructional opportunities such as dialogue, exploration, and peer assistance may show a significant relationship between metacognition and learning.

A third conclusion is that the Forever Earth intervention leads to significant gains in attitudes about the program, about learning, and knowledge. There are several reasons for the growth observed in the present study. One is that many of the students have relatively little knowledge of the curriculum prior to their participation in Forever Earth. A second reason is that the curriculum they encounter during the floating laboratory experience is developmentally appropriate and linked to current grade-level science instruction. This makes the information relevant to ongoing science instruction in the classroom. A third reason is that the Forever Earth program capitalizes on real-life, hands-on science learning that strongly engages younger students from both cognitive and motivational perspectives.

We believe our findings shed light on the importance of metacognitive knowledge in nonschool settings. Like the school classroom, the Forever Earth experience used a structured curriculum to enhance student learning. However, it differed from a traditional classroom in that it was low stakes, hands on, experiential, and based in a novel setting. All of these new characteristics of the learning environment probably required students to use a broader array of metacognitive skills than a traditional classroom learning experience. It is our assumption that students faced more conditional knowledge demands due to the new learning environment and engaged in more self-monitoring than in typical classroom settings. We also assume that students were more motivated (based on attitude data) to use their existing metacognitive skills than they might have been in a traditional classroom. It may be the case that students would not have applied their metacognitive knowledge to the same degree to classroom learning. We believe that future research should compare the role of metacognitive knowledge inside and outside the classroom using the same students to test this possibility.

Educational Implications

Consistent with a number of previous studies, the present research highlights the importance of promoting metacognition in science learning (Linn and Bat-Sheva 2006). There are at least four related instructional strategies that educators might use to promote metacognitive awareness based on previous instructional research. Although these strategies have been studied primarily in traditional classroom settings, we believe they can be taught and used effectively in a variety of settings such as the field-based experiences described above. One is to assess students' metacognitive knowledge and self-regulatory skills prior to instruction. Students with more metacognitive awareness find it easier to learn and remember. Students who report low metacognitive knowledge may benefit from explicit instruction and collaborating with a more experienced learner.

A second way to improve learning is to activate metacognitive skills through pre-learning activities such as brainstorming and group discussion. Pre-learning activities can activate relevant background knowledge and remind students to use cognitive and metacognitive skills in their learning repertoire. Inquiry methods also can be an especially effective way to activate strategies and relevant metacognitive knowledge (Chinn and Hmelo-Silver 2002). Inquiry teaching promotes self-regulation in two ways. One is to stimulate active engagement in the learning process by using cognitive learning strategies and metacognitive strategies to monitor their understanding. A second is to help increase motivation to succeed in science by using modeling, active investigation such as predict-observe-explain (POE) (Windschitl 2002), or question asking.

A third approach to improving learning is to help students develop and refine metacognitive knowledge and regulatory skills. Zohar (2006) reported that explicit metacognitive instruction improved strategy use, problem-solving, and learning in older students. Schraw (2001) proposed the use of a strategy evaluation matrix in classroom or field-based settings in which students collectively discuss different learning strategies as well as how, when, and why to use them to improve learning. This method provides explicit discussion and reflection on key learning strategies. Schraw (2006) also proposed the use of a metacognitive checklist to be used during learning to plan, monitor, and evaluate one's learning in a systematic way.

A fourth approach is to promote metacognitive knowledge and regulation through active reflection and dialogue. Blank (2000) proposed a model of critical thinking in science called the *metacognitive learning cycle* (MLC). The MLC emphasizes the systematic use of discussions and reflection to promote explicit metacognitive understanding of critical thinking and problem-solving. The MLC consists of four interrelated steps, which include concept introduction, concept application, concept assessment, and concept exploration. Students were asked to reflect upon their progress at each step either individually or in small groups. In comparison with groups that did not use explicit reflection, the MLC experienced greater conceptual restructuring and understanding of course content.

Taken collectively, these strategies are well known to facilitate metacognitive knowledge and skills in a manner that promotes science learning (Linn and Bat-Sheva 2006). Blank (2000) also has argued that metacognitive skills are learned better when encountered within highly contextualized science learning experiences. We believe that the Forever Earth program provided specific learning goals and content for students in a supportive learning context that enabled them to use their metacognitive knowledge and skills in an optimal fashion and to share their skills collaboratively with other students.

Conclusions

The goal of this chapter was to provide an overview of metacognition and present data that link different types of metacognitive knowledge to attitudes and knowledge scores in a field-based science learning experience administered to 4th and 5th grade students. We administered the Jr. MAI and extracted knowledge of cognition and regulation of cognition factors. These factors were positively related to attitudes and posttest knowledge scores. The knowledge and regulation factors also were significantly related to each other. The half-day Forever Earth program produced large effect size gains for both attitudes and knowledge. Together, these results suggested that metacognitive knowledge is an important component of science learning and is related to higher attitude and knowledge scores. We concluded with several suggestions for improving metacognitive knowledge in younger students.

