

## HOW DOES AN AFFECTIVE SELF-REGULATION PROGRAM PROMOTE MATHEMATICAL LITERACY IN YOUNG STUDENTS?

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**Abstract:** The study compared two groups of Israeli fifth graders. The research group ( $n = 54$ ) solved mathematical literacy tasks following an affective self-regulation intervention program preceded by a general introduction to solving authentic problems. The control group ( $n = 53$ ) only received a general introduction to solving authentic problems. The groups were compared regarding: positive and negative emotions, performance in solving mathematical literacy tasks with different levels and representations, and long-term reflections on the program. Students in the affective self-regulation group performed better on all aspects of the mathematical literacy tasks and showed a greater reduction in negative emotions than the control group. Furthermore, during interviews held three months after the intervention, the research students commented on the importance and effectiveness of the strategy they had experienced. The theoretical and practical implications of the study are discussed.

**Key words:** Affective self-regulation program, Mathematical literacy, Mixed methods

### MATHEMATICAL LITERACY

Standards established in educational reform have focused on mathematical literacy within a broader curriculum approach that seeks to develop meaningful learning (National Council of Teachers of Mathematics, 2000; Organization for Economic Cooperation and Development [OECD], 2003). Mathematical literacy is defined as the ability to solve math problems in various authentic real time contexts and to apply

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mathematical reasoning by describing, modeling, explaining, and predicting real-life phenomena (OECD, 2003).

With mathematical literacy tasks, students tackle authentic problems of varying complexities. These problems (a) are often presented in story form, (b) contain mathematical data, (c) are solvable in different ways, (d) are based on different types of mathematical knowledge (such as symbols or patterns) and skills (such as strategies and representations), and (e) justification is often required. In order to solve authentic problems students need to translate them into mathematical steps (such as using calculations), apply the solution to the real-world original context, and finally interpret and validate the results (OECD, 2003).

Students often view these multi-processes difficult (OECD, 2003). This is especially true for low achievers who have difficulties understanding the texts of mathematical problems because they have difficulties with reading and comprehension anyway. These students also have difficulty seeing the alternative ways that exist to solve math problems. They also lack confidence when calculating and verifying solutions (Desoete, Roeyers, & De Clercq, 2003; Schoenfeld, 1992) and find it hard to distinguish between relevant and irrelevant information in authentic texts (Verschaffel, Greer, & De Corte, 2000). Even high achievers have difficulty solving authentic problems, that is, difficulty applying their knowledge to authentic problems presented in unfamiliar real-life contexts (OECD, 2003). Researchers (including Schoenfeld, 1992; Verschaffel et al., 2000) have also shown that students' problem-solving failures do not always stem from a lack of mathematical knowledge but arise rather from the ineffective activation of their knowledge since they lack the metacognitive skills needed to control, monitor, and reflect on their solution processes.

As a result of these cognitive / metacognitive difficulties, many students develop negative feelings towards mathematics, which hamper their learning processes and achievements (Artino, 2009; Duckworth, Akerman, MacGregor, Satler, & Vorhaus, 2009; Efklides & Petkaki, 2005). As we will see, self-regulated learning serves as an effective means of coping with these difficulties. Self-regulated learning is an active, constructive process involving the components: cognition / metacognition, motivation / emotions, and behavior. Self-regulated learning allows learners to determine their own learning goals, and to try to monitor, regulate, and control them, while being guided and constrained by the goals and contextual features of learning environment (Pintrich, 2000).

Until now, mathematical literacy interventions have focused on the metacognitive component of self-regulated learning. They found that metacognitive self-regulation can improve achievement in adult learners (Kramarski, Mevarech, & Liberman, 2001;

Kramarski & Mizrahi, 2006). The present research focused on the emotional component of self-regulated learning and developed an affective self-regulation intervention aimed at enhancing mathematical literacy among young learners.

### ***Emotions and learning***

The definition of emotion employed here is based on Rosenberg's (1998) analysis. Rosenberg stresses the different intensities and durations of moods and emotions: moods last longer and emotions are characterized as episodes that are brief though intense.

A combination of different emotions and moods usually make up the more general constructs of "positive" and "negative" affect. These two broad, and for the most part, uncorrelated factors, can be reliably identified as the dominant features of emotional experience.

As noted earlier, research in recent years has highlighted the impact of emotions on learning. Affect guides and regulates cognitive and motivational systems (Olafson & Ferraro, 2001; Pintrich, 2003). It also affects working memory load by using cognitive resources that could be devoted to the academic task. There is a number of ways that emotions affect cognitive processing: they create emphases on attention and memory; they activate action tendencies, and they are considered functional and as playing a key part in the coping and adaptation of human beings (Zan, Brown, Evans, & Hannula, 2006).

