



Emotional and cognitive effects of peer tutoring among secondary school mathematics students

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Abstract

This paper describes an experience of same-age peer tutoring conducted with 19 eighth-grade mathematics students in a secondary school in Castellon de la Plana (Spain). Three constructs were analysed before and after launching the program: academic performance, mathematics self-concept, and attitude of solidarity. Students' perceptions of the method were also analysed. The quantitative data was gathered by means of a mathematics self-concept questionnaire [45], an attitude of solidarity questionnaire [46] and the students' numerical ratings. A statistical analysis was performed using Student's t-test. The qualitative information was gathered by means of discussion groups and a field diary. This information was analysed using descriptive analysis and by categorizing the information. Results show statistically significant improvements in all the variables and the positive assessment of the experience and the interactions that took place between the students.

Keywords: peer tutoring, solidarity, mathematics self-concept.

Introduction

Student heterogeneity is a reality, mirroring the heterogeneity of our society, and it must be seen as a chance to “maximize” the teaching/learning processes. Diversity should be turned into a challenge, an opportunity to learn with and from human differences. The fact that every single person is different must be recognized, therefore allowing each child to receive the best educational response possible at school [1]. Over the last decade, the theoretical framework of inclusive education has been used to enhance the positive evaluation of diversity. This movement is considered to be a system of values and beliefs that is a crucial element in the improvement process [2]. In our context, cooperative learning is still not sufficiently rooted in our education system and remains underrated, which contradicts the intense demands of today’s society for social and teamwork skills [3]. If the socialization processes in the family and in society are important for academic performance, then socialization in the classroom, which takes place through the social interaction among classmates, might be even more important. Ashman and Gillies [4,p.20] claim that cooperative learning activities “*provide an ideal vehicle for teachers to structure the environment for successful peer interactions and [...] provide students with the coaching and support they need to develop their social and emotional skills and understanding*”. Dialogue, discussion and mutual explanations encourage cognitive thinking and develop understanding; but furthermore, confrontation between different points of view also helps to restructure knowledge schemes through the appearance of socio-cognitive conflict [5]. These issues materialize in a learning method known as peer tutoring, the subject of this article.

Peer Tutoring: learning to teach and teaching to learn

As mentioned above, the interaction between students and their classmates has a significant impact on the learning process. By interacting with others, students generate a series of cognitive conflicts that make them learn [6]. Authors such as Duran [7] state that sometimes students can be better mediators than adults. They argue that because students have just recently learned the contents, they are more sensitive to the areas in which their classmates might require more help. In addition, they use more direct language and have the added advantage of sharing cultural and linguistic references. Topping [8,p.2] defines peer tutoring as *“people from similar social groupings who are not professional teachers helping each other to learn and learning themselves by teaching”*.

Different types of peer tutoring essentially depend on two factors: the ages of the pairs and the continuity of the role.

The first type includes cross-age tutoring and same-age tutoring. Cross-age tutoring is the most prevalent in the North American context. Linton [9] claimed that tutees make greater progress with tutors four years older than themselves. According to Lippit [10], the difference in age guarantees the quality of the process, and considers the ideal difference to be between 2 and 4 years. Allen and Feldman [11] concluded that students preferred this format. Nevertheless, recent studies show that the most effective tutoring occurs between students of the same age, the second type (same-age tutoring). Burnish [12] and Topping [13] showed that peer tutoring between people of the same age was at least as effective, or more so, than tutoring between people of different ages. Same-age tutoring has the added advantage of the proximity between students, and because it takes place in the same class group it does not require any previous organizational actions [14]. A meta-analysis carried

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3 out by Leung [15] examined the effectiveness of cross-age and same-age peer tutoring.
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5 Results showed they were both equally effective.
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8 Same-age tutoring may involve two types of tutoring, fixed or reciprocal, depending on
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10 the role of the students. In fixed peer tutoring the tutor student and the tutee student always
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12 have the same role: one of them explains and the other asks questions. In contrast, in
13
14 reciprocal tutoring the roles are exchanged. The research reported in this paper concerns
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16 fixed peer tutoring.
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23 **State of the art: the potential of peer tutoring**

