How Should Students Learn in the School Science Laboratory? The Benefits of Cooperative Learning

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Abstract

Despite the inherent potential of cooperative learning, there has been very little research into its effectiveness in elementary school laboratory classes. This study focuses on an empirical comparison between cooperative learning and individual learning in the school science laboratory, evaluating the quality of learning and the students' attitudes. The research included 67 seventh-grade students who undertook four laboratory experiments on the subject of "volume measuring skills." Each student engaged both in individual and cooperative learning in the laboratory, and the students wrote individual or group reports, accordingly. A total of 133 experiment reports were evaluated, 108 of which also underwent textual analysis. The findings show that the group reports were superior, both in terms of understanding the concept of "volume" and in terms of acquiring skills for measuring volume. The students' attitudes results were statistically significant and demonstrated that they preferred cooperative learning in the laboratory. These findings demonstrate that science teachers should be encouraged to implement cooperative learning in the laboratory. This will enable them to improve the quality and efficiency of laboratory learning while using a smaller number of experimental kits. This saved expenditure, together with the possibility to teach a larger number of students simultaneously in the laboratory, will enable greater exposure to learning in the school science laboratory.

Introduction

The integration of experiments in science learning is a key component in the teaching of sciences in schools (Olufunke 2012), and is standard practice from early childhood and the elementary grades through the end of high school. In Israel, high school students in science tracks undergo individual examinations that require them to plan and execute laboratory experiments. The implementation of experiments intends to promote active learning and experience of scientific research and to enhance the motivation to study the sciences (Hofstein & Lunetta 2004). It has also been argued that laboratory experience helps to develop technical and cognitive skills, such as scientific thought and exploration, and promotes a better understanding of the essence of science (Wang et al. 2014).

The activation and equipping of a school laboratory and the training of teachers demand the allocation of substantial resources not required by other forms of academic study. In many schools, science lessons for large classes (of 30-40 students) typically involve the division of the class, so that half the class go the laboratory at any given time. This naturally halves the number of laboratory lessons. One solution to this is the use of virtual laboratories employing computer technologies. However, this type of learning does not secure the goal of actual experimentation and the practical performance of experiments. Another solution is to perform the laboratory experiments in groups of 4-6 students, while cutting the costs of the experimental kits and exhaustible materials. This also allows the holding of a larger number of laboratory lessons without the need to divide the class.

Despite the advantages of cooperative learning in groups, as frequently noted in the research literature, it is difficult to find any empirical studies indicating the effectiveness and advantages of cooperative learning in the elementary school science laboratory. Moreover, some science teachers remain unconvinced regarding the effectiveness of executing experiments (planning, execution, and reporting) in groups, and even oppose such a practice for various reasons (Clyde 1998). This highlights the questions surrounding this form of learning. Accordingly, in this study we sought to examine whether the standard of learning in small learning groups in the school science laboratory is inferior to individual learning, and to study the students' attitudes toward collective and individual learning in the science laboratory.

Review of the Literature

Cooperative Learning

Cooperative learning is a form of active learning characterized by small learning groups of two to six students, where learning is undertaken and managed by all the members of the group (Springer, Stanne & Donovan 1999). This learning has been examined in the context of numerous age groups and disciplines, including mathematics, technology, and engineering (Leikin & Zaslavsky 1999), foreign language studies (Alghamdi & Gillies 2013), the exact sciences (Aydin 2011; Lord 2001) and earth and social sciences (Chun-Yen & Song-Ling 1999; Scheuerell 2010).

Cooperative learning includes mutual listening, particularly in lessons involving self-expression and language study (Han, 2015), and the exchange and sharing of knowledge, either directly (Leikin & Zaslavsky 1999) or by means of various computer technologies (Lou, Abrami & d'Apollonia, 2001). Cooperative learning is also the foundation for challenging and meaningful study using the problem based learning method (Nicholl & Lou 2012) and using project-based learning (Piccinini & Scollo 2006).