Emotions can also influence certain aspects of self-regulation, including strategy selection. Experimental mood research shows in particular that negative affect can cause more analytical, detailed, careful, and inflexible ways of processing information, whereas positive affect can generate creative, flexible and holistic thinking which is beneficial for heuristic processing (Fiedler, 2001; Linnenbrink & Pintrich, 2002; Pintrich, 2003). Indeed, many of the studies on emotions and mathematics highlight this subject as deserving special attention. Meta-analytic studies have demonstrated that these negative attitudes and emotions have far-reaching consequences. These consequences include avoiding mathematics (Hembree, 1990), stress (Tobias, 1978) and feelings of hopelessness (Verschaffel et al., 2000), at different stages of the solution process (Zeidner, 1998). Researchers have found that these symptoms already appear in elementary school children and peak in grades 5-6 (Pekrun, Frenzel, Götz, & Perry, 2007).

As noted above, an affective self-regulation program was developed to help alleviate these difficulties and address their implications for the solution of mathematical literacy tasks. The aim of the present study was to develop an affective

self-regulation intervention and examine its influence on affective self-regulation among young students.

### *Affective self-regulation*

Affective self-regulation deals with the activities and strategies in which students engage during learning in order to help themselves plan and control their emotions while learning (Pintrich, 2000). The present study examined the affective component of Pintrich's self-regulated learning model (Pintrich, 2000), and adapted it for young learners.

The affective self-regulation model has three main phases:

*Pre-learning stage.* This focuses on forethought, planning, and activation which includes emotional activities before solving the problem. This phase deals with the learner's reason for performing the problem and her judgments about the easiness / difficulty of the problem.

*During learning stage.* This focuses on two central processes: monitoring and control. Monitoring relates to emotional awareness and the process of monitoring feelings about the problem while working on the problem. Control focuses on selecting and adapting strategies to help manage affect.

*Post-learning stage.* This focuses on reactions and reflections. This stage concerns the learner's affective reflections, and includes affective reactions upon completing the problem (Weiner, 1986). Affective reactions lead to changes in the student's abilities, expectations, and emotions regarding similar problems in the future (Zimmerman, 2000).

In the present study, an affective self-regulation program was developed which is based on two key factors that were found effective in metacognitive regulation interventions: explicit training and asking self-questions.

*Explicit training.* This is a training approach in which the teacher explains the appropriate learning strategies to the students while stressing their meaning and importance (Otto, 2009; Veenman, 2007). Research has shown that students gain most benefit when they are taught explicit strategies (Camahalan, 2006; Kistner et al., 2010) because self-regulation skills are not innate and not acquired naturally (Dignath & Büttner, 2008; Kramarski, Weiss, & Kololshi-Minsker, 2010; Masui & De Corte, 2005; Perels, Gürtler, & Schmitz, 2005; Turner & Meyer, 2000; Van Luit & Kroesbergen, 2006; Veenman, Van Hout-Wolters, & Afflerbach, 2006).

*Self-questioning.* It is a metacognitive activity through which students practice generating questions during and after problem solving in order to help boost their awareness of their own comprehension. Studies of metacognitive self-questioning in the context of solving mathematical problems have proved that this strategy can

boost student achievement (King, 1990, 1992; Kramarski & Mevarech, 2003; Mevarech & Kramarski, 1997; Schoenfeld, 1992; Veenman et al., 2006). Following this, the strategy was applied to emotions and its effectiveness in solving authentic mathematical problems was examined.

The study compared two groups of fifth-grade students, an experimental group and a control group. The experimental group received an intervention program related to affective self-regulation through self-questioning preceded by a general introduction to solving authentic problems. The control group only received the introduction to solving authentic problems. Three variables were examined: positive and negative emotions, mathematical literacy measured by students' performance in solving authentic problems, and posttest reflections three months after the intervention.

Regarding changes in positive / negative emotions, it was hypothesized that:

1. The group that participated in the affective self-regulation program would demonstrate a greater increase in positive emotions after the intervention compared with the group that did not;
2. The group that participated in the affective self-regulation program would show a greater decrease in negative emotions than the control group;

Regarding changes in mathematical literacy, it was hypothesized that:

3. Mathematical literacy would increase more in the experimental group that participated in the affective self-regulated learning program than in the control group. This hypothesis is based on the assumption that self-regulation provides learners with the requisite tools for dealing with negative emotions and that negative emotions need to be decreased to enable more effective learning, leading in turn to higher achievement. It is also based on studies demonstrating a link between emotions, motivation, and achievement. Accordingly, the increase in positive emotions and the decrease in negative ones causes increased motivation while encouraging students to apply metacognitive strategies and increase their efforts, thereby enhancing achievement (Grant & Dweck, 2003; Kramarski et al., 2010; Linnenbrink, 2005; Wolters, 2004; Zimmerman, 2000).

## **METHOD**

### ***Sample***

The study sample consisted of 107 fifth graders (54.2% boys and 45.8% girls) aged 10-11 years. Students came from three middle socio-economic schools with the same nurturance index. Four classes were selected randomly from the schools and

the pupils were randomly assigned to two groups: an affective self-regulation group ( $n = 54$ ) and a control group ( $n = 53$ ). Testing prior to intervention found no significant differences between the groups for gender  $\langle \chi^2 = 1.61, df = 1, p > .05$  and mathematical and linguistic level,  $F(3,100) = 0.46, p > .05$ .

