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Teaching Cognitive and Metacognitive SRL Strategies in the Science Class: An Experimental Design to Determine Effect on Academic Achievement

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Abstract: The purpose of the study was to investigate the effect of teaching cognitive and metacognitive SRL strategies on the academic achievement of seventh grade students through an experimental design with a pre and posttest and a comparison group. The Reciprocal Causation Model based on Bandura's social cognitive theory and Zimmerman´s Model of Self-Regulation were used as the theoretical framework. The intervention provided to the experimental group (Group A; *n*=15) consisted of the direct and explicit instruction of cognitive and metacognitive SRL strategies. The intervention in the comparison group (Group B; *n*=15) consisted of self-directed learning. The effect of the intervention was determined by running a *t*-test to compare pre and posttest results. A significance level of .05 was established for each of the four hypotheses. The results from the *t*-test (.032) from the posttest of the experimental group and the comparison group show that the differences found were statistically significant. Moreover, a Cohen's *d* coefficient of 0.82 was obtained, which represents a large effect size. This finding suggests that the direct and explicit instruction of cognitive and metacognitive SRL strategies has a greater effect on the academic achievement than self-directed instruction. Contrarily, the results from the *t*-test (.112) that compared the sample means ($\bar{x}$) obtained from the pre and posttest of the experimental group (Group A) indicated that the differences found were not statistically significant. However, a Cohen's *d* coefficient of 0.58 was obtained, representing a moderate effect size. This finding could suggest that the complexity of the design requires additional controls to be put into place. With regards to the comparison group (Group B), and according to student responses in the SRL strategy

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use logs, it was evidenced that these strategies were used infrequently. Recommendations for future investigations are provided.

Key-Words: Self-Regulation, Self-Regulated Learning (SRL), Cognitive Strategies, Metacognitive Strategies, Direct and Explicit Instruction, Self-Directed Learning.

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1. Introduction

The skills and competencies required for personal, academic, and professional success in the 21st century have caused a paradigm shift in educational environments. The onslaught of information and the variety of media devices used by all and sundry are a reminder that the source of obtaining said information is not solely dependent on the teacher figure anymore. Thus, classroom environments that tend to be linear in nature, although predominant in education, do not satisfy these new paradigms. The end result is a classroom environment in which instruction is mostly content-based without effectively teaching and modeling the strategies that will empower students to become self-regulated learners (Kumi-Yeboah, 2012; Moos and Ringdal, 2012; Dignath and van der Werf, 2012).

It is possible to model and teach self-regulation strategies to students as part of the teaching-learning process through direct and explicit instruction (Nilson, 2013; Vassallo, 2011; Mayer, 2011; Zumbrunn, Tadlock, and Roberts, 2011). Teaching students to become self-regulated learners requires teachers to understand how it is that students learn in order to model the strategies effectively and appropriately. By the same token, the learning environment has to be conducive to the enhancement and development of self-regulatory abilities in students (Germeroth and Day-Hess, 2013; Vassallo, 2011; Kistner, Rakoczy, Otto, Dignath, Büttner, and Klieme, 2010). Therefore, although it is important to teach the content of a particular subject, the educational process is enhanced through the direct and explicit instruction of cognitive and metacognitive SRL strategies (Moos and Ringdal, 2012; Velayutham, Aldridge and Fraser, 2012). In addition to modeling SRL strategies, a support system in the form of teacher feedback in all instances of the teaching-learning process, meaning before, during, and after instruction, will promote the development of SRL competencies in students (Mayer, 2011; Vassallo, 2011; Schunk, 2009; Campbell, 2009). Such feedback should focus on student performance, opportunities for improvement, student strengths, and the value of the task at hand. It is important to note that teaching SRL strategies should not be incidental or independent of the content, but instead, as an integrated part of the course or subject matter (Lovett, 2013; Schunk, 2009). Teaching SRL strategies should be taken one step further in that they should be taught in such a manner so as to be transferable and used in a variety of contexts, assignments, and tasks.

Students that show higher levels of self-regulation tend to be actively engaged and involved in their own learning process, make constant decisions related to their learning activities and take responsibility for their own learning. Studies that have explored the topic of self-regulation have suggested that successful students use cognitive and metacognitive strategies more often and more effectively than students with lower levels of academic achievement (Moos, 2011; Kistner, Rakoczy, Otto, Dignath, Büttner, and Klieme, 2010). Furthermore, the ability to self-regulate is accompanied by other factors that affect academic outcomes, such as motivation and self-efficacy (Schunk and Usher, 2011). Self-regulation models offer the opportunity to promote the development of cognitive and metacognitive abilities in students to become proactive, strategic, independent, self-directed learners (Davis and Nietzel, 2011; Vassallo, 2011).

2. Problem

According to the results of the standardized tests submitted by the Department of Education of Puerto Rico corresponding to the 2010-2011 school year, and up until the 2013-2014 school year, it was possible to identify a decrease in the academic achievement of middle school students in the content area of science. The data were obtained from the report titled "Perfil Escolar del Departamento de Educación de Puerto Rico" of the 2010-2011, 2011-2012, 2012-2013, and 2013-2014 school years (DEPR). The statistics included in the report provide information on the number of students that performed at the proficient and advanced levels in science in the fourth, eighth, and eleventh grades. At the elementary level, 68%, 66%, 68%, and 67% demonstrated proficient and advanced levels of performance in science during the 2010-2011, 2011-2012, 2012-2013, and the 2013-2014 school years, respectively. The results corresponding to proficient and advanced performance for middle school were significantly lower: 27% in 2010-2011; 27% in 2011-2012; 29% in 2012-2013, and 26% in 2013-2014. In eleventh grade, 46% of the students tested reached proficient and advanced levels during the 2010-2011 school year; 44% for the 2011-2012 test administration; 43% for the 2012-2013 school year, and 48% performed accordingly during the 2013-2014 school year. Based on these results, and although it is evident that academic achievement must be improved across the board, the priority is clearly to increase the level of performance and the academic achievement of middle school students in their science class.

In addition, the personal and academic difficulties that middle school students face in adjusting to new environments upon entering their adolescent years, requires the implementation of effective teaching models and strategies in the classroom. In an effort to attend to and deal with the problem under investigation, the development of SRL strategies presents itself as a viable alternative to improve the academic achievement of seventh grade students in the science class. The investigation contemplated two interventions with the purpose of developing cognitive and metacognitive SRL strategies in seventh grade students during the science class: the direct and explicit instruction of cognitive and metacognitive SRL strategies in the experimental group (Group A; n=15), and self-directed learning in the comparison group (Group B; n=15).

3. Objectives and Research Hypotheses

3.1 Objectives

This study was designed to investigate how the direct and explicit instruction of SRL cognitive and metacognitive strategies affected the academic achievement of seventh grade students in the science class when compared to self-directed instruction. A variety of cognitive and metacognitive strategies were considered in the development of the resources and instruments for the experiment. These strategies were: a) strategies for the management and organization of information; b) strategies for the interpretation and representation of information; c) self-monitoring strategies; d) self-evaluation strategies; e) self-reflection strategies, and f) teacher feedback. The strategies were aligned to the content of the seventh grade science course, as per the curriculum adopted by the Department of Education of Puerto Rico. Thus, the classroom activities incorporated content, as well as strategies for the development of cognitive and metacognitive self-regulation skills in students. Both the experimental and the comparison group participated in the administration of the pre and posttest and received the instructional resources that were developed for the study.