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27 Nearly all the meta-analyses in the literature reflect the great potential of peer tutoring
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29 and its positive impact on students' academic performance and affective construct. Ritter et
30
31 al. [16] evaluated the efficacy of 21 voluntary peer tutoring programs and found that these
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33 interactions had a positive effect on the students' academic achievement. Apart from the
34
35 purely academic variables, peer tutoring also had a positive impact on the emotional
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37 variables. Spencer [17] carried out a review of 38 studies concluding that peer tutoring had
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39 a positive impact on the emotional and behavioural disorders of the students whether they
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41 **are** tutors or tutees. Byrd [18] analysed 18 empirical studies. She concluded that, among
42
43 other benefits, peer tutoring reported benefits on students' integration, self-esteem,
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45 performance or classroom atmosphere.
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51 In secondary education studies the benefits students acquire when they participate in
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53 peer tutoring programs **has also been documented**. Duran and Flores [19] checked how
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55 students' reading self-concept improved **because of** peer tutoring. Gavota et al. [20]
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57 **investigated** how their students improved their writing skills by reviewing and correcting
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3 their peers. Scheeler et al. [21] concluded that the immediate feedback given by the tutors
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5 improved the oral expression of their peers. Spörer and Brunstein [22] showed the benefits
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7 in the reading comprehension skills of the students by using peer tutoring. Duran and
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9 Monereo [23] research documented an increase in the students' self-concept using both,
10
11 fixed and reciprocal peer tutoring. In other subjects such as physics, Ismail and Alexander
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13 [24] presented better results with structured peer tutoring programs. In mathematics, the
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15 studies of Gautreaux [25] and Nazzal [26] showed how peer tutoring helped students
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17 improve their academic performance.
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22 All these benefits correspond to the aspects that most teachers aspire to achieve in
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24 their classrooms: advantages referring to instructional, social and affective aspects. The
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26 research essentially highlights the academic value of learning between peers in different
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28 fields of study.
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31 Three constructs that form part of this study emerged from the literature review. We now
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33 look at some of their key aspects.
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38 *Academic performance*

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40 To test the efficiency of a learning-teaching method, the impact it has on performance or
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42 the acquisition and consolidation of the contents and/or abilities needs to be demonstrated.
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44 Academic performance refers to the assessment of knowledge acquired in the school
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46 environment; it is a measure of students' abilities that express what they have learned
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48 throughout a training process. Knowles [27, p.273] defines academic performance as "*the*
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50 *demonstrated achievement of learning as opposed to the potential for learning*",
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52 understanding achievement as "*knowledge attained or skills developed in school subjects*
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54 *usually designed by test scores or marks assigned by the teacher or both.*"
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3 The secondary education students' performance in mathematics has been the subject of
4 numerous studies. Martin and Debus [28] concluded that both motivation and mathematics
5 self-concept played a determining role in students' mathematics performance, reinforcing
6 the idea posited by Pajares [29] according to which those students who see themselves as
7 more competent in a subject or field of study are more likely to engage in tasks related to
8 these learning domains, and obtain better grades in the subject. For their part, Miñano and
9 Castejón [30], in a study with 341 seventh grade students, pointed out that self-concept
10 varied depending on the experiences of the students in the classroom. Students'
11 motivational profiles and school success are not so much modulated by their individual
12 aptitudes, but more by their experiences of success and/or failure in the corresponding
13 areas, stressing the reciprocal relation between motivation and learning/execution. In other
14 words, motivation influences the learning and execution processes, and what the students
15 learn and do affects their motivation; this idea had previously been expounded by authors
16 such as Pintrich, Marx and Boyle. [31]

Mathematics self-concept

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19 Although many authors have studied self-concept, there is no unanimous definition of
20 what it is. According to Hattie [32,p.37], self-concept is "*the cognitive appraisal one makes*
21 *of the expectations, descriptions, and prescriptions that one holds about one's self.*"
22 Shavelson and Bolus [33,p.1] define self-concept as "*a person's perception of him or*
23 *herself. [...] Those perceptions are formed through one's experience with and*
24 *interpretations of one's environment and are influenced especially by evaluations of*
25 *significant others, reinforcements, and one's attributions for one's own behaviour.*"

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3 As the present study focuses on the field of mathematics, we now address the concept of
4 mathematics self-concept. According to Gómez-Chacón [34], a student's mathematics self-
5 concept is one of the constructs that will ultimately have the greatest influence on his or her
6 own learning. Many authors consider that mathematics self-concept plays a key role in
7 mathematics teaching and is related to the student's attitudes, mathematics world
8 perspective and social identity. [35, 36] Some key elements of mathematics self-concept
9 are: interest in mathematics, efficiency in mathematics, motivation and taking pleasure in
10 mathematics, and attributing success or failure in mathematics to chance. According to
11 Gomez-Chacón [34], mathematics self-concept refers to people's self-image in terms of the
12 way they perceive and value themselves when learning mathematics. She considers it to be
13 linked to the beliefs that each individual holds about the world of mathematics, beliefs that
14 are shaped throughout the students' schooling.