### *Intervention program structure and research design*

Two groups (affective self-regulation and control group) participated in the four phases of the study as shown in Table 1 below.

Table 1 presents the phases of the research process and research design.

*Table 1. Phases of the research process and research design*

Phase	Affective self-regulation group	Control group
Pre-intervention	<b>Test / Questionnaire</b> - Authentic pattern problems (Tests) - Prior mathematical knowledge (Test) - Linguistic knowledge (Test) - Positive and Negative Emotions Questionnaire	
<b>Intervention</b>	Both groups received 10 one-hour intervention sessions, twice weekly, for five consecutive weeks. The program structure was the same for both groups. The intervention was different.	
	Affective self-regulation while solving authentic pattern problems.	Knowing the characteristics of solving authentic pattern problems.
Post-intervention	<b>Test / Questionnaire</b> - Authentic pattern problems (Tests) - Positive and Negative Emotions Questionnaire	
3 months post-intervention	Reflective interview on the intervention for 10 participants chosen randomly from each group	

The interventions were taught by four math teachers during the regular scheduled math lessons. Math teachers received training regarding the intervention from the researcher (author). First, the researcher met with the teachers as a group to explain the general design of the study. Second, the researcher sat with each teacher for an hour and a half to explain the program itself. Teachers were provided with an individual intervention binder for each student, containing questionnaires, tests, and assignments. The researcher sat with each class during the intervention, and at the end of each lesson discussed the next stage with the teacher.

*Affective self-regulation group intervention*

The intervention consisted of ten sessions:

*Session 1:* (a) In this session, a situation, dialogue, and conclusions were presented to the participants: the participants viewed a situation involving two learners who could not solve a learning task. The teacher then facilitated a classroom dialogue focusing on the positive emotions of the two learners in the situation presented (examples of positive emotions were: being relaxed, feeling in control) and negative emotions (worried, tense). The participants were then asked to give examples of how they felt when solving mathematical problems (for example: “Whenever I feel hopeless, I don’t want to do anything”). The students were then asked to classify the emotions they had identified as either positive emotions or negative emotions. This task demonstrated to the students the need to have strategies for dealing with negative emotions during learning.

(b) Building an affective self-regulated learning strategy (Pintrich 2000). The affective self-regulated learning strategy was built in collaboration with the students with guidance from the teacher. The affective component of Pintrich’s self-regulated learning (SRL) model provided the theoretical foundation for building the strategy. The strategy included the four stages of Pintrich’s model: forethought, monitoring, control, and reflection. The model was adapted for young learners by organizing it around three time points and using self-questioning (see Table 2 below).

(c) Discussion on the importance of the affective self-regulation for learning, and

(d) Authentic pattern problem: Expose learners to features of authentic problems.

Table 2 shows the affective self-regulation model based on Pintrich’s model, as adapted for young learners.

*Table 2. The affective self-regulation model (based on Pintrich’s model as adapted for young learners)*

Phase	Affective self-regulation
Pre-Learning (Forethought)	"How do I feel?" "Is the problem easy or hard?"
During Learning (Monitoring & Control)	<b>How shall I deal with negative emotions?</b> <b>Affective management strategies</b> 1. Say to myself “I can do it” 2. Try to relax 3. Take time out 4. Reread the task and see if I understood it
Post-learning (Reflection)	“How do I feel?”

*Sessions 2-9.* Three main phases were involved: (a) Review: At the beginning of each class, the teacher reviewed the affective self-regulation questions that pupils should ask themselves during the three phases of learning and their importance for the learning process. (b) Students were given two types of authentic pattern problems to solve. Problem complexity increased with each session, and (c) The group discussed the process involved in solving the authentic problem and the effectiveness of affective self-regulation processes.

*Session 10.* In Session 10, the teacher summarized the intervention and discussed the helpfulness of the program with the pupils.

#### *Control group intervention*

The first meeting focused on authentic pattern problem characteristics and the development of strategies for solving authentic problems. No reference was made to affective self-regulation. Sessions 2-9 consisted of three main phases: (a) Review of problem characteristics; (b) Solving two authentic pattern problems identical to those solved by the affective self-regulation group; (c) Discussion of the process for solving the problems. The tenth and final session was spent summarizing authentic problem characteristics.

#### **Measures**

The study utilized quantitative tools that were administered before and after the intervention (achievement tests on solving authentic pattern problems and the positive and negative emotions questionnaire) and a qualitative tool (semi-structured reflective interviews).

#### *Numeric pattern problems*

The problems (which were all of the same level of complexity) were processed from the Grade Five Meitzav standardized exam developed by the Israeli Ministry of Education (2004) and administered before and after the intervention (after numbers were changed). Each problem had two sections. To answer the questions, the students needed to understand the pattern and make inferences from it based on the data supplied, using Yes / No responses. The score were "1" for the right answer and "0" for the wrong answer. The pre-intervention reliability estimate for this problem, calculated using Cronbach's alpha was  $\alpha = .89$ . The post-intervention reliability for this problem calculated using Cronbach's alpha was  $\alpha = .86$ .