3.2 Research Hypotheses

Four research hypotheses were established with a significance level of .05. Each one included a null hypothesis and an alternative hypothesis.

First hypothesis: H_o: There are no statistically significant differences between the sample means ($\bar{x}$) of the scores obtained from the pretest of the experimental group and the comparison group ($p \geq .05$).

H_a: There are statistically significant differences between the sample means ($\bar{x}$) of the scores obtained from the pretest of the experimental group and the comparison group ($p \geq .05$).

Second hypothesis: H_o: There are no statistically significant differences between the sample means ($\bar{x}$) of the scores obtained from the posttest of the experimental group and the comparison group ($p \geq .05$).

H_a: There are statistically significant differences between the sample means ($\bar{x}$) of the scores obtained from the posttest of the experimental group and the comparison group ($p \geq .05$).

Third hypothesis: H_o: There are no statistically significant differences between the sample means ($\bar{x}$) of the scores obtained from the pre and the posttest of the experimental group ($p \geq .05$).

H_a: There are statistically significant differences between the sample means ($\bar{x}$) of the scores obtained from the pre and posttest of the experimental group ($p \geq .05$).

Fourth hypothesis: H_o: There are no statistically significant differences between the sample means ($\bar{x}$) of the scores obtained from the pre and the posttest of the comparison group ($p \geq .05$). *H_a:* There are statistically significant differences between the sample means ($\bar{x}$) of the scores obtained from the pre and posttest of the comparison group ($p \geq .05$).

4. Literature Review

During the process of self-regulation, individuals transform their mental abilities, behavior, and feelings into actions that are geared towards the attainment of personal and academic goals (Silver, 2013; Kumi-Yeboah, 2012; Zimmerman and Schunk, 2011; Schmitz and Perels, 2011; Peters and Kitsantas, 2010; Schunk, 2009; Zimmerman, 2008). It is a dynamic, contextual, and multidimensional process that involves the attitude, the behavior, the affective states, and the cognitive and metacognitive development of the learner. The prevailing contextual factors are also influential in self-regulation. The interaction of these elements plays a significant role when students are faced with the need to use their cognitive and metacognitive abilities, which, in turn, are manifested in actions conducive to the regulation of learning.

The effective use of cognitive and metacognitive SRL strategies helps students improve their academic achievement across all disciplines and subjects, and promotes independent lifelong learners that are able to engage in strategic decision making. (Davis and Nietzel, 2011; Kistner, Rakoczy, Otto, Dignath, Büttner, and Klieme, 2010). In today's setting, self-regulation is pointedly relevant for academic success because: 1) information is constantly exchanged through a variety of media at an alarming rate and at all times; 2) teachers are not always present, especially during after school hours when students are expected to continue with the learning experience through extracurricular activities, homework, and others; 3) it grants students responsibility for their own learning, and 4) it provides the chance to adapt and respond to the particular context and needs of any given occasion or instance (Kumi-Yeboah, 2012; Schmitz and Perels, 2011). Hence, the role of teachers is to guide students to become self-regulated learners.

Students that have not developed their self-regulation abilities tend to set inappropriate goals, implement self-monitoring processes that are ineffective, and do not establish a well-thought out plan. They exhibit limited cognitive and metacognitive controls and limited skills for academic success. The need to enhance their abilities sets the stage for the adoption of teaching models that include the instruction of cognitive and metacognitive strategies to promote SRL in students. However, it has been found that teachers do not engage in SRL strategy instruction due to, either a lack of training on matters regarding self-regulation, or because of the amount of extra work and time that planning for SRL instruction entails (Kistner, Rakoczy, Otto, Dignath, Büttner, and Klieme, 2010). Educational programs that have included interventions for the development of SRL strategies have, for the most part, been successful because they incorporate activities and educational tasks that give students the opportunity for decision-making and gradually grant independence and autonomy. Moreover, they promote self-evaluation, peer assessment, and they allow for instances in which collaborative activities are carried out. Self-regulation is enhanced through the creation of educational environments where high levels of cognitive and metacognitive activities prevail (Kistner, Rakoczy, Otto, Dignath, Büttner, and Klieme, 2010).

Academically successful students use an array of acquired SRL strategies that they adjust depending on the context of the situation, such as: setting goals; planning; determining when it is appropriate to reward themselves; organizing information; transforming information; keeping a record of their activities, results, and outcomes; the use of think alouds and other verbal learning protocols; the elaboration of information; explaining; analyzing the task; choosing strategies; monitoring their own progress; judging and evaluating their work and their learning, and keeping themselves motivated (Ambrose, Bridges, Lovett, DiPietro, and Norman, 2010). It is possible to teach self-regulation processes through direct and explicit instruction or through indirect methods (Dignath and Büttner, 2008; Schunk, 2009; Germeroth and Day-Hess, 2013). Research has shown that indirect instruction is the least effective, even though it is the predominant method used for the development of SRL strategies (Moos and Ringdal, 2012). Indirect instruction occurs when teachers structure the environment for opportunities to use the SRL strategies, but does not teach or model them.

Many theories and approaches support the use of self-regulation models as part of the learning process. Although there are differences among models, they share certain elements. They agree that the individual: 1) is a proactive learner; 2) can exert control over his/her own learning; 3) is capable of controlling the environment, and 4) establishes goals, implements strategies, monitors progress, and makes adjustments during this cyclical process before, during, and after the learning experience (Campbell, 2009; Clark, 2012). This study was based on Bandura's social cognitive theory and Zimmerman's self-regulation model (Dignath and Büttner, 2008). The social cognitive theory

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contemplates the learning experience as a series of events that are influenced by the interaction of personal, social and behavioral factors, also known as the Triadic Reciprocal Causation Model (Moos and Ringdal, 2012; Zimmerman and Schunk, 2011; Schunk and Usher, 2011; Moos, 2011). This perspective tries to explain the relationship between social and cognitive events that individuals depend on for adaptation and change, so the learning process is an area of interest to this theory. According to the social cognitive theory, learning is not only a reflection of personal factors, but also a reflection of the reciprocal roles of social factors and behavior (Zimmerman and Schunk, 2001). Social processes, such as modeling, verbal persuasion, and observation of what is going on in the environment, leads to self-evaluation and to making adjustments whenever necessary (Zimmerman and Schunk, 2001). According to Bandura's theory, the development of self-regulation abilities occurs in four levels: 1) observation; 2) emulation; 3) self-control, and 4) self-regulation (Peters and Kitsantas, 2010).