Appendix 1

The Jr. MAI adapted from Sperling et al. (2002)

How I Study

We are interested in what students do when they study. Please read the following sentences and circle the answer that describes you and the way you are when you are doing school work or home work. There are no right answers – please describe yourself as you are, not how you want to be or think you ought to be.

	1 = never	*2 = seldom*	*3 = sometimes*	*4 = often*	*5 = always*
1. I know when I understand something.	1	2	3	4	5
2. I can make myself learn when I need to.	1	2	3	4	5
3. I try to use ways of studying that have worked for me before.	1	2	3	4	5
4. I know what the teacher expects me to learn.	1	2	3	4	5
5. I learn best when I already know something about the topic.	1	2	3	4	5
6. I draw pictures or diagrams to help me understand while learning.	1	2	3	4	5
7. When I am done with my schoolwork, I ask myself if I learned what I wanted to learn.	1	2	3	4	5
8. I think of several ways to solve a problem and then choose the best one.	1	2	3	4	5
9. I think about what I need to learn before I start working.	1	2	3	4	5
10. I ask myself how well I am doing while I am learning something new.	1	2	3	4	5
11. I really pay attention to important information.	1	2	3	4	5
12. I learn more when I am interested in the topic.	1	2	3	4	5

Appendix 2

Attitude Questionnaire

1. I would tell my friends to do this program on the Forever Earth Floating Classroom.

Strongly agree	Agree	Not sure	Disagree	Strongly disagree
5	4	3	2	1

2. Learning about water at Lake Mead was very interesting to me.

Strongly agree	Agree	Not sure	Disagree	Strongly disagree
5	4	3	2	1

3. The forever Earth activities were fun.

Strongly agree	Agree	Not sure	Disagree	Strongly disagree
5	4	3	2	1

4. I would like to do another Forever Earth program.

Strongly agree	Agree	Not sure	Disagree	Strongly disagree
5	4	3	2	1

5. I learned how important Lake Mead is to plants, animals, and people.

Strongly agree	Agree	Not sure	Disagree	Strongly disagree
5	4	3	2	1

6. I learned important things today about the water.

Strongly agree	Agree	Not sure	Disagree	Strongly disagree
5	4	3	2	1

7. I learned how people can use Lake Mead without hurting it.

Strongly agree	Agree	Not sure	Disagree	Strongly disagree
5	4	3	2	1

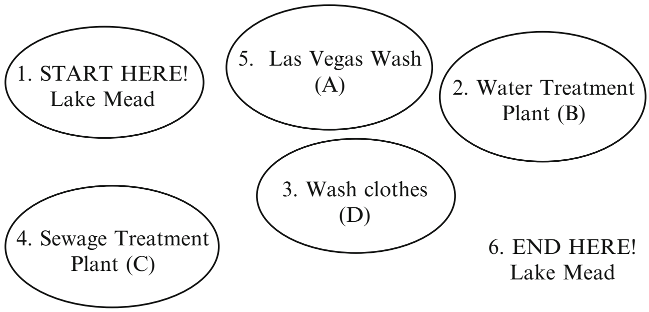
8. Because of what I learned today, I think it’s important to take care of Lake Mead.

Strongly agree	Agree	Not sure	Disagree	Strongly disagree
5	4	3	2	1

Appendix 3

Fourth Grade Assessment Items and Scoring Guide

1. Describe what happens when Lake Mead's water is used by people by putting these steps in order from 1 to 6. Write the number on the line in each circle.



More complete: 2 points

- Response has 3–4 items in the correct order

Partial complete: 1 point

- Response has 1–2 items in the correct order

Less complete: 0 points

- Response has no items in the correct order

2. How is the water from Las Vegas Wash different from water already in the lake? Answer "yes" or "no" to the following questions.

   – Yes Would one water sample be clearer than the other sample?
   – No Would the plankton be different?

More complete: 2 points

- Response has both items answered correctly

Partial complete: 1 point

- Response has one item answered correctly

Less Complete: 0 points

- Response has neither item answered correctly

3. List some of the reasons why the water is so low in Lake Mead.
   More complete: 2 points

   - Response has 2 correct responses and no more than 1 incorrect answer
     - People have used the water for different things
     - Evaporation
     - Drought

   Partial complete: 1 point

   - Response must include one correct positive item

   Less complete: 0 points

   - Response does not include any correct items
     - The dam has a leak
     - Pollution

4. What can you do to save and protect the water in Lake Mead?

   More complete: 2 points
   - Response includes two correct answers
     - Take shorter showers
     - Turn off the tap when brushing teeth
     - Don't litter
     - Only use what you need
     - Use less water
     - Recycle

   Partial complete: 1 point
   - Response includes one correct answer or one less-specific answer
     - Don't waste water

   Less complete: 0 points
   - No information or incorrect information provided

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