In light of the diverse possibilities and approaches to cooperative learning in small groups, Leikin and Zaslavsky (1999) defined the main characteristics of this learning: The students are mutually dependent in their cooperative work; the learning environment offers the students equal opportunities for mutual cooperation relating to the learning tasks and encourages them to communicate; every member of the group is responsible for contributing to the group work and is committed to the group learning process; and the learning environment is structured in a manner that facilitates the above-mentioned requirements. Merely creating the groups is not sufficient to ensure cooperative learning. The teachers must structure the learning plan and the learning environment on the basis of the above-mentioned characteristics.

Most of the research into cooperative learning is based on the theory proposed by Vygotsky (1978), who argues that learning entails the internal structuring of external social activities. This structuring comprises three processes. First, the students learn to adopt symbols and signs that others use to describe processes, while executing actions such as attention, logical reasoning, and conceptualization. Next, ideas and perceptions expressed by others are internalized on the personal level. Lastly, a transformation takes place so that external actions become internal; this happens by means of long-term mental developmental processes. Thus, accordingly to Vygotsky, cooperative learning clearly offers added value, since the mutual social interaction it entails builds additional cognitive abilities that are not structured to the same extent by other forms of learning.

Most of the studies reflect clear advantages to cooperative learning in small groups, both for the individual learner and in terms of group achievements as apparent in the review of Lou, Abrami and d'Apollonia (2001). The chief characteristic of this type of learning is not necessarily the fact that it takes place in a small group, but rather the ramifications of this fact – i.e. the manner in which it permits proactive learning undertaken by the members of the group, in a setting where each of the participants can express themselves and their own capabilities (Emmer & Gerwels 2002; Hsiung 2012). In some cases the students act in the role of a teacher, sharing their knowledge and insights with their peers (Leikin & Zaslavsky 1999). Benefits include enhanced academic achievements (Hsiung 2012) and stronger commitment as well as personal and group responsibility among the students during the learning process (Emmer & Gerwels 2002).

In the context of the demands of the contemporary job market, the importance of these advantages is amplified (Strommen 1995). Group learning has been found to be efficient in developing such skills as team work, problem solving, and the ability to manage controversial issues efficiently inside and beyond the work group. Cooperative learning has also been found to have advantages in creating a calm and interesting study environment and in reducing tension and anxiety among students. An improvement has also been found in concentration, attentiveness, and in the interpersonal relationships among the students and between the students and the teacher (Han 2015).

Although cooperative learning is considered a major success story, as reflected in numerous studies (Johnson & Johnson 2009), its implementation in schools appears to be relatively limited by comparison to frontal learning, which still plays a very central role (Lv 2014; Mehta & Kulshrestha 2014). Cooperative learning requires the preparation, coaching, and training of the teaching staff. Many teachers find it difficult to change their teaching approach and to make the transition from teaching an entire class to guiding small groups. There is also a need to amend and adapt the curricula, develop forms of practice, and prepare appropriate tests for the group (Clyde 1998). These requirements entail extensive investments of time and resources, a factor that deters teachers from adopting this teaching method. Additional reasons may discourage teachers from adopting this method: teachers are concerned that they will lose control over the class as a whole; fear that they will not manage to complete the planned study content; uncertainty regarding how to evaluate and grade the individuals within the group; and sometimes a fear of negative reactions from the students to this type of learning process (Clyde 1998).

Individual Learning

Despite the emphasis in educational research on the advantages of cooperative learning, Yadin and Or-Bach (2010) argue that this success must be based on the presence of individual capabilities that can be developed through individual learning alone. Individual learning recognizes that each learner has their own unique character. It does not include elements of interaction with other learners, and precisely for this reason it promotes internal motivation, autonomy, and independence on the part of the learner (Yadin & Or-Bach 2010). Studies have emphasized the contribution individual work makes to the quality of learning, emphasizing that cooperative learning often loses its functionality, whereas individual learning can enhance the learner's interest and curiosity (Hsiung 2012). In the absence of careful preparations, including the development of adapted learning strategies and the coaching of teachers, cooperative learning is liable to lead to disappointing results. Conversely, it has been found that detailed feedback and support for the learners can create a clear advantage for individual study employing advanced technologies (Lou, Abrami & d'Apollonia 2001). Moreover, although the overall achievements of cooperative learning may be high, this is not necessarily the case regarding each individual in the group. Heterogeneity in the group may lead to vague and irrelevant work, and even to a situation where certain students are passive to the point of sitting and doing nothing (Wolf & Fraser 2008) – something that does not happen in individual learning.