Zimmerman's cyclical model of self-regulated learning suggests that the process occurs in three cyclical and dynamic phases: 1) the forethought phase; 2) the performance phase, and 3) the self-reflection phase (Bembenutty, 2011). During forethought, students exhibit their disposition to engage in learning by analyzing the task, awarding value to the task, establishing goals, and developing a plan (see Figure 1). In the performance phase, students implement the plan and selected strategies. During self-reflection, the student reflects and thinks about the process, evaluates the final product, and makes the decisions needed to improve the learning experience (Germeroth and Day-Hess, 2013; Silver, 2013; Kumi-Yeboah, 2012; Bembenutty, 2011; Kistner, Rakoczy, Otto, Dignath, Büttner, and Klieme, 2010; Schunk, 2009).

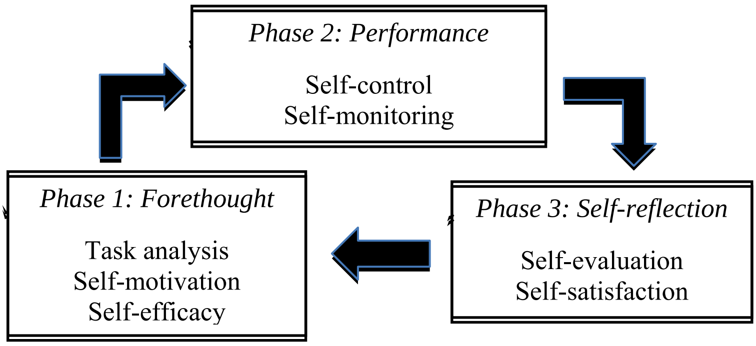

Figure 1. *Zimmerman's cyclical model of self-regulated learning*. Source: Zimmerman (2008).

Self-regulatory abilities are manifested in the cognitive and metacognitive strategies that students use for learning. Teaching students to outline, summarize, interpret, and organize information in tables, graphs, and other forms of representation, enhances cognitive strategies. Cognition is also strengthened when students are taught to practice and learn information through repetition, mnemonics, by creating mental images, by formulating questions about the information, and by studying with others (Germeroth and Day-Hess, 2013;). Self-monitoring, self-evaluation, and self-reflection are SRL metacognitive strategies that are reinforced through rubrics, logs, checklists, assessment instruments, effective modeling, progress reports, compelling feedback, verbal protocols, technological supports, and the identification of errors in the learning process, among others (Germeroth and Day-Hess, 2013; Bannert and Reimann, 2012; Schmitz and Perels, 2011; Mayer, 2011). Continuous self-monitoring allows the student to revise performance and progress, to make adjustments, and to calibrate learning. (Kumi-Yeboah, 2012; Schmitz and Perels, 2011). Self-evaluation can come from the learner or as a result of the feedback given by others, and involves the formulation of value judgments about performance and quality of work that is usually based on comparing results to a standard that, on occasion, could be the student's previous results (Lovett, 2013). On the other hand, self-reflection supports the development of metacognitive abilities, allows for the validation of the learning process and has the potential to increase motivation and self-efficacy.

Research suggests that academic success is highly dependent of the effective use of SRL strategies on the part of the student. In studies with students from K-12, results have indicated that direct and explicit instruction of SRL strategies helps improve academic achievement (Kistner, Rakoczy, Otto, Dignath, Büttner, and Klieme, 2010). Studies related to SRL have explored a variety of topics such as: the perception of teachers with respect to their role in the development of SRL strategies, assessment, and their epistemological beliefs (Davis and Nietzel, 2011; Nash-Ditzel, 2010; Dignath and Büttner, 2008). Results show that teachers maintain control of all aspects related to the teaching-learning process, including the strict adherence to content instruction and the use of assessment as an evaluation method. In addition, research suggests that students with the greatest academic success have high levels of cognitive and metacognitive development. The instruction of SRL strategies coupled with effective modeling techniques for prolonged periods of time and sound feedback are more effective than other teaching methods, especially for the development of metacognition (Nash Ditzel, 2010; Dignath and Büttner, 2008). Students that excel at self-regulation exhibit high levels of self-efficacy, the inclination to invest time and effort towards learning, high organizational skills, the ability to establish priorities accordingly, and the ability to recognize when it is time to ask for help. Students that do not exhibit self-regulation abilities have low self-efficacy levels, poor time management skills, a lack of interest in engaging in learning tasks, and an unwillingness to make the effort to do so (Usher, 2009). Some activities that help students engage in SRL are: the use of diaries; planning for the task at hand; the use of a variety of resources to aid in the learning process, and the assertive management of the environment, among others (Campbell, 2009).

Investigations have been conducted to study the instructional process related to the following topics on SRL; how peer groups influence SRL, and how behavior factors play into self-regulation (Kistner, Rakoczy, Otto, Dignath, Büttner, and Klieme, 2010). These studies have concluded that self-efficacy and motivation play a determinant role in the development of SRL skills. (Sartawi, Alsawaie, Dodeen, Tibi, and Alghazo, 2012). Results have also pointed gender differences: girls exhibit greater levels of intrinsic motivation and goals that are oriented towards the mastery of a given task, while boys are more performance oriented and depend more on extrinsic motivation. Self- efficacy and motivation determine, to an extent, the scope of the use of SRL strategies in students, and as a result, their academic achievement. Another aspect of interest emphasized in research is that when SRL strategies are taught through direct and explicit instruction, academic achievement increases (Kistner, Rakoczy, Otto, Dignath, Büttner and Klieme, 2010). Successfull students are organized and tend to: use SRL strategies with greater frequency; verify and manage information effectively; evaluate the content of the information, and ask for help (Rytkönen, Parpala, Lindblom-Ylänne, Virtanen, and Postareff, 2012). If learning is considered malleable, more effort will be put into the process; if it is seen as a fixed ability, there is an unwillingness to engage in the process, which can adversely affect academic achievement. In general, in experimental groups with interventions based on the direct and explicit instruction of SRL strategies, improvement in student work was observed along with an increase in academic achievement (Tuckman and Kennedy, 2011;). They have provided evidence that point to SRL strategies as effective in increasing self-efficacy, knowledge, and academic achievement. In general, results from research confirm that the use of SRL strategies correlates positively to academic achievement (Eilam, Zeidner, and Aharon, 2009).

4.1 Direct and explicit instruction

SRL models provide teachers with a perspective that allows them to visualize their students as proactive and strategic learners, and themselves as professionals that are able to reflect on their practice, that are able to adapt and revise their pedagogical styles in order to better accommodate student needs accordingly (Zumbrunn, Tadlock and Roberts, 2011; Moos 2011). Consistent with Bandura's social cognitive theory, studies have demonstrated that direct and explicit instruction of cognitive and metacognitive SRL strategies, when taught systematically, is positively correlated to academic achievement (Germeroth and Day-Hess, 2013; Nilson, 2013; Clark, 2012; Zumbrunn, Tadlock, and Roberts, 2011; Peters and Kitsantas, 2010; Kistner, Rakoczy, Otto, Dignath, Büttner and Klieme, 2010; Schunk, 2009;

Zimmerman, 2008). This type of instruction combines personal factors, such as: cognitive processes; metacognitive processes, the affective and motivational state of the learner (Bannert and Reimann, 2012; Moos, 2011; Zimmerman and Schunk, 2011; Schunk and Usher, 2011). During the learning process, the teacher specifies when SRL strategies can be used, how they are used, what the benefits of one strategy over another are depending on the situation and context, and when to make adjustments in order to enhance their benefit (Kumi-Yeboah, 2012; Moos and Ringdal, 2012; Vassallo, 2011; Davis and Nietzel, 2011). The task of guiding students through the process of the development of self-regulating abilities requires effective modeling skills on the part of the teacher, which includes support and awarding gradual independence as the student starts to show mastery (Zumbrunn, Tadlock, and Roberts, 2011). The incorporation of self-regulation strategies into the teaching process is more effective in getting students to transfer these skills to new contexts and study disciplines than teaching these strategies in isolation (Silver, 2013; Bannert and Reimann, 2012; Schunk, 2009).