*Pictorial and verbal pattern problem (Kramarski et al., 2010)*

The pre-intervention problem included a pictorial pattern whereas the post-intervention problem included a verbal pattern (see Appendix A). In this way the level of the problem complexity was increased.

The problems included three parts and participants had to continue applying the pattern and determine a formula for the pattern. Answers were written as a number. A score of “1” was awarded for the right answer and “0” for a wrong answer. A reliability estimate of  $\alpha = .80$  was obtained for the pictorial representation problem when tested with Cronbach’s alpha. Cronbach’s alpha for the verbal pattern problem was  $\alpha = .87$ .

*Reasoning and generalization problem (Kramarski & Mizrachi, 2006).*

A single reasoning and generalization problem was administered after the intervention only. The problem consisted of a graph and demanded a high level of cognitive ability (analysis, comparison, conclusions). This question had two parts. Participants were given three alternative answers to the problem, and scoring was: “1” for a correct answer and “0” for a wrong answer. The reliability estimate for this problem was  $\alpha = .76$  when tested with Cronbach’s alpha.

*Positive and negative emotions questionnaire*

The questionnaire was administered before and after the intervention to determine the effect of the intervention on participants’ positive and negative emotions. The questionnaire was based on the Hebrew version (Margalit & Ankonina, 1991) of Moos’ Affect Scale (Moos, Cronkite, Billings, & Finney, 1987). The scale consisted of 20 items. In order to examine various factors, a principal component analysis was carried out. The analysis revealed two factors which could explain 46% of the variance. Table 3 shows the factor analysis for the positive and negative emotions.

As we can see from the table, in Factor I, 10 items had factor loadings greater than 0.50, and in Factor II 8 items had loadings greater than 0.50. The loading was 0.47 for Item 1 and less than 0.36 for Item 17. The items in Factor I were characterized by positive emotions and the items in Factor II, including item 17, were characterized by negative emotions.

Two measures were derived from this questionnaire using the mean values of the items loading on each factor. The measures were formulated as items statements and participants rated the extent to which each item described their emotions when

*Table 3. Factor analysis of positive and negative emotions*

II	I	Item	No.
21.-	75.	confident	14
25.-	73.	alert	18
08.-	73.	determined	19
17.-	72.	Feel in control	15
15.-	71.	Happy	20
21.-	68.	Successful	9
11.-	68.	Sociable	6
02.-	68.	Energetic	2
14.-	63.	Dependable	12
40.-	57.	Relaxed	5
70.-	30.-	Tense , Nervy	7
67.-	28.-	Tired, Exhausted	16
65.-	15.-	Sad	3
65.-	10.-	Lonely	10
62.-	07.	Worried	13
60.	17.-	Scared	8
59.	12.-	Have problems concentrating	4
56.	04.-	Restless	11
47.	19.-	Angry	1
36.	21.-	Feel sorry for myself	17

solving authentic problems, on a five-point Likert scale ranging from: 1 (*Not accurate*) to 5 (*Very accurate*). Two categories of statements were identified: the first with 10 statements relating to positive emotions (e.g., happy, relaxed); the second with 10 statements relating to negative emotions (e.g., afraid, angry.) The split which was obtained was the same as the original split.

The internal consistency test for positive feelings revealed a reliability of  $\alpha = .82$  when tested with Cronbach's alpha. The internal consistency test for negative feelings revealed a reliability of  $\alpha = .83$  when tested with Cronbach's alpha.

#### *Reflective interview regarding the intervention program*

Three months after the program concluded, ten participants were randomly chosen from each group and interviewed using a semi-structured interview. The interview consisted of two reflective questions about the intervention. The first question solicited a description of the intervention ("What do you remember about the

program?") The second question related to the participants' views regarding the effectiveness of the intervention ("Did the strategy work for you?"). The interview aimed to evaluate the intervention program as seen from the subjective standpoint of the learner and to establish its internalization three months after its conclusion. The researcher conducted the interview and all participants were interviewed for approximately thirty minutes. The participants' comments were written down, and Strauss and Corbin's (1998) data analysis suggestions were followed. The primary analysis method was continuous coding. The first stage involved open coding: data were examined line by line to identify actions or events in the data. The coding analysis aimed at sharpening and indicating all borrowed (Strauss & Corbin, 1998). Step two involved analyzing axial coding to identify conceptual connections between a category and its subcategories. The third stage involved defining concepts and sub-concepts further using selective coding.

## RESULTS

### *Pre-/ posttest differences in the positive and negative emotions*

The MANOVA performed in order to examine the differences between the two groups in the measurement carried out before the intervention revealed no statistically significant differences between the groups:  $F(2,103) = 0.41, p > .05$ .