In well-planned individual learning, the learners assumed greater responsibility, developed independent and autonomous learning, and demonstrated strong work and exercise habits; the learners themselves were aware of the advantages of individual learning (Yadin & Or-Bach 2010). When learning is well planned, cooperative learning is not necessary found to be preferable to individual learning (Cavalier & Klein 1998). These arguments highlight the need to examine the quality of cooperative learning by comparison to individual learning, as undertaken in the current study.

Cooperative Learning in the School Science Laboratory

There is general consensus regarding the need for a science laboratory as a vital and integral part of the process of science teaching (Bordenstein, Brothers, Wolfe, Bahr & Minckley 2010; Olubu 2015). Learning through investigation in the science laboratory helps to develop students' skills such as critical thought, problem solving, analysis, synthesis, and an understanding of the scientific method (Hofstein & Lunetta 2004). No less important, however, is that laboratory work has been found to promote such non-cognitive parameters as curiosity, interest, self-confidence, satisfaction, perseverance, cooperation, interpersonal communication, and a love of science (Hofstein & Lunetta 2004). Despite this, there are relatively few empirical reports examining the laboratory learning approach in general, and the effectiveness of cooperative learning in school science laboratories, in particular. Aydin (2011) undertook a comparison between cooperative learning in small groups and individual learning in a science laboratory for university students. He found that cooperative learning was significantly more effective in promoting academic knowledge, familiarity with the laboratory equipment, and the development of a positive approach to laboratory studies. Keys (1996) examined the ways in which cooperation and verbal discussion in laboratory work by pairs of ninth-grade students influenced the standard of their laboratory reports. She found a correlation between the positive social interaction between the students and an improvement in their cognitive capabilities.

Group learning in the laboratory creates opportunities for different interactions between students: negotiation, observation of the ways others solve problems, and the use of scientific language to represent scientific ideas and promote science learning (Keys 1996; Olubu 2015). The interaction between the students during the performance of laboratory work, in order to formulate complex explanations in the research summary or the laboratory report, is a constructive component that entails processes such as the detailing and expansion of text, as well as explanation and elaboration. Keys (1996) indeed reports that mutual discussions between the pairs of students during the drafting of the laboratory report enabled the students to present and reflect connections between ideas, engage in discussions and present their arguments, and thereby played an important role in developing the students' perceptions and ideas. Thus cooperative work in the science laboratory can be highly effective in promoting individual learning. Team work in the laboratory that includes joint discussions and writing, creates opportunities for the individual to observe and practice higher thinking skills through the use of verbal, visual, and mathematical symbols, and to engage in problem solving. All these constitute components of active and experiential learning, something that has been found to be vital to high-quality learning (Springer, Stanne, & Donovan 1999).

In addition to the direct advantages for learning, cooperative learning in the laboratory also offers advantages in economic terms. The need to prepare a smaller number of experimental kits means that cooperative learning in the laboratory can cut costs and allow teachers to offer a greater number of laboratory lessons.

Since cooperative learning is not generally employed in science lessons in school laboratories, for the reasons discussed above (Clyde 1998), the present study addressed this concern, which has seldom been investigated. It examined whether the standard of learning in small groups is inferior to individual learning in terms of learning outcomes. We also examined what the students themselves think about individual and cooperative learning in the laboratory, after they experienced both types of learning. The students were asked how much they enjoyed each of the two methods of learning used in the laboratory and about their level of satisfaction and understanding. We regarded all their responses as the students' attitudes. The research questions were:

1. What are the differences between the grades for the group laboratory reports and the grades for the individual reports?
2. What is the character of the differences between the group and the individual reports in terms of the level of detail of the answers, the number of grounds quoted, and the number of approaches or solutions proposed?
3. What are the students' attitudes regarding cooperative learning as compared to individual learning in the laboratory?

Methodology

Research Population

The research population comprised 67 female students aged about 12 years from two seventh-grade classes (one class had 33 students and the other 34 students). The students attended a Jewish religious school for girls in the Southern District of Israel. The students' socioeconomic level was average and both classes were heterogeneous in terms of learning levels. The students planned, executed, and reported on four laboratory experiments, some in groups and others on an individual basis.