Attitude of solidarity

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17 For each compulsory school subject, the Spanish education system stipulates a series of
18 principles that should be encouraged in classroom. One of them is the principle of solidarity
19 which is referred to on seven occasions in the LOE (Organic Law of Education). This
20 principle is therefore an integral part of the objectives and aims of the current education
21 system. According to Hondrich and Koch-Arzberger [37, p.14], solidarity may be defined
22 as “*a sense of community between persons who, despite their differences, believe to have*
23 *the same objective(s) that one has achieved more than the other, from which rises the*
24 *voluntary obligation to support the other, coupled with the entitlement to support from the*
25 *other should the situation be reversed.*” Aside from what is provided by law, most authors
26 agree that students must receive instruction not only from an academic perspective, but also

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3 from a moral one. According to Cortina [38] moral education and the forming of attitudes
4 are basic tasks that are even more important than the transfer of contents. Prosocial
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6 conducts refer to actions designed to benefit others in some way. Attitude is the direction of
7
8 the conduct, an evaluative affirmation or judgment in relation to objects, people or facts.
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10 [39, 40]. Prosociality is understood as those behaviours that benefit other people, groups or
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12 social goals, as well as increasing the probability of generating a positive, high quality
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14 reciprocity based on solidarity in interpersonal or social relations, protecting the identity,
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16 creativity and initiative of the people or groups involved. [41] By recognizing otherness, a
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18 true “we” without borders is created; this universality is the prime place for the action of
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20 teaching. The dynamic relation between the recognition of the individual and the opening
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22 up to the world is the specific space of solidarity. [42]
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32 Peer tutoring is a cooperative learning strategy with potential advantages that can greatly
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34 benefit students. The aim of this research is therefore to analyse the effects of fixed peer
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36 tutoring in emotional (self-concept), attitudinal (solidarity) and academic (performance)
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38 constructs of mathematics students. We also aim to discover their level of satisfaction and
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40 the interactions and help that take place in the peer tutoring program through their
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42 perceptions and participant observation.
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47 **Hypotheses**

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50 - Students’ mathematics self-concept will increase significantly with the
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52 implementation of the peer tutoring program.
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- Students' academic performance will improve significantly with the implementation of the peer tutoring program.
- Students' attitude of solidarity will increase significantly with the implementation of the peer tutoring program.
- The students will be satisfied with the implementation of the peer tutoring program and with the interactions and help established.

Method

The peer tutoring program

The components of the peer tutoring program implemented are described below. This experience is based on the *Llegim en Parella* (Reading in pairs) project (GRAI research group).

-Grade level, subject area, objectives, strands and competences.

Grade level: Eighth Grade

Subject area: Mathematics

Objectives: Below we list some of the objectives stipulated in the DOGV (Decree 112/2007, of 20 July) concerning the subject of mathematics that the students worked with on this program: To address concepts from situations that students find intuitive. These concepts are then returned to at a later date and addressed from different perspectives that add new, more complex elements; to develop students' capacity to verbally express the processes they followed to solve the problems; to increase the students' confidence in their

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3 own capacities to interpret, value and take decisions on situations that have a mathematical
4 basis, highlighting the importance of affective teaching factors and learning mathematics;
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6 to improve capacity for reflective thinking and incorporating ideas; to deal with the
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8 problems of daily life following the intrinsic modes of mathematical activity by exploring
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10 alternatives systematically, using precise language, being flexible and adaptable to changes
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12 in points of view, and persevering in seeking solutions; to develop a positive attitude
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14 toward problem-solving, show confidence in one's own capacity and succeed in solving the
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16 problem, and acquire an appropriate level of self-esteem that allows the student to enjoy the
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18 creative, manipulative, artistic and useful aspects of mathematics; and to value mathematics
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20 and consider them as an integral part of our culture, both from a historical point of view and
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22 from the perspective of the current role they play in today's society.
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29 *Contents:* The contents correspond to the second and third term of the eighth-grade
30 mathematics course. Other contents common to all the subjects stipulated in the decree
31 were also studied using the peer tutoring program: figures that have the same shape and
32 different dimensions. Geometrical proportions. Proportional segments. Identification of
33 geometrical relationships; Pythagoras' theorem and Thales' theorem. Solving problems and
34 checking relationships between figures; Polyhedrons and solids of revolution. Flat surface
35 development and characteristic elements. Classifications considering different criteria.
36 Using properties, regularities and relationships to solve physical world problems; Volumes
37 of geometric objects. Solving problems involving estimations and calculation of lengths,
38 surfaces and volumes.
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53 -Scheduling
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3 The program was scheduled to run over 15 sessions, all held during the third term of
4 the course. In the first session the students completed questionnaires on their mathematics
5 self-concept and attitude of solidarity. The second session was devoted to training students
6 in the peer tutoring program. Ten peer tutoring sessions were then held on separate days.
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8 The length of each session varied according to the difficulty and complexity of the
9 problems and the students were given more or less time to solve them accordingly. At the
10 end of these sessions, the students took the final third term exam on the material studied
11 over the period. The program concluded with the students once again completing the
12 questionnaires on the mathematics self-concept and attitude of solidarity, and then they
13 formed discussion groups to appraise the experience.
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26 27 -Selecting the peers