A 2x2 MANOVA (Groups  $\times$  Time) was conducted with repeated time measurements to determine whether the positive and negative emotions of the groups differed after the intervention. This analysis found no significant difference in terms of time  $F(2, 101) = 1.50, p > .05$ . Statistically significant interactions were, however, found between Groups  $\times$  Time,  $F(2, 101) = 4.26, p < .05$ , partial  $\eta^2 = 0.08$ .

Table 3 presents the pretest and posttest means, standard deviations, F values and partial  $\eta^2$  effect sizes of the repeated measures ANOVAs for the positive and negative emotions of the various groups.

As we can see in Table 3, the analyses analyses of variance for each measure demonstrate a statistically significant interaction for negative emotions only. A reduction took place in the affective self-regulating group's negative emotions. This contrasts with the increased negative emotions in the control group. Simple effects analyses to compare the before and after measurements of the different groups revealed a statistically significant difference between the affective self-regulation group,  $F(1, 50) = 8.28, p < .01$ , partial  $\eta^2 = .15$  and the control group,  $F(1, 52) = 1.03, p > .05$ .

**Table 4. Pretest and posttest means and standard deviations, F values and partial  $\eta^2$  effect sizes of the repeated measures ANOVAs for the positive and negative emotions of the two groups**

Measure		Group						Group x Time	
		Affective self-regulation			Control			F (1, 102)	Partial $\eta^2$
		Pretest	Posttest	d	Pretest	Posttest	d		
<b>Negative Emotions</b>	<i>M</i>	2.11	1.76	-1.24	2.02	2.13	0.13	8.34**	.08
	<i>SD</i>	.87	.62		.80	.76			
<b>Positive Emotions</b>	<i>M</i>	4.01	4.07	0.008	3.89	1.78	-2.45	.80	.01
	<i>SD</i>	.74	.77		.86	.81			

**Note:** \*\*  $p < .01$ . Cohen's  $d$  effect size was calculated as the ratio between the posttest minus the pretest value, and the average standard deviation of the pretest.

### ***Authentic pattern problems achievement***

As noted, differences in the groups' achievement were examined using three authentic pattern problems with varying degrees of difficulty: numeric pattern problem, verbal pattern problem, and reasoning and generalization problem. The first two problems were given to students before and after the program. The third problem was only administered after the intervention.

### ***Pre-/posttest differences in the authentic numeric and verbal pattern problems***

To examine the differences between the groups for the numeric and verbal problems, we first conducted a MANOVA to compare performance of the two groups prior to the intervention. The analysis revealed no statistically significant difference between the two groups,  $F(2, 104) = 0.57, p > .05$ . To examine the differences between the groups due to changes in the pre- and post-intervention measurements, a 2x2 MANOVA (Groups x Time) was conducted with repeated time measurements. A significant difference was found between the pre-intervention and post-intervention measurements:  $F(2, 98) = 177.92, p < .001$ , partial  $\eta^2 = .78$ . A significant interaction was also found between Groups x Time,  $F(2, 98) = 11.59, p < .001$ , partial  $\eta^2 = .19$ .

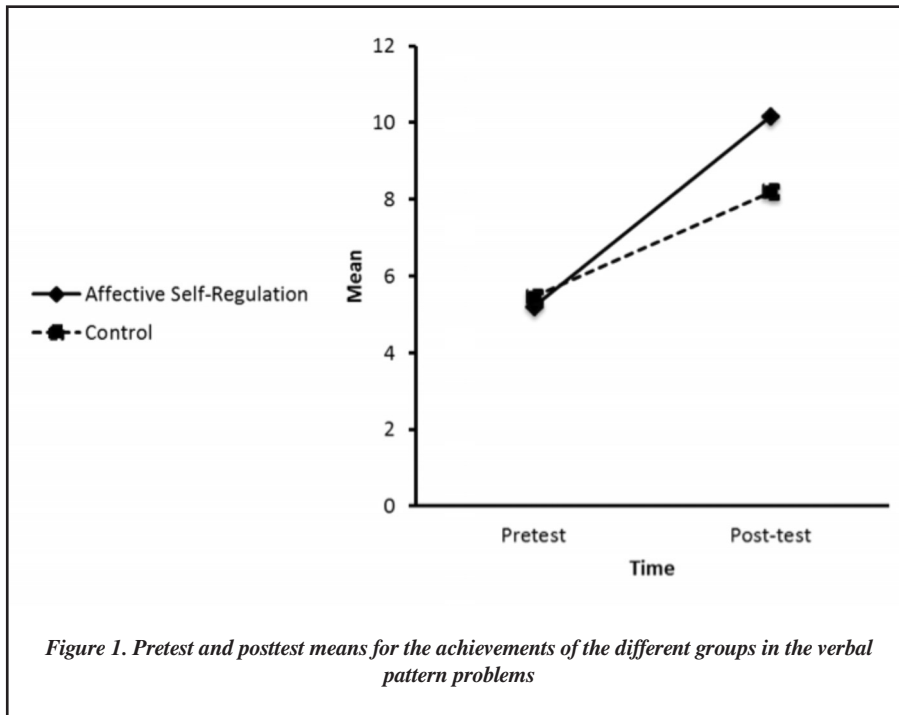
Table 4 shows the pretest and posttest means, standard deviations, F values and partial  $\eta^2$  effect sizes of the repeated measures ANOVAs for verbal and numeric pattern problems of the various groups by time.