Research Tools

1. The experiment reports: The structure and questions in the four reports were taken from the textbook "The Nature of Matter," Bar Ilan University, Bonus Publishing (in Hebrew) on the subject of the measurement of the volume of solids of defined and undefined shapes and of liquids in various vessels. In each of the four experiments, the students were given a research problem relating to the measurement of volume and were required to plan the measurement method, propose measurement tools, describe the measurement method and results, and draw conclusions. The reports also included summarizing questions the students were required to answer, such as proposals for measuring the volume of differing quantities of liquid or of other bodies with different shapes. The four experiments are described in the appendix.
2. Attitude questionnaire: A five-point Likert scale questionnaire (where 5 represents the maximum level of agreement and 1 the minimum level of agreement) relating to the method of learning in the laboratory. The questionnaire was based on the questionnaires on cooperative learning as used in the study of Pan and Wu (2013), and on individual learning as used in the study of Yadin and Or-Bach (2010). The questionnaire included a total of 23 questions: 10 pairs of identical questions relating to group learning and individual learning (a total of 20 questions); and three additional questions relating solely to cooperative learning. The questions addressed the benefit of the learning approach to learning, understanding, and drawing conclusions, and the level of interest, enjoyment, and satisfaction with the learning method. The main adjustments made to the questionnaire were the focus on laboratory learning (as opposed to English or computer familiarization studies). All the questions included in the questionnaire are presented in the results section. The overall reliability of the questionnaire was $\alpha=0.76$.

The Research Method

The research was conducted over a period of approximately six weeks during which the two seventh-grade classes studied with the same teacher. The teacher has approximately 10 years' experience in science teaching, and participated in the research as part of her studies toward a master's degree in science teaching. The teacher had not previously engaged in group teaching in the laboratory, and from her perspective this study examined a tangible need. She taught the subject of "volume", including the definition of the concept of volume; instruments for measuring volume; volume measurement units; everyday uses; and methods for measuring volume in various states. After the teacher taught the theoretical basis in the classroom, the students were asked to plan and conduct four experiments in the laboratory, each lasting 45 minutes. Experiment no. 1 was performed by four groups (including a total of 16 students) and by 46 students working individually. Experiment no. 2 was performed solely in groups – 21 groups with a total of 67 students. Experiment no. 3 was performed by 4 groups (16 students) and 42 students working individually. Experiment no. 4 was performed by 16 groups with a total of 60 students. Accordingly, the number of students who planned and conducted experiments on an individual basis was 88, while the number of students who planned and conducted experiments on a group basis was 160. The total number of group reports was 45 – the same as the number of groups.

Of the four experiments, two were performed by each individual either alone or in a group (experiments 1 and 3), while the other two were performed solely in groups (experiments 2 and 4). Each group comprised four students; the teacher determined the composition of the groups on the basis of social and pedagogical considerations. While conducting the group experiments, the teacher encountered specific difficulties unique to this method. For example, the discussions and arguments within the groups were productive but took a relatively long time. The teacher was obliged to shorten the discussions and allocate limited time. Another problem was that every member of the group wanted to experience performing the experiment by themselves. Accordingly, the teacher imposed a rotation, whereby each student performed a specific part of the activity. Thus each student experienced both individual work (in at least one experiment, and 63 percent of the participants performed two experiments on an individual basis), as well as group work in 2 or 3 experiments. The students completed a structured experiment report received at the beginning of the lesson and submitted this to the teacher at the end of the laboratory class.

After conducting all four experiments, the students completed the questionnaire about learning in the laboratory, almost all of whose questions were presented in a parallel manner regarding individual and cooperative work.