Part of the direct and explicit instruction of SRL strategies should include self-monitoring skills through a variety of instructional resources, such as: modeling; scaffolding; collaborative work; assessment; formative feedback, and gradually granting the opportunity for decision making in matters related to the task at hand (Kumi-Yeboah, 2012; Clark, 2012). Assessment and formative feedback are powerful communication devices that provide valuable information to students about their progress and how to strengthen their self-monitoring and self-evaluation skills. The probability of developing SRL strategies in students and guiding them to become independent learners increases when the teacher provides explanations, offers demonstrations, provides direct and explicit instruction on cognitive and metacognitive strategies, and provides activities for collaboration and decision making (Clark, 2012; Davis and Nietzel; 2011). When students use SRL strategies they become proactive learners. In particular, metacognitive strategies allow for effective decision-making and provide an awareness of the learning process (Silver, 2013). Feedback should be high quality and should stress performance over the final product, thus allowing students to identify the cognitive and metacognitive strategies that could potentially become part of their repertoire of successful learning strategies (Hattie and Yates; 2014; Clark, 2012; Moos, 2011; Mayer, 2011; Ambrose, Bridges, Lovett, DiPietro and Norman, 2010). Therefore, assessment activities and effective feedback are strong learning tools when they promote self-monitoring, self-reflection, and self-evaluation at the same time that they advance the development of self-regulation abilities in students. Consequently, students that learn to use SRL strategies effectively and with purpose, will, in turn, improve their academic achievement (Moos, 2011; Zimmerman and Schunk, 2011; Kistner, Rakoczy, Otto, Dignath, Büttner, and Klieme, 2010).

4.2 Self-Directed Instruction

In self-directed instruction, students are able to: 1) establish learning goals; 2) locate and access learning resources; 3) adopt strategies and activities pertinent to the learning goal; 4) monitor and evaluate the results and outcomes of their learning, and 5) reflect on the strategies implemented during the learning process, and 6) make adjustments, if needed. (Kim, Olfman, Ryan and Eryilmaz, 2014; Avdal, 2013). Self-directed learners display a proactive attitude, responsibility, and autonomy towards learning. This implies that the learner controls the learning process, be it individually or through the interaction with others. Students that engage in self-directed learning exhibit: high levels of self-efficacy; control over their learning; high motivation; organization; independence towards their learning; effective use of cognitive and metacognitive strategies; goal-oriented attitudes, and the ability to transfer knowledge to new situations. They are empowered, they are active and proactive in their learning, can make decisions regarding their own learning, which translates to high levels of academic achievement. Contrarily, those that do not possess the skills for successful self-directed learning exhibit poor time management, poor organizational skills, very little responsibility, low levels of motivation, and little overall academic discipline. According to literature, self-directed learning can be enhanced and is contingent on taking into consideration the variables that influence the development of a self-regulated learner, along with adequate classroom management skills that include well-structured learning environments and thoughtful planning by the teacher. (Kim, Olfman, Ryan and Eryilmaz, 2014; Avdal, 2013).

5. Method

5.1. Research Design

The research design implemented in this study was an experimental design with a pre and posttest and comparison group (see Figure 2) which is appropriate when the investigator looks to establish causal inferences (Shadish, Cook and Campbell, 2002). In this investigation, the causal inferences were related to the effects of teaching cognitive and metacognitive SRL strategies on the academic achievement of seventh grade students in the science class. This design allows the researcher to consider a cluster sample in which it is possible to randomly assign the experimental group and the comparison group. Two interventions were chosen for the study: 1) the direct and explicit instruction of SRL strategies in the experimental group (Group A), and 2) self-directed instruction of SRL strategies in the comparison group (Group B). The time allotted to the interventions was approximately 10 weeks. The independent variables were the two teaching methods, and the independent variable was academic achievement, and was measured based on the scores of the seventh grade science pre and posttest developed by the research team.

Group A: R _______ O_1 _______ X_1 _____ O_2
Group B: R _______ O_1 _______ X_2 _____ O_2
Where: R, represents the random sample
O_1, represents the pretest
O_2, represents the posttest
X_1, represents the intervention in the experimental
X_2, represents the intervention in the comparison group

Figure 2. *Diagram of an experimental design with pre and posttest and comparison group.* (Source: Shadish, Cook and Campbell, 2002).

6. Instruments

A total of nine instruments were developed: 1) a specifications table that guided the development of the pre and posttest; 2) a pre and posttest based on the contents of the first semester of the seventh grade science course, as per the curriculum of the science program of the Department of Education of Puerto Rico; 3) a student manual that included information about cognitive and metacognitive strategies and activities that were aligned to the seventh grade science curriculum; 4) a teacher's manual that was used as the guide in the intervention provided in the experimental group; 5) a cognitive and metacognitive strategy use log that was administered to the participants in the comparison group; 6) a guide used to train the science teacher; 7) a validation instrument for the specifications table and for the pre and posttest; 8) a validation instrument for the teacher's manual, and 9) a validation instrument for the student's manual. Possible threats to validity were identified and controls were put into place to minimize their effect on the results of the investigation (Shadish, Cook, and Campbell, 2002). Some of these controls include actions towards minimizing threats due to maturation, instrumentation, history, testing, and statistical power, among others.

7. Participants

As previously mentioned, the sample was a cluster sample with random assignment of groups. Cluster samples, even though they rely on the use of intact groups, are convenient in experimental methodologies because they are representative of the population (Vogt, 2007). The selection of a cluster sample implies that all of the members of the group are included in the sample. The sample was a probability sample made up of two groups of seventh grade students from a public middle school, located in the western region of Puerto Rico. A total of 30 students (N=30) comprised the total number of participants, 15 in each group (*n*=15). The selection of the participating school was based on the following criteria: 1) the results in the science section of the standardized test corresponding to middle school had to be similar to the statewide results; 2) the school had to have, at least, two seventh grade groups in its organization, and 3) the participants had to be officially enrolled in the seventh grade. Therefore, schools that performed at proficient and advanced levels on the science test were not considered for the study. Other criteria for exclusion from the study were those with only one seventh grade group and schools that did not have a regular curriculum to service its students, such as pre-vocational centers. A total of eight schools from one of the districts from the western region qualified to participate in the study.