**Table 5. Pretest and posttest means and standard deviations,  $F$  values and partial  $\eta^2$  effect sizes of the repeated measures ANOVAs for verbal and numeric pattern problems of the two groups by time**

Measure		Group						Time $F(1, 99)$	Partial $\eta^2$	GroupxTime $F(1, 99)$	Partial $\eta^2$
		Affective self-regulation			Control						
		Pretest	Posttest	$d$	Present	Posttest	$d$				
Verbal	$M$	5.20	10.17	4.43	5.46	8.20	2.26	280.96***	.74	23.34***	.19
Pattern	$SD$	1.12	3.99		1.21	2.26					
Numeric	$M$	4.14	8.30	1.72	4.60	8.16	1.84	166.61***	.63	.96	.01
Pattern	$SD$	2.41	2.32		1.93	2.14					

**Note:** \*  $p < .05$ , \*\*  $p < .01$ , \*\*\*  $p < .001$ . Cohen's  $d$  effect size was calculated as the ratio between the posttest minus the pretest value, and the average standard deviation of the pretest.

As we see in Table 4, the analyses of variance performed for each measure separately showed statistically significant differences linked to time, although a statistically significant interaction was found only for the verbal pattern problems. Figure 1 presents the pre- and posttest means for the achievement of the different groups in the verbal pattern problems.



As we can see in Figure 1, the achievement of two groups after the intervention was higher than the achievement before the intervention. As noted above, a Groups x Time interaction was found. To test the reason for the interaction, simple effects analyses were used. This involved comparing the measurements for the verbal pattern problem both before and after the intervention, for both groups. The analysis showed significant difference in the affective self-regulation group's pre- and posttest achievement,  $F(1, 51) = 64.10, p < .001, \text{partial } \eta^2 = .56$ . We see that the effect size (partial  $\eta^2$ ) for the affective self-regulation group was much higher in comparison to the control group and that there was a greater improvement in the affective self-regulation group performance.

#### *Reasoning and generalization problem performance*

A one-way ANOVA was performed to examine the differences between the groups for this measure. The analysis showed a significant difference between the two groups  $F(1, 98) = 6.86, p < .01, \text{partial } \eta^2 = 0.07$ . The ability of participants to carry out rule-based reasoning was greater in the affective self-regulation group ( $M = 2.54, SD = 1.53$ ) than in the control group ( $M = 1.81, SD = 1.27$ ).

#### *Reflections on the program-Semi-structured interviews*

Three months after the conclusion of the program, the researcher conducted semi-structured interviews with ten participants drawn randomly from each research group. The interview consisted of two reflective questions regarding the program. The first question aimed to elicit a description of the program from the participant ("What do you remember about the program?") The second question focused on the participant's views about the efficacy of the program ("Did you find the strategy effective?")

#### *Program description*

Regarding the affective self-regulation group, the participants talked mostly about the question: "What do I feel?" This was a basic question that was promoted throughout the intervention. The question "What do I feel?" asked participants to relate to their positive / negative emotions. Students were constantly encouraged to monitor their emotions and to choose and adopt emotion-management strategies whenever they identified negative emotions- most of them focused on "taking time out."

Gal: *“We learned about feelings- positive and negative feelings-and how to cope with problem-solving situations. If I don’t succeed I must tell myself that I can do it, that I must not give up. If that doesn’t succeed, then [I must] take a time out or ask someone for help.”*

Dar: *“You check how you feel all the time, but you only use this strategy when you feel negative emotions. Because if you feel okay, you carry on. The most important thing is to check all the time so as not to despair and give up.”*

Yahli: *“You need to take time out, relax, and then continue.”*

It was interesting to see from the interview analysis that although the members of the affective self-regulation group were exposed to both the problem characteristics and to the affective self-regulation component, they only referred to the affective self-regulation aspect.

It was also interesting that without being asked, the participants in the affective self-regulation group spontaneously mentioned the program’s positive impact on their emotions while learning:

Noy: *“We learned to solve exercises in a more enjoyable and pleasant way; we learned methods that make solving easier.”*

Interviewer: *What methods?*

Noy: *“We learned a strategy that helped us feel good about solving [problems]. For example, when I feel upset I use the strategy and then I feel better and get more enjoyment out of solving the problems. It is important to enjoy solving problems.”*

However, the control group talked about program characteristics:

Oren: *“We learned about math problems, and all kinds of ways to solve them”*

Maya: *“We learned to find pattern.”*

Amir: *“To solve hard problems, which you need to think about properly in order to solve them ... How should I explain this? Instead of just an exercise you had to think.”*