Analysis of the Findings

1. The experiment reports were examined in two stages. In the first stage, all the individual and group reports were examined (a total of 133 reports) using a uniform indicator in which a constant maximum score could be awarded for such components as the accuracy of the definition of the experiment goal; the experiment method; the hypothesis; the description of the result; and the conclusions for each experiment, as well as the accuracy of the answers to the questions presented in each experiment. The average of all the scores was calculated for the four reports using each of the study methods in the laboratory. In the second stage, a textual analysis was undertaken of 108 reports written both individually and in groups. The reports that were textually analyzed were from experiments 1 and 3. The textual analysis of 88 individual reports and 20 cooperative reports was undertaken according to three criteria: 1) Content: the level of detail of the answers, the richness of the text, and the number of grounds presented. 2) The number of solutions offered to the problems presented. 3) The standard of organization and presentation of the text. This analysis enabled an assessment of the richness of verbal expression, the depth of understanding and conceptualization of the study topic, and the ability to organize and present the information.
2. The averages and standard deviations were calculated for each of the questions in the attitude questionnaire. A paired t test was undertaken between the 10 pairs of questions comparing individual and group work in the laboratory.

Findings

Learning Method and Grades

The grades awarded to the reports in accordance with the indicator reflected the students' ability to report correctly on the experiment and to complete all the sections of the report properly. A maximum grade reflected proper planning of the measurement, correct results, accurate drawing of conclusions, and correct answers to the questions. Table 1 presents the average grades for the individual and group laboratory reports. As can be seen, the average grade for the cooperative reports was 14 points higher than the average for the individual reports (87.52 compared to 73.02). This difference was found to be statistically significant.

Show Table 1 here.

Textual Analysis of the Experiment Reports

In terms of content, almost all the cooperative reports included long texts. The sentences were more detailed and precise, while only half the individual reports included long sentences with a similar number of words. Approximately half the short individual reports did not include all the details of the structure and stages of the experiment, or did not state all the goals of the experiment. Moreover, the description of the findings and the method of conceptualization were short, while the cooperative reports generally included more grounds or more detailed explanations of the problem solving. The following example relates to the calculation of the volume of a cube and cuboid – experiment 1:

> Group report: "Method 1: Length of cuboid: 2 cm. Width of cuboid: 6 cm. Height of cuboid: 2 cm. Volume of cuboid: 2x2x6 = 24 cu.cm. Calculation by method 2: length, width, and height of the cube: 2 cm. Volume of the cube: 2x2x2 = 8 cu.cm. Volume of the cube: 3x8 = 24 cu.cm."
>
> Individual report: "Result: The volume of the cube is: 6x2x2 = 24 cu.cm."

A further example: In experiment 3, the students were asked to state the goal of the experiment (they were only given a general name of the experiment and were asked to define the goal and to propose the measurement method and tools). Most of the group reports included a more precise and detailed wording of the goal of the experiment, by comparison to the individual reports. For example:

> Group report: "We want to examine whether the volume of liquid is constant and whether it changes when it is moved from one container to another."
>
> Individual report: "Is the volume of liquid constant?"

As mentioned prior, the students were also asked to describe the method of experiment 3. The vast majority of the group reports included a full and detailed description, whereas only half (44) of the individual reports included the required description of the experiment method. For example:

> Group report: 1) "We pour the water from the conical bottle into the measuring cup and write down the volume. 2) We pour the water into the chemical cup and measure the volume of water by transferring to the measuring the cup. 3) We write down the volume of the water."
>
> Individual report: "Pour water into a first vessel and then measure, and into another vessel and see."

The conclusions phrased in the group reports were also more detailed in most cases. The following example from experiment 3 relates not only to volume, but also to the shape of the liquid:

> Group report: “Our conclusions from the experiment are that the volume of water does not change when it is moved from one container to another – the volume of water is constant, but the shape of the liquid changes according to the shape of the container. The best measurement tool for measuring volume is the measuring cup.”
>
> Individual report: “The volume of the water does not change.”

It is important to note that some of the individual reports included detailed conclusions, such as the example below. However, the frequency of such conclusions was about half that of the group reports:

> Individual report: “The volume of the liquid does not change from one container to another, each container according to its shape, for example if the container is narrow and tall, then the liquid will appear taller, but the volume will be the same as in a wide container in which the liquid will reach a lower height. The volume of the liquid is constant.”

In terms of the organization of the text, we found that the cooperative reports showed a higher level of organization of the data. In some of the reports, the data were presented in tables or clarified by means of arrows. This level of organization was not found in the individual reports.

An example of the presentation of the solution in a group report by means of arrows:

“A.2 x 2 x 2 = 8 cu.cm. volume of one cube.