8. Procedure

To start the investigation, the research team complied with all of the documentation required by the IRB and the Department of Education. Investigation forms and protocols, letters, applications, and the required IRB, RCR, and HIPS certifications were among the documents submitted. Once the authorization to carry out the research project was received, the research team started to identify the schools on the western part of the island of Puerto Rico that qualified to participate in the study. A total of eight schools from the district that was selected met the criteria for participation. Letters were sent to each one, and three schools answered. Two of the schools sent letters that indicated their availability to participate in the study. A third school expressed availability through a phone call. The research team decided to consider the two schools that sent letters. The first school to answer was used for the pilot test, and the second school was chosen for the experiment. In each phase of the study, parent consent forms and student assent forms were filled out and returned to the research team. Likewise, orientations were provided to all the participants, teachers and students, both during the validation phase and the experimental phase of the study. Guarantees were provided for confidentiality, voluntary participation, and the chance to withdraw from the study without the fear of being penalized.

Validation phase. The first phase of the study involved the validation of instruments and the pilot test. The four instruments that were validated included: 1) the specifications table that was used to guide the development of the pre and posttest; 2) the pre and posttest based on the contents of the first semester of the seventh grade science course, as per the curriculum of the science program of the Department of Education of Puerto Rico; 3) the student manual that included information about cognitive and metacognitive strategies and activities that were aligned to the seventh grade science curriculum, and 4) the teacher's manual that was used as the guide in the intervention provided in the experimental group. The panel of experts that validated each of the four instruments consisted of three seventh grade science teachers, one science facilitator, and one expert in the field of education with a doctorate's degree in curriculum development. The instruments were validated based on the criteria provided in the validation forms that, in turn, were designed based on Lawshe's model for measuring content validity (Lawshe, 1975). A CVI value of 1.00 was obtained for each instrument. Thus, no substantial changes were required. In addition, the reliability coefficient (Cronbach's alpha) of the pre and posttest was obtained from the results of the administration of a pilot test to 15 seventh grade students that had completed the first semester of the science course. A Cronbach's alpha, $\alpha = .731$ was obtained, which is considered satisfactory and denotes reliability of the test. It was decided that no item would be eliminated from the test because such an action would not result in a significant increase of Cronbach's alpha.

Experimental phase. With regards to the experiment, the teacher who participated in the study was a middle school science teacher with a valid teaching license emitted by the Department of Education of Puerto Rico. The two groups were randomly assigned to either the experimental group (Group A) or to the comparison group (Group B). The participants in both groups took the pretest and received a student manual for the development of cognitive and metacognitive SRL strategies. The experimental group (Group A) used the student manual as part of the direct and explicit instruction of SRL strategies. In previous studies, the direct and explicit instruction of SRL strategies has correlated positively to academic achievement, especially when the instruction incorporated opportunities for the development of metacognitive strategies (Kistner, Rakoczy, Otto, Dignath, Büttner and Klieme, 2010).

The teacher provided instruction in the direct and explicit instruction modality based on the directives in the teacher's manual that served as the script to follow during the intervention provided to the participants of Group A. A total of nine, 30-minute instructional lessons were designed for the 10-week time frame during the first semester of the academic school year. The topics included in the manual were related to the following cognitive and metacognitive strategies: 1) self-monitoring and self-evaluation; 2) self-reflection and teacher feedback; 3) note-taking and study techniques; 4) mnemonic techniques; 5) how to outline; 6) how to design graphic organizers; 7) how to design tables; 8) how to plot graphs, and 9) how to make representations, diagrams, and illustrations. The comparison group (Group B), on the other hand, used the student manual for the self-directed instruction intervention. This means that the participants in Group B did not receive direct and explicit instruction on SRL strategies. In addition to the student manual, the students in the comparison group (Group B) completed a strategy log on four occasions during the 10-week intervention. The purpose of the log was to maintain a record of the cognitive and metacognitive strategies used by the comparison group during the experiment.

Throughout the experiment, the research team visited the teacher and made follow-up visits to coordinate, to retrieve documents, to provide assistance when needed, to confirm the implementation of the interventions, and to keep the experiment on track. At the end of the 10 weeks, which was near the end of the first semester, the posttest was administered in both groups and the strategy use log was administered one last time in the comparison group (Group B). It is important to note that evaluations regarding the contents of the student manual were also administered, both in the experimental group (Group A) and in the comparison group (Group B).

The data considered in the analysis were the scores obtained from the pre and posttest administered to both Group A and Group B, the strategy use log results, and the evaluation results. The results from the statistical analysis, based on the *t*-test that compared the sample means ($\overline{x}$) of the pre and posttest, were used to either retain or reject each of the four hypotheses of the investigation. A final written report that included the findings, the conclusions, and the recommendations was submitted. Upon completing the study, the research team requested the IRB to close the investigation in accordance with standard procedure.

9. Results

9.1. Descriptive results and statistics

A total of 30 students took the pre and posttest for a 100% participation. For the pretest administered in the experimental group (Group A), the minimum score was 27, and the maximum score was 73 (see Table 1). The scores with a frequency (*f*) of one were: 27; 33; 43; 47; 50; 53; 63; 67, and 73. The scores with a frequency (*f*) of two were: 40; 57, and 60. In the comparison group (Group B), the minimum score was 27. The maximum score was 63. The scores with a frequency (*f*) of one were: 27; 47, and 57. The scores with a frequency (*f*) of two were: 37; 40; 43; 50; 53, and 63.

Pretest Group A				**Pretest Group B**			
Scores	*f*	%	Cumulative %	Scores	*f*	%	Cumulative %
27	1	6.7	6.7	27	1	6.7	6.7
33	1	6.7	13.3	37	2	13.3	20.0
40	2	13.3	26.7	40	2	13.3	33.3
43	1	6.7	33.3	43	2	13.3	46.7
47	1	6.7	40.0	47	1	6.7	53.3
50	1	6.7	46.7	50	2	13.3	66.7
53	1	6.7	53.3	53	2	13.3	80.0
57	2	13.3	66.7	57	1	6.7	86.7
60	2	13.3	80.0	63	2	13.3	100.0
63	1	6.7	86.7				
67	1	6.7	93.3				

73	1	6.7	1000				
Total	15	100		Total	15	100	

Note: *N=30: Group A, n* = 15; *Group B, n* = 15.

Table 1. *Pretest frequencies for the experimental group (Group A) and the comparison group (Group B).*

For the posttest administered in the experimental group (Group A), the minimum score was 43, and the maximum score was 80 (see Table 2). The scores with a frequency (*f*) of one were: 43; 53; 57; 70; 77, and 80. The scores with a frequency (*f*) of two were: 50; 63, and 67. Three participants obtained a score of 47. In the comparison group (Group B), the minimum score was 13. The maximum score was 77. The scores with a frequency (*f*) of one were: 13; 37; 43; 47; 57; 60 and 77. The scores with a frequency (*f*) of two were: 23; 40; 50, y 67.