Shavit: *“We worked on ways of solving math problems, all sorts of questions with tables. We needed to write the method.”*

### *Program effectiveness*

Ninety percent of the respondents in the affective self-regulation group found the strategy effective and only 10% (one respondent) felt that the strategy did not work for her. Participants also stated that they applied the strategy when experiencing difficulty and negative emotions: Seventy percent used the time-out relaxation technique to help them cope with negative emotions when learning:

Yale: *“The strategy is very helpful. It relaxed me and improved how I solved the tasks.”*

The participants in this group also stated that they used the affective-management strategy in other areas too and understood its importance for learning:

Yahli: *“The strategy is very helpful. I still use it on difficult questions. Especially in math . . . If I don’t feel like studying I take time out, relax a bit.”*

Guy: *“...I tell myself that I can do it and take a break if I’m having problems. Not just in math, also in other subjects.”*

Gal: *“Of course! I use it in other lessons, too. For example, in the Hebrew language lesson, we need to describe the source of the feud in the story. At first I was stuck and I did not understand. So I used the strategy and stopped. I took a break, I calmed down and I could go on. In the past, I didn’t do that... I did not think of it ... I used to look at it, not understanding, and at most I asked for help”*

The control group participants also felt they had benefited from the program and that their ability to solve this type of task had improved: 90% found the strategy effective. As noted, the control group received strategic training in solving authentic tasks. Here are some of their comments:

Naama: *“I liked the questions. I learned there are lots of patterns and how to discover the pattern...”*

Amir: *“I learned something new: how to use numbers in tables...”*

## **DISCUSSION AND CONCLUSIONS**

The research tested the contribution of an affective self-regulation intervention to changing achievement in solving authentic mathematical problems and positive and negative emotions. This section discusses the differences between the groups in the



following variables: (a) Positive and negative emotions, and (b) Solving authentic mathematical problems.

### ***Positive and negative emotions***

The findings show that negative emotions were decreased only in the affective self-regulation group. It can be assumed that this decrease is related to the nature of the program in which this group participated. The students received an explicit intervention, which was designed to regulate emotions by asking self-questions emphasizing emotional examination in all the learning phases (“How do I feel?”) They were also taught different specific strategies for managing negative emotions (“*I am capable of doing it*”, “*I relax and take time out*”, “*I reread the problem to understand*”, “*If I can’t do it, I ask for help from an adult or friend*”).

The focused and intensive training which the students received enabled them to create a state of calmness for themselves that, in turn, led to a reduction in negative emotions. Thus, when the students identified a negative emotion while working on a task, they responded to it with the emotion-management strategy they had practiced in order to deal with it.

This finding is most important since, as we see from other studies, negative emotions exercise a negative effect on the learning process. According to these studies, negative emotions generate feelings of alienation from school and a disengagement from the learning process (Artino, 2009; Kramarski et al., 2010; Reschly, Huebner, Appleton, & Antaramian, 2008; Sherman & Wither, 2003). The affective self-regulation program was found to lower these negative emotions. This result was substantiated by the reflective interviews when most of the affective self-regulation students said they had monitored their emotions (“*How do I feel?*”) throughout the problem-solving phases and had applied the emotion-management strategies whenever they experienced negative emotions (“*The most important thing is to examine how you feel. If I feel bad, like upset, I take time out and try to relax.*”).

Regarding changes in students’ positive emotions, the findings showed no differences in the positive emotions of the two groups at both the beginning and the end of the intervention. The students indicated high levels of positive emotions before the intervention, creating a ceiling effect caused by students exaggerating their positive emotions at the start. This is in line with Labuhn, Zimmerman, and Hasselhom’s (2010) findings. It may be that students’ understanding that they were participating in an intervention boosted their confidence and increased their positive emotions. Future research should therefore test this hypothesis using interviews with the participants.

***Post-intervention achievement in authentic mathematical problems***

No differences were found between groups as regards achievement for the numeric pattern problems. The requirements and complexity of the numeric pattern problems were the same before and after the intervention. It therefore seems that the exposure to authentic numeric pattern problems contributed to achievement in the affective self-regulation group and the control group in a similar way.

However, in the verbal pattern problem and the reasoning and generalization problem, the study showed that the affective self-regulation students outperformed their control group peers. Both of these types of problems required higher-order thinking than the problems given before the intervention. Several explanations for the efficacy of the affective self-reasoning program in solving these problems are proposed. First, the lower level of negative emotions in the affective self-regulation group tells us that learners were sufficiently emotionally available to solve mathematical problems requiring complex cognitive and metacognitive processes. This equipped them better for tackling problems and helped to improve their achievement. Other studies examining the link between positive and negative emotions and higher metacognitive functioning and achievement have supported the view that negative affect exacerbates task-irrelevant thoughts, thus, overloading working memory and reducing learners' available cognitive capacity (Zan et al., 2006). Negative emotions were also found to hamper learning (Ashcraft & Kirk, 2001; Efklides, 2011; Pekrun, Götz, Titz, & Perry, 2002). Conversely, positive emotions have been found to enhance creative academic engagement (Linnenbrink & Pintrich, 2003) and cognitive processing by redirecting the learner's attention, biasing memory retrieval, activating action tendencies, and improving appraisal performance during decision making (Linnenbrink, Ryan, & Pintrich, 1999; Zan et al., 2006).