Length width height

B. 3 x 8 = 24 cu.cm. volume of three cubes.

Volume of one cube x number of cubes”

Another example illustrates the use of a table in the students’ report:

“Result:

Length	Width	Heig ht	Volume of cuboid
2 cm	6 cm	2 cm	2x2x6 = 24 cu.cm.

“

A further finding in the study suggests that cooperative work was more beneficial than individual work in terms of the ability to develop and implement different solutions to the problems presented to the students. The following examples from a group and individual report relate to finding solutions for calculating the volume of a cuboid:

> Group report: 1) Using a ruler, we measure the width, length, and height of the cubes. 2) We write down the measured data in the result. 3) We calculate the volume of each cube and add the results to get the volume of the whole cuboid. 4) There is also another way: we put the cubes together and then use a ruler to measure the length, width, and height, multiply them, and the result obtained is the volume of the cuboid.

> Individual report: We take the cube and measure the length and then multiply this by the width and then multiply by the height, and the result is the volume of the cube.

Attitudes toward Cooperative and Individual Learning in the Laboratory

The attitude questionnaire was given to all the students who participated in the study, all of whom experienced both types of learning in the laboratory – individual and group. Each question (with three exceptions) related to group work and was accompanied by an identical question relating to individual work. As the results in Table 2 show, in all the questions, without exception, the students expressed a strong and statistically significant preference for group work over individual work. This preference was evident in different aspects of learning. The students felt that group learning benefited them more in terms of understanding the study subject (statements 1,2,6); in terms of their enjoyment and interest (statements 4,7,8,9); and in terms of general satisfaction with the learning method (statements 3,5,10). In the statements that were only relevant to group work, and that examined cooperation and the benefit of group discussion to learning (statements 11,12,13), the students gave high scores showing that they prefer group work. Despite the unequivocal overall picture, it is important not to ignore the data for statistical deviations. The relatively high standard deviation scores for most of the questions reflect heterogeneity and variance among the students. Some of the students evidently had an opposite preference, or did not have a clear preference for either learning method.

Show Table 2 here.

Discussion

The main objective of this study was to compare cooperative and individual learning in an elementary school science laboratory. Our study found that the cooperative work in groups was superior to individual work, both in terms of cognitive achievements as reflected in the students' laboratory reports and in terms of the students' positive attitudes. The analysis of the reports showed that the group work led to more accurate and better explained planning for solving the problem. The written content of the report was more precise, complete, and detailed. The text included richer content, the explanations were more extended, and more than one solution was suggested for the problems. The level of organization of the data was also high. The laboratory reports suggest that group work was more successful in promoting stronger abilities on the students' part to summarize and organize the experiment method in writing. These findings are consistent with previous studies that are relatively unanimous in their conclusion regarding the advantages of group learning for teaching (Johnson & Johnson 2002; Johnson 2014; Springer, Stanner & Donovan 1999). Our findings also expand on the findings of Aydin (2011) regarding the effectiveness of collective leaning in science laboratories. By means of knowledge tests, Aydin drew conclusions concerning the effectiveness of collective learning in developing academic knowledge and in fostering familiarity with laboratory equipment. However, our study differs from Aydin's in two key respects. Firstly, we examined elementary school students, whereas Aydin focused on university students. Secondly, Aydin found that collective learning contributes to knowledge, whereas the present study used textual analysis and the evaluation of the reports to show that such learning is also effective in developing and encouraging an understanding of a complex abstract concept (volume), as reflected in the learning outcomes. In addition, the collective outcomes showed a greater ability to cope with new issues relating to this concept and to identify more solutions to the calculation problems presented to the students.

It has already been reported that the fact that students were part of a work team that engages in discussion for the purpose of problem solving, while the members of the group assume responsibility, enhanced their thinking and problem-solving capabilities (Emmer & Gerwels 2002).