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29 Peers were selected as follows: the list of students was split in two according to their
30 marks from previous assessments; the first half was the group of tutors and the second, the
31 tutees. Pairs were formed in such a way that the most proficient tutor was paired with the
32 most proficient tutee and so on until the list was completed.
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38 39 -Training

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41 One of the key aspects of this program is the training the students receive prior to the
42 experience. One full session was dedicated to this training, where particular emphasis was
43 placed on the fact that everyone stood to gain from the program and highlighting the
44 benefits for both tutors and tutees. Its ultimate success largely depends on the students'
45 attitude and interest; it is therefore essential that they have a positive perception of the
46 program from the beginning. The students were informed of the program's aims and were
47 invited to indicate which qualities they thought good tutors and tutees should have, which
48 the teacher wrote on the blackboard. The most important qualities identified for tutors were
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3 showing respect and interest, and being understanding, patient and responsible; and for
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5 tutees, being hardworking and respectful, showing interest, and paying attention. They were
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7 also taught about the basis of peer tutoring, the basic rules, the tutor and tutee roles, and the
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9 benefits for both tutors and tutees.
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12 -Materials and resources

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14 The materials used in each session were the same worksheets the students worked with
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16 during the class. Each worksheet was handed out to the students and contained a theoretical
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18 question and a problem. The theoretical question was designed to be easy and to help the
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20 student solve the problem and strengthen their knowledge on this subject. The complexity
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22 of the problems varied according to the worksheet, and had either one or two sections.
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25 Extra activities were also added in case some pairs finished the task before the rest of the
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27 class.
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32 Students were also given additional materials to help them understand the problem and
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34 tackle it with greater confidence. One example was the problem set in worksheet 6. The
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36 students were asked to calculate the lateral area of a pyramid, a challenging task for pupils
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38 of that age due to the spatial vision it requires. Along with the worksheet the students were
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40 therefore given cardboard pyramids with a toothpick in the centre representing the height of
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42 the pyramid, and the apothem of the pyramid marked in pencil, the key data to calculate the
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44 lateral area.
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52 Figure 1. Worksheet number 6 and the extra material provided for this session
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3 -Before and after the sessions. Classroom dynamic.
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5 Prior to the sessions, the teacher prepared the list of tutors and their respective tutees.
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7 The students were told how much time they had to solve each question on the worksheets,
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9 which were completed entirely in class. The worksheets were handed out and the students
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11 worked on them without help. They only took them home to finish in exceptional
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13 circumstances if they could not complete them in class. When the time was over, if most of
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15 the tutors had solved the questions they gathered with the teacher for a few minutes while
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17 the tutees continued working on the worksheets, since the tutees were generally slower than
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19 the tutors. At this point the teacher checked the tutors' results and the methods they had
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21 followed to make sure they were appropriate. Before looking at the tutors' worksheets, the
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23 teacher had had time to walk around the desks, observe the results and help both tutors and
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25 tutees with any questions. During the session with the tutors, the teacher explained what
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27 they should have done to solve the problem. Once the teacher had checked that the tutors
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29 had the right answers and understood the problem, they started working with their
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31 respective tutees and the peer tutoring session began.
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40 -Monitoring and assessment
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43 Tutor and tutee worked autonomously during the tutoring process, while the teacher
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45 observed to ensure that the students were working properly. Assessing the results of peer
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47 tutoring is an important aspect of this process. The questionnaires that the students took before
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49 and after the program show whether the peer tutoring experience had positive effects on their
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51 learning, their perceptions of mathematics, or their social abilities. At the same time, students'
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53 attitudes in class and toward mathematics can also be observed on a day-to-day level.
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Research design