Posttest Group A				**Posttest Group B**			
Scores	*f*	%	Cumulative %	Scores	*F*	%	Cumulative %
43	1	6.7	6.7	13	1	6.7	6.7
47	3	20.0	26.7	23	2	13.3	20.0
50	2	13.3	40.0	37	1	6.7	26.7
53	1	6.7	46.7	40	2	13.3	40.0
57	1	6.7	53.3	43	1	6.7	46.7
63	2	3.3	66.7	47	1	6.7	53.3
67	2	3.3	80.0	50	2	13.3	66.7
70	1	6.7	86.7	57	1	6.7	73.3
77	1	6.7	93.3	60	1	6.7	80.0
80	1	6.7	100.0	67	2	13.3	93.3
				77	1	6.7	100.0
Total	15	100		Total	15	100	

Note: *N=30: Group A, n* = 15; *Group B, n* = 15.

Table 2. *Posttest frequencies for the experimental group (Group A) and the comparison group (Group B).*

Table 3 provides the descriptive statistics for the pretest. In the experimental group (Group A), the sample means ($\overline{X}$) was 51.33 and the la median (*Mdn*) was 53.00. Also, multiple modes were identified (*Mo*): 40, 57 and 60. The standard deviation (s) and the variance (s^2) for the experimental group (Group A) was 12.938 and 167.381, respectively. The range was 46, with a minimum of 27 and a maximum of 73. In the comparison group (group B), the sample means ($\overline{X}$) was 46.87 and the median (*Mdn*) was 47.00. Multiple modes were identified (*Mo*): 37, 40, 43, 50, 53 and 63. The standard deviation (s) and the variance (s^2) for the comparison group (Group B) was

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10.113 and 102.267, respectively. The range was 36, with a minimum of 27 and a maximum 63.

	Pretest Group A	Pretest Group B
N	15	15
Means	51.33	46.87
Standard Means Error	3.340	2.611
Median	53.00	47.00
Mode	40[a]	37[a]
Standard Deviation	12.938	10.113
Variance	167.381	102.267
Range	46	36
Minimum	27	27
Maximum	73	63

Note: [a.] There are multiple modes, *Mo*.

Table 3. *Descriptive statistics calculated from the scores obtained from the administration of the pretest.*

Table 4 provides the descriptive statistics for the posttest. In the experimental group (Group A), the sample means ($\overline{x}$) was 58.73 and the la median (*Mdn*) was 57.00. The mode *(Mo)* was 47. The standard deviation (*s*) and the variance (s^2) for the experimental group (Group A) was 11.756 y 138.210, respectively. The range was 37, with a minimum of 43 and a maximum of 80. In the comparison group (group B), the sample means ($\overline{x}$) was 46.27 and the median (*Mdn*) was 47.00. Multiple modes were identified (*Mo*): 23, 40, 50, and 67. The standard deviation (*s*) and the variance (s^2) for the comparison (Group B) was 17.930 and 321.495, respectively. The range was 64, with a minimum of 13 and a maximum of 77.

	Posttest Group A	Posttest Group B
N	15	15
Means	58.73	46.27
Standard Means Error	3.035	4.630
Median	57.00	47.00
Mode	47	23[a]
Standard Deviation	11.756	17.930
Variance	138.210	321.495
Range	37	64
Minimum	43	13
Maximum	80	77

Note: [a.] There are multiple modes, *Mo*.

Table 4. *Descriptive statistics calculated from the scores obtained from the administration of the posttest.*

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The Shapiro-Wilk normality test was performed to determine the normality of the distribution of the scores from the pretest. For the experimental group (Group A), a significance value of .967 was obtained. For the comparison group (Group B), the obtained value was .843 (see Table 5). Because these results are higher than the significance level established by the research team, .05, it was determined that there were no statistically significant differences between the groups. Thus, the null hypothesis was retained. Likewise, Levene's test for equality of variances was performed. The significance level obtained for Levene's test was .297. Again, because the value obtained was higher than the significance value established by the researchers, .05, it was determined that there were no statistically significant differences between the groups. Therefore, the null hypothesis was retained. The results from these tests tend to indicate that, because there were no differences, the scores were normally distributed within the population, that the variances are homogenous, and that the population from which the different samples were drawn were equal.

Test	**Sig. Value**	
Shapiro-Wilk Normality Test	Group A	.967
	Group B	.843
Levene's test for equality of variances		.297

Table 5. *Results of Shapiro-Wilk normality test and Levene's test for equality of variances.*

6.2 Inferential results and statistics

The first hypothesis compared the sample means ($\bar{x}$) from the scores of the pretest administered to the experimental group (Group A) and the comparison group (Group B). The *t*-test provided a level of significance of .301, so the null hypothesis was retained (see Table 6). It was concluded that there were no statistically significant differences between the sample means ($\bar{x}$) obtained from the pretest scores in both groups. Because of this, it is assumed that, both groups were homogenous in terms of knowledge of the subject matter prior to the interventions. For the second hypothesis, a significance level of .032 was obtained after running the *t*-test to compare the sample means ($\bar{x}$) from the posttest scores obtained from both the experimental group (Group A) and the comparison group (Group B). Based on this result, the null hypothesis was rejected (see Table 6). It was concluded that the differences obtained were statistically significant. Moreover, a Cohen's *d* coefficient of 0.82 was obtained, to ensure that the Type I Error was minimized. This value represents a large effect size, meaning that the intervention carried out in the experimental group (Group A), the direct and explicit instruction of cognitive and metacognitive SRL strategies, had a greater effect on the academic achievement of seventh grade students in their science class than self-directed instruction. It was also possible to compare the sample means ($\bar{x}$) obtained from the administration of the pre and posttest within the same group. The third hypothesis compared the sample means ($\bar{x}$) from the scores obtained from the pre and posttest of the experimental group (group A). In this case, the results from the *t*-test (.112) indicated that the differences found were not statistically significant (see Table 6). Therefore, the null hypothesis was retained. A Cohen's *d* coefficient of 0.58 was obtained, which represents a moderate effect size. When the sample means ($\bar{x}$) were observed, it is noted that there were gains. However, these gains cannot be attributed to the intervention in and of itself. This finding could suggest that the complexity of the research design requires additional controls to be put into place, especially those related to the duration of the intervention and the teacher training phase. As for the fourth hypothesis, the *t*-test yielded a level of significance of .113 (see Table 6). Based on this result, the null hypothesis was retained, meaning that no significant differences were found. It was concluded that the intervention in the comparison group (Group B), self-directed instruction, had no effect on the academic achievement of the seventh grade students in their science class. When the sample means ($\bar{x}$) were observed, it is noted that there were no gains whatsoever between the administration of the pretest and the administration of the posttest.