Also, importantly, a relationship has been identified between emotions and motivation: positive emotions increase motivation (Pekrun et al., 2002) and lead to learning out of a desire to understand (Turner, Meyer, & Schweinle, 2003). This also leads to higher achievement (Götz, Frenzel, Pekrun, & Hall, 2006; Reschly et al., 2008) in tasks requiring higher cognitive competency (Zimmerman, 2000). Lower levels of negative emotions among the affective self-regulation group probably led to the realization of these capabilities, capabilities in the form of higher achievement compared to the control group. This explanation gains additional corroboration from the interview findings. The students indicated that the affective self-regulation program contributed both to their learning processes and to increasing their motivation to hammer away at the problems: *"The strategy helped me a lot, I felt more relaxed; I solved the tasks better. When I feel pressure I cannot do the tasks."*

Another important point relates to the kinds of difficulty caused by the authentic problems. Studies show that the entire process of authentic problem solving is accompanied by difficulty—from understanding the problem, planning the solution phases, reasoning, choosing an effective strategy, to thinking reflectively about the solution reached (Verschaffel et al., 2000). Affective self-regulation proved to be effective in coping with this ongoing difficulty. The reason is that students were taught to identify negative emotions and deal with them throughout the process, so that they did not give up, but coped with the task despite its complexity. Proof of this effect emerged from the interviews: *“You must check what you feel all the time ...otherwise you can’t continue.”*

This finding is supported by earlier studies showing that self-questioning during metacognitive self-regulation is effective and boosts achievement (Kramarski & Mizrachi, 2006; Kramarski et al., 2010). The present study took self-questioning one step further by examining the effectiveness of the strategy for fostering affective self-regulation. It was found that the strategy could reduce negative emotions and improve young learners’ achievements in solving authentic mathematical problems.

This was also corroborated by the reflective interviews conducted three months after the intervention. The students accurately described the intervention program showing they had internalized the program fully: *“You check how you feel all the time. If good...continue... if not...use the strategy. Stop and tell yourself that you can take a break and then go back to it. If it’s really hard, you can ask a friend or teacher”.*

The students also stated that the program was effective both in math and in other subjects: *“...I say to myself that I can have a break whenever I have a problem. Not just in math but in other subjects as well.”*

### **Research contribution**

The study makes theoretical, methodological, and applied contributions to the literature. In theoretical terms, the current research deepens our understanding of the conceptualizations supporting the cultivation of self-regulation. At the same time, it widens our knowledge of the emotional component of self-regulated learning. It also supports the transition from affective self-regulation theory to educational praxis. The affective self-regulation intervention reported above is based on Pintrich’s model (2000) of self-regulated learning. The main focus of Pintrich’s model is on the metacognitive and motivational aspects of self-regulated learning in adult learners. In the present study, however, we focused on the affective aspect of self-regulated learning using self-generated questions specifically designed for young learners, which were found to be effective and internalized over time.

Methodologically, a wide range of qualitative and quantitative measurement tools (mixed method) were used in this research. These tools included a pre/post program quantitative questionnaire and a reflective interview. Self-regulation researchers recently recommended using these tools (Greene & Azevedo, 2010; Veenman, 2007).

In terms of the practical contribution, a special, affective self-regulation program was developed specifically for young learners. The study proves that this program is effective and internalized over time. The program can therefore serve a foundation in teacher training and in-service training regarding the diverse approaches to affective self-regulation. In addition, these programs can be adapted for use with mature and young learners alike.

### ***Limitations and further research***

The study examined the effect of the affective self-regulation intervention (compared to the control group) only for solving authentic pattern problems, and we only used one teaching method (explicit instruction and self-questions). In addition, the focused intervention consisted of just 10 sessions whose effect was examined three months after their conclusion. It is therefore proposed to examine the effectiveness of this intervention in a variety of learning environments, such as in cooperative learning and in fading conditions. Longitudinal studies would also be useful to determine the impact of the various programs and to establish their transfer effect over time. A comprehensive examination of interventions is proposed for different types of learner, such as boys and girls, students with different achievement levels (high / low / average in mathematics), students with learning disabilities, and students with math anxiety. It would be also worthwhile for future research to carry out a process analysis. For example, students could solve authentic problems out loud. Given that the present study focused on quantitative data and interviews, future research could examine affective self-regulation processes, by analyzing them in real time as well, as suggested by Greene and Azevedo (2010).

### ***Appendix A. Verbal pattern problem***

Dan builds a model with small hearts in several stages:

At the first stage- 5 hearts; At the second stage- 9 hearts; At the third stage- 15 hearts.

How many hearts will be in the fourth stage, the sixth stage and the 25th stage? Explain.

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