Quasi-experimental statistical design without control group was used due to the human ecologic nature of the study. Innovative education interventions in schools give rise to ethical problems concerning the use of control groups. In this particular study, we were unable to have a control group because no other group was working with the same subject contents at the same time, the lessons studied between the groups were mismatched, and they were assessed in different ways. Moreover, the second generation of studies on cooperative learning states that once the effect of this methodology has been demonstrated in relation to others (with comparative studies between groups), the focus should turn to the data from the process that may help to explain it. [43] The constructs covered in this study are mathematics self-concept, attitude of solidarity and academic performance. In order to review the mathematics self-concept and the attitude of solidarity students took the two questionnaires before and after the peer tutoring program (see quantitative instruments). The students' academic performance was compared using the marks from the first and second terms (before the program) and the marks from the third term (after the program).

Participants

The participants in the study were students from an eighth-grade class in Castellon de la Plana (Spain). Although 27 students were enrolled in the course, some of them were frequently absent from school, and only 18 students participated actively in the program, of whom 13 were girls and 5, boys. They were aged between 13 and 15 years, and 9 were Spanish, 7 Romanian, one Peruvian and one Chinese. This study employed a non-probability

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3 and random sampling method, as the choice of the sample did not depend on the probability,
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5 but on the possibility of access. [44]
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10 **Techniques and instruments used to collect information**

11 *Quantitative instruments*

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16 - The questionnaire designed and validated by Gil, Guerrero and Blanco
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18 [45] was used to measure students' mathematics self-concept (Questionnaire on
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20 beliefs and attitudes toward mathematics). The questionnaire has 52 items each with
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22 four possible answers (strongly disagree, disagree, agree and strongly agree). This
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24 questionnaire was selected for the research because it had already been used in other
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26 studies and because its authors took into account previous research on beliefs and
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28 attitudes of secondary school students toward mathematics.
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32 - To measure the students' attitudes toward solidarity, we used the attitude of
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34 solidarity questionnaire designed and validated by Ortega and Minguez [46]. As in
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36 the previous case, this questionnaire was selected because it had already been used
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38 in previous studies on cooperative learning and peer tutoring. [47] The
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40 questionnaire's 23 items are evaluated on a 5-point Likert scale from very strongly
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42 disagree (1) to very strongly agree (5).
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46 - The students' academic performance was measured by comparing their
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48 marks (out of 10) in the subject in the first and second term with those for the third
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50 term. During the first and second term, the teacher used traditional teaching
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52 methods in the class, whereas during the third term the peer tutoring program was
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54 implemented (10 sessions) alongside the teacher's lessons.
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Qualitative instruments

- The students' perceptions of peer tutoring were uncovered through discussion groups. This method consists of setting up an interview with a group of people chosen for their relevance to the research question. [48] The interview is unstructured and the composition of the group is usually heterogeneous. In our case, 14 questions were asked, of which 10 were addressed to the entire group, 2 were specifically addressed to the tutors and the other 2 specifically to the tutees.

- Participant observation was used to study the interactions and help given between peers to solve the problems. This type of observation has a high degree of researcher involvement in the situation being observed. Information is generally recorded as narrative, in which natural language is maintained to register everything observed without translating it into specific codes generated for research. [48] In this case the most relevant behaviours were written down in a field diary. The researchers observed the class, the tutor-tutee interaction and the classroom atmosphere.

Data analysis

SPPS software (version 22) was used to analyse the data collected from the questionnaires. This is a statistical program developed to analyse quantitative data. We obtained the statistical average and the standard deviation, and Student's t-test (95% confidence level) was used to determine whether there were any significant differences between before and after the program. To ensure reliability of the mathematics self-concept

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3 and the attitude of solidarity questionnaires, Cronbach's alpha, Cronbach's alpha if item
4 deleted and Guttman split-half for each questionnaire were run on the scores before the
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6 deleted and Guttman split-half for each questionnaire were run on the scores before the
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8 intervention. [49, 50] The information collected from the discussion groups was compared
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10 with that from the field diary to analyse the qualitative data. A descriptive analysis was
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12 carried out on the students' contributions in the discussion groups and the data gathered
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14 through participant observation. In order to guarantee **the anonymity of the students and**
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16 **to identify their interventions, in the results section the interventions of the**
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18 **participants were coded in the following way:** Discussion group (DG) / T (tutor), t (tutee)
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20 / number assigned to the participant.
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24 Results