Hypothesis	**Sample means ($\bar{x}$)**		***t* Test**
1	Group A (pretest): ($\bar{x}$), 51.33	Group B (pretest): ($\bar{x}$), 46.87	.301
2	Group A (posttest): ($\bar{x}$), 58.73	Group B (posttest): ($\bar{x}$), 46.27	.032
3	Group A (pretest): ($\bar{x}$), 51.33	Group A (posttest): ($\bar{x}$), 58.73	.112
4	Group B (pretest): ($\bar{x}$), 46.87	Group B (posttest): ($\bar{x}$), 46.27	.113

Table 6. *Sample means ($\bar{x}$) and t-test results for each of the four hypotheses.*

In addition to the administration of the pre and posttest, data were also collected from the responses provided by the participants in the comparison group (Group B) in their SRL strategy use logs. This instrument was administered on four occasions during the intervention in order to gather information on the use and frequency of the SRL strategies that were included as part of the intervention. It was observed that, according to the responses recorded by the participants, the strategies that were most frequently used were those that are part of their daily routine and those that did not require higher levels of cognitive and metacognitive ability (see Table 7). Hence, in general terms, participants reported engagement in learning activities that did not require a greater investment of time and effort than what they normally engage in on a day to day basis, such as: 1) paying attention to the observations of the teacher; 2) taking organized notes; 3) taking notes during class time; 4) keeping a record of their performance in their notebooks; 5) revising their work, and 6) using memorization techniques to study.

SRL strategies most frequently used	%
I paid attention to the observations of the teacher (M)	88
I took notes in an organized manner (C)	77
I took notes during class (C)	73
I kept a record of my performance in my notebook (M)	72
I revised my work (M)	67
I used memorization techniques (C)	50

Note: M refers to metacognitive strategies; C refers to cognitive strategies

Table 7. *SRL strategies most used by students according to strategy use logs (Group B)*

Contrarily, the strategies that were identified in the SRL strategy logs as being used less frequently were those that require a greater investment of time and effort on the part of students (see Table 8). They also require higher levels of cognitive and metacognitive development. The metacognitive strategies that the participants did not use frequently were: 1) correcting and improving their work, and 2) engaging in self-reflection of their work. By the same token, the comparison group participants (Group B) did not use higher order cognitive SRL strategies, such as: 1) using abbreviation techniques to study; 2) preparing illustrations, diagrams, drawing, graphs, tables, graphic organizers, and outlines; 3) using abbreviation techniques, rhymes, acrostics, acronyms, and acronym sentences to study; 4) reading the course material every day and practicing the class material out loud, and 5) consulting and studying with others.

SRL strategies used less frequently	%
I corrected and improved my work (M)	48
I engaged in self-reflection of my work (M)	47
I used abbreviation techniques to study (C)	43
I prepared illustrations, diagrams, and drawings of the material (C)	32
I prepared graphs from the material (C)	30
I consulted with others whenever I had doubts	27
I prepared tables from the material (C)	25
I prepared graphic organizers from the material (C)	22
I prepared outlines from the material (C)	18
I made acronym sentences from the material (C)	17
I made acronyms from the material (C); I practiced the material out loud (C)	15
I studied with other people; I made rhymes from the material (C)	13
I made acrostics of the material (C)	12
I read the course material every day (C)	8

Note: M refers to metacognitive strategies; C refers to cognitive strategies

Table 8. *SRL strategies less used by students according to strategy use logs (Group B)*

In both groups, participants were given the opportunity to evaluate the student manual in two different ways. First, they evaluated each of the topics included in the manual, and secondly, they provided an overall evaluation of the student manual as a learning resource. With regards to the topics covered in the manual, significant differences can be observed between the responses of the participants in the experimental group (Group A) and those provided by the participants in the comparison group (Group B). The participants from the experimental group (Group A) considered that the topics were important (96%) and that the information helped them in their studies (88%). They also expressed that the information was presented in an organized manner (90%) and that the activities were clear (84%). Finally, 91% of the participants from the experimental group (Group A) reported that they learned about the topics presented in the student manual (see Table 9). The participants in the comparison group (Group B) reported less exposure and less interaction with the student manual. Although most of them considered the topics important (81%), only 46% thought that the information helped them in their studies; 58% considered that the information was presented in a clear manner, and 53% thought the activities were clear. Only 46% reported learning about the topics contained in the manual. It is worth noting that, in the comparison group (Group B), some participants did not provide answers in certain instances. They expressed that they did not feel comfortable providing an answer because they had neither read the information, nor tried to complete the activities in the manual.

Criteria	**Group A (%)**		**Group B (%)**		
	C	**P**	**C**	**P/NC**	**NR**
The topics are important.	96	4	81	5	14
The information helps me in my studies.	88	12	46	23	31
The information was presented in an organized manner.	90	10	58	12	30
The activities were clear.	84	16	53	16	31
I learned about the topic.	91	9	46	24	30

Note: *C, Complies; P, Partially complies; NC, Does not comply; NR, Did not respond.*
N=30: Group A, *n*=15; Group B, *n*=15

Table 9. *Results for the evaluations on the topics covered in the student manual.*

The difference in terms of the exposure and interaction with the manual between groups is further confirmed by the overall evaluations on the student manual administered to the participants (see Table 10). In the experimental group (Group A), 80% of the participants read the manual, and 73% had a chance to work on the exercises, whereas in the comparison group (Group B) the results were 20% and 40%, respectively. Most of the participants in the experimental group (Group A), considered that the information helped them

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in their studies, whereas 67% reported that they understood the information contained in the manual. However, of the 15 participants in the comparison group (Group B), only 54% indicated that the information helped them in their studies, and 40% expressed that they understood the information in the manual. Again, these results show that the participants in the experimental group (Group A) had more exposure to and interaction with the SRL strategies when compared to the participants of the comparison group (Group B). Finally, when asked if they would recommend the manual for other students to use, 87 % of the participants from the experimental group (Group A) expressed that they would recommend the manual, as opposed to only 73% from the comparison group (Group B).

Criteria	% Group A	% Group B
I had the chance to read the manual.	80	20
I had the chance to work on the exercises.	73	40
This information helps me in my studies.	87	53
I understood the information in the manual.	67	40
I would recommend this manual for other students to use.	87	73

N=30: Group A, *n*=15; Group B, *n*=15

Table 10. *Results for the student manual evaluations.*

10. Conclusions

Growing concerns in Puerto Rico over the low performance levels in the middle school science standardized test call for the identification of methods that have the potential to improve academic achievement. A study was designed in order to determine if teaching cognitive and metacognitive SRL strategies had an effect on the academic achievement of seventh grade students in the science class. The study used an experimental design with a pre and posttest and comparison group. The two interventions were: a) the direct and explicit instruction of cognitive and metacognitive self-regulation strategies in the experimental group (Group A), and b) self-directed learning in the comparison group (Group B). SRL has been hailed as a viable process to improve academic achievement in a variety of educational scenarios. The development of self-regulation abilities through the instruction of cognitive and metacognitive strategies promotes self-directed strategic students that are proactive and independent learners (Davis and Nietzel, 2011; Vassallo, 2011). Studies on self-regulation suggest that there is a positive correlation between self-regulation levels and academic achievement, and that high SRL is a predictor of academic success (Germeroth and Day-Hess, 2013; Nilson, 2013; Kumi-Yeboah, 2012; Zimmerman and Schunk, 2011; Schunk and Usher, 2011; Moos, 2011; Zumbrunn, Tadlock, and Roberts, 2011; Tuckman and

Kennedy, 2011; Kistner, Rakoczy, Otto, Dignath, Büttner, and Klieme, 2010; Peters and Kitsantis, 2010; Eilam, Zeidner, and Aharon, 2009; Zimmerman, 2008). Therefore, cognitive and metacognitive self-regulation strategies can be and should be incorporated as part of the teaching-learning process.