At the same time, we must note the importance of individual learning, which can develop vital abilities such as autonomy and personal responsibility in the learner (Yadin & Or-Bach 2008; Wolf & Fraser 2008). The present study did not examine these abilities. Neither should we ignore reports suggesting difficulties and problems in group learning, particularly due to the heterogeneity in terms of abilities and learning motivation among the members of the group (Hsiung 2010; Hsiung 2011). The possibility has also been noted that individuals may evade responsibility and refrain from investing in group learning (Yadin & Or-Bach 2010). In our opinion, therefore, it is important to take into account that heterogeneous classes should also take advantage of individual learning and include this method in some of the experiments in the science laboratory. The difficulties inherent in cooperative teaching should also not be overlooked. Learning in groups takes more time, as claimed by the teacher in the current study. Group discussions can grow protracted. In order to meet the objectives of the lesson, the teacher must plan every stage carefully and allocate time to each activity. Teachers also find it difficult to guide every group and to monitor the learning of individual students Teachers must cope with communication problems and tensions within a group and with the sense of loss of control over the class. All these factors may explain why many teachers are afraid of cooperative learning, as shown in Clyde's study (1998).

There has been very little attention in the research literature to examining what the students themselves think about cooperative learning (Köse, Sahin, Ergün & Gezer 2010). We examined which type of laboratory learning – cooperative or individual – was preferred by the students and were surprised by our strong and unequivocal findings. Most of the students were not only more satisfied and enjoyed group work more, but also believed that it was of greater benefit to their understanding of the subject and enabled them to develop skills in cooperative work. The satisfaction of learners in the science laboratory is an important factor in encouraging positive attitudes toward science studies in general among young learners (Shumow, Schmidt & Zaleski 2013). Work in the science laboratory in itself stimulates interest and enjoyment (Wang et al. 2014). The students' satisfaction as identified in this study can reinforce and strengthen their positive approach to science as a school subject.

It is important to emphasize that this study was undertaken regarding a small number of girl students in an elementary school, with a small number of laboratory experiments, and over a short period of time. Accordingly, it is difficult to generalize from the findings. Moreover, the fact that this trial was undertaken with a group comprised solely of girls, who have different social patterns to boys, may mean that it does not represent mixed classes. Further studies will certainly be needed in order to examine the stability of our findings, but if these are indeed corroborated, it has important pedagogical ramifications. At the same time, we should recall that cooperative learning may not be suited to certain students (Hsiung 2010; Hsiung 2011). Some students might be left behind during group working, while others benefit and make progress. Moreover, since different teaching methods have different advantages (Yadin & Or-Bach

2010), students should experience different ways of conducting experiments in the school laboratory: alone, in pairs, and in groups of three or four students.

Another limitation of this study is that the reports do not directly indicate the quality of the students' individual learning. It was certainly to be expected that the group reports would be superior to the individual ones, as we found; personal tests will enable further conclusions to be drawn regarding the relative effectiveness of cooperative and individual learning.

The study results also raise an interesting question regarding the expansion of the methods used to examine students in science laboratories. If group work is the preferable learning method in the laboratory, can it also be the preferable means of examination and evaluation? The standard and dominant method used for student assessment around the world is individual examinations. Although various studies have shown that cooperative work yields superior outcomes, as also shown in our study, group assessment is still rarely used in schools. It is worth noting that this contrasts with the practice in research and development groups, and in commercial companies and institutions-where it is usually assumed that collective work empowers and benefits individuals, and hence outcomes and accordingly assessment is almost always conducted collectively. Learning communities and social networks are a growing phenomenon worldwide, raising the need to consider the pedagogic value of cooperative rather than individual testing in the laboratory as well as in general learning.

In conclusion, the findings of this study suggest that science teachers should acknowledge the benefits of cooperative learning in the laboratory. This will enable them to secure better outcomes for the laboratory learning. Their teaching will be more effective and will be possible using a smaller and more economical number of experiment kits and laboratory equipment. The savings in experiment kits and the possibility to teach more students simultaneously may also encourage greater exposure to laboratory learning. It also appears that this learning method can enhance the students' satisfaction and enjoyment. As part of the training for science teachers, we suggest that units be included guiding the teachers in the execution of experiments in the science laboratory using the cooperative method, among others. Planning and guidance along these lines can improve the quality of learning in the school science laboratory.