25 Quantitative results

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28 We now present the results the students obtained before and after taking part in the peer
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30 tutoring program in the constructs of mathematics self-concept, attitude of solidarity, and
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32 academic performance.
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37 *Academic performance*

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40 In the case of academic performance, statistically significant differences were found
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42 between scores before and after the intervention. 18 students (n) took the first, second and
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44 third term exams. 9 of them were tutors and the other 9 were tutees. The mean grade for the
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46 first and second term was 4.25 out of 10 (before) with a standard deviation (SD) of 2.38,
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48 while the mean for the third term (after) was 6.01 out of 10 with a SD of 2.68. The
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50 statistical comparison (Student's t-test, 95% confidence level) proved that there was a
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52 significant increase in the students' grades after the peer tutoring program (.00, $p < .05$). The
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3 students' marks improved on those for the first two terms in most cases. Only 2 students
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5 out of the 18 who took the third term exam obtained poorer marks than in the two previous
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7 terms. The percentage of students failing was considerably reduced and many students saw
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9 a significant increase in their marks.
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17 Figure 2. Students' academic performance marks
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23 Table 1. Students' grades before and after the peer tutoring program.
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26 Statistically significant differences were also found when analysing tutors (.03, $p < .05$)
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28 and tutees (.02, $p < 0.05$) **separately**. The mean grade for tutors for the first and second term
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30 was 6.01 out of 10 (before) with a standard deviation (SD) of 2.07, while the mean for the
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32 third term (after) was 7.54 out of 10 with a SD of 2.46. The mean grade for tutees for the
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34 first and second term was 2.49 out of 10 (before) with a standard deviation (SD) of 0.87,
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36 while the mean for the third term (after) was 4.48 out of 10 with a SD of 1.96.
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48 Table 2. Tutors' grades before and after the peer tutoring program
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57 Table 3. Tutees' grades before and after the peer tutoring program
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Mathematics self-concept

Nineteen students completed the mathematics self-concept questionnaire before and after the peer tutoring program. 9 of them were tutors, 9 were tutees and the remaining student changed his role depending on the day. Differences between scores before and after the intervention for this questionnaire were statistically significant (.01, $p < .05$) for a confidence level of 95% of Student's t-test. The mean score before the program was 2.72 out of 5 with a standard deviation (SD) of 0.24, while the mean score after the program was 2.89 out of 5 with a SD of 0.23.

Table 4. Mathematics self-concept questionnaire scores

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When analysing tutors and tutees **separately**, statistically significant differences were found for tutors (.04, $p < .05$) but not for tutees (.1, $p < .05$). The mean score before the program for tutors was 2.85 out of 5 with a standard deviation (SD) of 0.21, while the mean score after the program was 2.97 out of 5 with a SD of 0.22. The mean score before the program for tutees was 2.59 out of 5 with a standard deviation (SD) of 0.23, while the mean score after the program was 2.79 out of 5 with a SD of 0.22.

Table 5. Tutors' self-concept scores before and after the peer tutoring program

Table 6. Tutees' self-concept scores before and after the peer tutoring program

Reliability tests for this questionnaire showed a Cronbach's alpha of 0.704 and a Guttman split-half coefficient of 0.688. Cronbach's alpha if item deleted ranged from $\alpha = 0.723$ to $\alpha = 0.677$.

Since a discussion of all the 52 items in the questionnaire would be very lengthy, we only review the items we consider to be of special relevance. First are the items related to the students' view of mathematics, which should have improved after the peer tutoring program. That is the case of items 1 (mathematics is useful and necessary in all areas of life), 2 (mathematics are difficult, boring and have little to do with reality), and 9 (the abilities and skills that I develop in class to solve problems have nothing to do with the ones I use to solve problems in my daily life). Figure 3 shows the average scores for these items before and after the peer tutoring program.

Figure 3. Mean scores (before and after the program) for items 1, 2 and 9 of the mathematics self-concept questionnaire.