The cognitive strategies considered in this study were related to how students study and learn the information provided in the seventh grade science course, strategies for the management and organization of information, and strategies for the interpretation and the representation of information. The metacognitive strategies considered were related to self-monitoring, self-evaluation, self-reflection, and teacher feedback. Both the experimental group (Group A) and the comparison group (Group B) had access to the learning resources and activities developed for the study. The intervention in the experimental group (Group A), the direct and explicit instruction of cognitive and metacognitive SRL strategies, is a method of instruction that presents itself as a viable alternative to improve academic achievement, especially for middle school students. The intervention in the comparison group (group B), self-directed instruction, presupposes that students have highly developed cognitive and metacognitive skills along with high levels of motivation and self-efficacy.

With regards to the first hypothesis, results from the Shapiro-Wilk normality test and Levene's test suggest that there were no significant differences between the sample means ($\overline{x}$) from the scores of the pretest of the experimental group (Group A) and the comparison group (Group B). The null hypothesis was retained, which means that the sample was normally distributed and homogenous. The second hypothesis compared the sample means ($\overline{x}$) from the scores obtained from the posttest of the experimental group (Group A) and the comparison group (Group B). The significance level obtained from the *t*-test was lower than the significance level established by the research team. Thus, the null hypothesis was rejected. According to these results, the intervention in the comparison group (Group A) had a greater effect on the academic achievement of the seventh grade participants in science and was more effective than the intervention in the comparison group (Group B). This result confirms the results of other studies that have found that the direct and explicit instruction of SRL strategies can improve the academic achievement of students (Kistner, Rakoczy, Otto, Dignath, Büttner, and Klieme, 2010; Eilam, Zeidner, and Aharon, 2009). Therefore, when students are exposed to SRL strategies and presented with the opportunities to interact with and use these strategies, they are in a better position to increase their academic achievement as opposed to allowing them to develop the strategies on their own without necessarily being ready to do so.

The third hypothesis compared the sample means ($\overline{x}$) obtained from the scores of the pre and posttest administered to the experimental group (Group A). According to the results, the null hypothesis was retained. Upon calculating Cohen's *d*, it was determined that the effect of the intervention was moderate, which leads to conclude that, although there was a moderate effect suggesting that the intervention was effective, it was also quite probable that greater controls needed to be put into place in order to observe a greater effect as a result of the intervention. The fourth hypothesis compared the sample means ($\bar{x}$) obtained from the pre and posttest administered to the comparison group (Group B). According to the results from the *t*-test, the null hypothesis was retained, and it was concluded that the intervention provided to the comparison group (Group B), self-directed learning, had no effect on the academic achievement of the seventh grade students. Therefore, it was deemed as not effective when compared to the direct and explicit instruction of cognitive and metacognitive SRL strategies.

The participants in both groups also completed evaluation forms. The results provide evidence to sustain that the participants in the experimental group (Group A) were exposed to and interacted with the SRL strategies to a greater degree when compared to the comparison group (group B). This data reaffirms the conclusion that when seventh grade students are exposed to and given the opportunity to interact with SRL strategies through a variety of activities and tasks that are incorporated into the educational process in the science class, it is possible to observe an increase in their academic achievement. Under the guidance of the teacher, the participants in the experimental group (Group A) read the student manual, worked on the activities, and understood the information on cognitive and metacognitive strategies. The comparison group participants (Group B) reported only a limited amount of interaction with the student manual. Thus, it is possible to conclude that, when complemented with additional educational resources that integrate SRL opportunities, the direct and explicit instruction of SRL strategies helps improve academic achievement. On the other hand, a limited exposure to and little to no interaction with SRL strategies may account for the fact that the impact of the intervention in the comparison group (Group B) on academic achievement was not observed.

The results of the strategy use logs completed by the participants in the comparison group (Group B) reinforce these conclusions. According to the responses, it was evident that there was limited use of the strategies in the comparison group (Group B), there was limited exposure to the strategies and, for the most part, participants were not inclined to invest the time and effort towards learning. The strategies used in the comparison group (Group B) were identified as the basic strategies that students ordinarily implement to get by on a day to day basis, such as: note taking, recording their test results, and memorization techniques. Most reported that they did not engage in the use of the SRL strategies that require a high level of cognitive and metacognitive development. These results suggest that in self-directed learning, much depends on the initiative of the student and the ability to effectively use SRL strategies in order to observe an effect on academic achievement, effect that was not observed in the comparison group (group B). It was evidenced that the direct and explicit instruction of cognitive and metacognitive SRL strategies has a greater effect on the academic achievement of seventh grade students in their science class than self-directed learning. Moreover, self-directed learning has no significant effect on academic achievement unless the student exhibits a high degree of cognitive and metacognitive development. Also, teachers play an essential role in the development of cognitive and metacognitive abilities in students, particularly when reinforced through effective modeling techniques. This, in turn, depends on teacher training programs that promote modeling as part of the instructional process, the development of educational resources, and the use of effective feedback systems to strengthen metacognition in students. Finally, it is possible to develop a profile of the characteristics of students that are self-regulated and that exhibit high levels of cognitive and metacognitive development. The adoption of SRL-based educational scenarios imply: 1) the development of pertinent learning materials that include SRL strategies; 2) the development of instruments, activities, and learning tasks based on SRL; 3) teacher training programs on effective modeling techniques; 4) the adoption of SRL strategies as part of the curriculum, and 5) access to opportunities for the development of SRL strategies.

Recommendations can be made for the field of education and for future studies. For the field of education, it is important to observe that SRL appears to be a viable tool to deal with the problem of low academic achievement in the seventh grade science course. Therefore, the adoption of the direct and explicit instruction of cognitive and metacognitive strategies as part of the seventh grade science curriculum and instructional process through the establishment of public policy, the identification of educational resources, and the allocation of financial resources to enable and facilitate teacher-training programs is recommended. These programs should emphasize effective modeling of cognitive and metacognitive strategies, lesson planning based on SRL strategies, the development of SRL activities in the classroom, and effective feedback techniques. For future investigations, other teaching models and methods that explore SRL should be considered. Also, it is possible to carry out studies with different designs that incorporate greater controls in terms of teacher training, the time allotted to the interventions, the experimental design itself, and the inclusion of students in the validation of instruments, among others. Finally, the use of other research methodologies is to be considered.

In conclusion, self-regulation is the process through which learners transform their mental abilities into academic performance skills (Zimmerman, 2010). This study explored the effect of cognitive and metacognitive self-regulation strategies as seen from the perspective of an active, dynamic process that can be maximized to improve academic achievement. The development of cognitive and metacognitive abilities is strengthened by putting in the time and the effort, and through effective models that incorporate SRL strategies as part of the instructional process. With the challenges brought on by contemporary educational scenarios, the direct and explicit instruction of cognitive and metacognitive SRL strategies presents itself as an effective tool to attend to the academic needs of the seventh grade student in the science class, in order to learn to learn, especially as part of the skills that are emphasized for success in the 21st century.

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