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Table 1. Average Grades for the Students' Reports, by Laboratory Learning Method (N=133)

Laboratory learning method	No. of reports	*M*	*SD*	*T*	*p*
Individual	88	73.02	13.74	-8.99	.000
Cooperative	45	87.52	8.52		

Table 2. Students' Attitudes toward Cooperative and Individual Learning (N=67)

Pairs of questions		*M (sd)* Group learning	*M (sd)* Individual learning	*t*	*p*
1.	To what extent did the laboratory work benefit you in terms of learning about the subject?	4.17 (.80)	2.85 (1.24)	6.73	.000
2.	To what extent did the way you executed the experiment (group/alone) help you understand the material?	4.03 (0.84)	2.92 (1.17)	6.12	.000
3.	How satisfied are you with the method of execution of the experiment?	3.89 (1.04)	2.98 (1.28)	4.26	.000
4.	How much did you enjoy the laboratory lesson?	4.53 (0.77)	2.47 (1.20)	11.18	.000
5.	To what extent would you rather participate in an experiment individually or in a group?	4.03 (1.25)	2.36 (1.28)	5.64	.000
6.	How much did drawing conclusions (jointly or individually) contribute to understanding the material?	3.92 (0.95)	2.94 (1.12)	5.60	.000
7.	How much did the method used to draw conclusions contribute to your enjoyment of the lesson?	3.80 (0.95)	1.18 (1.12)	8.14	.000
8.	To what extent did the execution of the experiment in groups or alone interest you more?	4.06 (1.08)	2.61 (1.25)	6.83	.000
9.	To what extend did you prefer executing the experiment in a group of alone?	4.03 (1.26)	2.32 (0.83)	7.25	.000
10.	What grade would you give to the learning when you executed the experiment in groups and alone?	4.50 (1.30)	2.85 (1.26)	8.10	.000
Non-paired questions		M	*sd*		
11.	How much did your ability to work in cooperation improve?	3.95	0.85		
12.	How much did the sharing of opinions among the members of the group contribute to understanding the material?	3.86	0.94		
13.	How much did the group discussion help in writing the experiment reports?	3.91	1.06		

Appendix: Description of the Four Experiments

1. Experiment 1: Addressed the measurement of the volume of a solid in the form of a cuboid. The students were given cubes from which they made a cuboid and measured its volume. The structured experiment sheets instructed the students to name the experiment, define its goal, and describe the tools used and their method. They were also required to answer the following questions:

   How many dimensions does the cuboid have? How did you calculate the volume of the cuboid and what units of measurement did you use to determine the volume of the cuboid? Calculate the volume of a cuboid whose dimensions are: width 5 cm, length 10 cm, height 4 cm.
2. Experiment 2: Addressed the measurement of the volume of liquid. The students were asked to measure various volumes of water using measuring cups of different volumes. They were given three cups with the volumes 10 cu.cm., 20 cu.cm., and 100 cu.cm. They were required to determine the measuring range of each cup and the measurement units, and to plan a way of calculating the volume that could be contained in each cup. They also had to determine what was the most appropriate measuring cup for measuring 90 cu.cm. of water, 9 cu.cm., and 19 cu.cm. They were required to execute the experiment, enter the findings in a comparative table, and draw conclusions. In their conclusions, they were also asked to state two common properties of all three measuring cups and three differences between the cups.
3. Experiment 3: Addressed the measurement of liquid in different containers. In the previous experiment, the students learned how to measure the volume of a liquid. In this one, they examined whether a volume of liquid remains constant. When we transfer liquid from one container to another, does its volume change? The students were given 50 ml of water and three containers: a 250 ml chemical cup, a 100 ml measuring cup, and a 200 ml conical bottle. They were required to plan an experiment answering the above-mentioned questions. They were asked to define the goal of the experiment, write down the method using the containers and materials available to them, describe the results, and draw conclusions.
4. Experiment 4: Addressed the measurement of volume of solids of a defined geometrical shape and without a defined geometrical shape. The students were given three items: a wooden cube, a stone, and a piece of modeling clay. They were also given a tape measure, a measuring cup, and water. They were required to suggest ways of measuring the volume of the three items. After they wrote down the experiment method and the tools and materials needed for the measurement, they presented their proposal to the teacher and received approval to execute the measurement. They then wrote down the results and their conclusions.