Second are the items related to students' confidence in their abilities when solving mathematical problems: items 17 (when I solve a problem I am not usually sure if the result is correct), 18 (I have confidence in myself when I take on mathematical problems), 19 (I

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3 consider myself very capable and competent at mathematics), 44 (I usually quit when I
4 come up against a difficult mathematical problem), 45 (when I work on a mathematical
5 problem I am very curious to know the answer), and 46 (I feel anxious and fearful when the
6 teacher asks me by surprise to solve a problem). Improvements were seen in all these items,
7 as shown in figure 4.
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16 Figure 4. Mean scores (before and after the program) for items 17, 18, 19, 44, 45 and 46
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18 of the mathematics self-concept questionnaire.
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24 *Attitude of solidarity*

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29 Nineteen students (n) took the attitude of solidarity questionnaire before and after the
30 peer tutoring program. The mean score before the intervention for this questionnaire was
31 3.35 out of 5 with a standard deviation (SD) of 0.37, while the mean score after the
32 intervention was 3.62 out of 5 with a SD of 0.39. Differences between scores before and
33 after the intervention for this questionnaire were statistically significant (.00, $p < .05$) for a
34 confidence level of 95% of the Student's t-test.
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45 Table 7. Attitude of solidarity questionnaire scores (before and after the program)
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52 When analysing tutors and tutees **separately**, statistically significant differences were
53 found for both tutors (0.01, $p < .05$) and tutees (0.04, $p < .05$). The mean score before the
54 program for tutors was 3.35 out of 5 with a standard deviation (SD) of 0.36, while the mean
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3 score after the program was 3.60 out of 5 with a SD of 0.31. The mean score before the
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5 program for tutees was 3.39 out of 5 with a standard deviation (SD) of 0.39, while the mean
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7 score after the program was 3.67 out of 5 with a SD of 0.50.
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17 Table 8. Tutors' solidarity scores before and after the peer tutoring program
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26 Table 9. Tutees' solidarity scores before and after the peer tutoring program
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33 Reliability tests for this questionnaire showed a Cronbach's alpha of 0.736 and a
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35 Guttman split-half coefficient of 0.704. Cronbach's alpha if item deleted ranged from $\alpha =$
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37 0.751 to $\alpha = 0.692$.
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40 Items in which we detected the greatest improvements in students' scores were items 10
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42 (It is not worth complicating things to help others), item 13 (collaborating with others is a
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44 waste of time and a useless task), 14 (given the few resources that I have, I can't do much
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46 to help others) and 15 (my studies can only benefit me, not others)
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49 The results of this study therefore allow us to confirm the first three research hypotheses.
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Qualitative results

The teachers noted that most of the students positively engaged with this methodology and felt comfortable in a situation in which some of the tutees expressed a desire to become tutors. “We have enjoyed a lot working in pairs, but I would have liked to be a tutor and explain things to my peer that he doesn’t know” (DG, t2). None of the tutors wanted to give up their role as tutor and went to great lengths to keep it. This observation was confirmed in the discussion groups where most of the students claimed that they had found the methodology useful in helping them to solve the mathematical problems “I always had the worksheet done and prepared because the teacher reviewed it and if it was done we knew that we would continue being tutors (DG, T4). They stated that the worksheets had enabled them to review what they had learned in class, and they were helpful in preparing for the exam.

Furthermore, because the students were taking an active role in their work in class, they accepted it as normal when the teacher asked one student to explain to a classmate an exercise they had successfully solved. In this way, the teacher could help more students at the same time in the class. As the sessions advanced, more peer tutoring situations took place during the daily teaching period and outside the peer tutoring program, “Sometimes, even if it’s not mathematics class, I also ask my tutor to help me when I don’t understand something”. (DG, t8). Most of the tutors stated that they found it very useful to help their peers with the problems. Some tutors also valued the program as a different and unconventional alternative to what they normally do in class, “In the other subjects we always do the same, the teacher explains and then we do the exercises, but here we are the teachers and we can help our peers” (DG, T6). For their part, almost all the tutees

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3 considered the methodology had been useful, and especially praised their peers' excellent
4 explanations and teaching, "When my tutor explained to me I understood it better, I
5 understood her words, they were much easier for me"" (DG, t1).
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10 Regarding the students' attitude, from day one a healthy competition was noted, started
11 by some of the tutees who aspired to become tutors. They made greater efforts in class and
12 they did their best to become tutors at some point in the future. This attitude was manifest
13 by some tutees calling attention to the teacher and showing their correct answers while the
14 teacher was talking with the tutors, "I would have liked to be a tutor. Sometimes I showed
15 the worksheet to the teacher so he could see I was working hard" (DG, t3). These tutees'
16 insistence earned them the title of 'all-rounder tutors'. All-rounder tutors are tutees who are
17 waiting for their chance to become a tutor and if one of the tutors does not attend class, they
18 take on that role. In addition most of the tutors were observed to make a great effort. None
19 of them wanted to lose their position and they made every effort to solve the problems to
20 the best of their ability. This attitude was confirmed in the discussion groups. When they
21 were asked how they felt in their respective positions, most of them answered that they had
22 felt important, "I think I have helped my tutored peer a lot. Besides, as I explained it looked
23 like I was the teacher" (DG, T4). Furthermore, although the tutees gave diverse responses
24 when asked about their position, none of them reported feeling uncomfortable or annoyed.
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45 In this regard, a considerable improvement was noted in the students' social skills. We
46 also observed that most of them had lost the shyness they had before the peer tutoring
47 program. At the beginning of the program, the students had to be asked to go to the board.
48 After a few sessions, both tutors and tutees insisted on going to the board by themselves
49 and, despite knowing that they would have to explain the problem to all their peers, they
50 were not afraid or embarrassed to do so. Even those who were more competent at
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3 mathematics had been nervous about explaining a problem before the program started.
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5 During the discussion groups, most of the students said they found it easier to explain a
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7 problem on the board than before the peer tutoring program, “Now going up to the
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9 blackboard and explaining problems is easier for me. I think I have already practised with
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11 my peer and I’m not afraid” (DG, T7).
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15 A considerable improvement was also observed in the classroom dynamics as the
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17 sessions progressed. The students finished the worksheets more quickly than before and
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19 had a better understanding of the steps of the process. The improvement on the first
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21 sessions was considerable. What the students most liked about the worksheets was that the
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23 problems they worked with were quite different from the ones they worked with in class.
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25 Some students stated that the best thing about the program was that they had learned more
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27 and that it had been easier for them to take the exam, “As the worksheets contained
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29 exercises similar to the ones in the exam, I remember how they explained to me and I was
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31 able to do them”. This is consistent with the question “Would you like to try another
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33 cooperative learning technique?” which all students answered in the affirmative. All the
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35 students stated that they would be pleased to work in groups, although some of them
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37 pointed out that every single member of the group must make a commitment to carry out
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39 the tasks assigned to them.
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48 **Discussion of results**

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51 As stated previously, the results from the quantitative information revealed statistically
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53 significant differences in the three constructs tested (academic performance, mathematics
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55 self-concept and attitude of solidarity) after the experience. The first three research
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3 hypotheses are therefore confirmed. In the same vein, we found studies conducted by
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5 Karsenty [51] and Gautreaux [52], who showed that their peer tutoring programs in
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7 mathematics and secondary education increased their students' academic performance.
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9 Similar results were found in studies by Schneck [53], Lazarus [54] and Calhoon and Fuchs
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11 [55] in which the effects of peer tutoring programs on students' academic performance
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13 were tested with pretest-posttest control group designs. All these studies found significant
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15 increases between the mean score before the peer tutoring program and the mean score after
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17 the peer tutoring program. This improvement is in line with the meta-analysis conducted by
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19 Leung [15], which showed that peer tutoring has a positive impact on students' academic
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21 achievement and that same-age tutoring can have a considerable positive effect on the
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23 students.
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30 Regarding the students' mathematics self-concept, two previous peer tutoring
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32 experiences by Fantuzzo and Davis, and Topping et al. in mathematics showed increases in
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34 this construct [56, 57]. Although these studies were conducted in primary education and
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36 one of them involved cross-age tutoring, they support the mathematics self-concept results
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38 found in this study. Another peer tutoring study conducted by Mosca and Santiviago [58]
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40 for new students enrolling in college mathematics courses found improved perceptions of
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42 students' own skills. It is important to note that while all these studies used a qualitative
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44 approach to analyse mathematics self-concept, in this research we followed a quantitative
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46 approach. Although not in the field of mathematics, we found successful peer tutoring
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48 experiences also including self-concept conducted by Topping, Duran and Van Keer, H.
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50 [59] and Flores and Duran [60] in reading skills, and by Alrajhi and Aldhafri [61] in
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52 learning English, which also showed that peer tutoring had positive effects on students'
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54 self-concept. The fact that tutees' self-concept improvement was not significant is
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3 supported by Flores and Duran [60]. As they state [60, p. 309] “tutees **are** likely to attribute
4 such improvement to the help received from their tutors instead of acknowledging their
5 own dedication and efforts”.
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12 Regarding attitude of solidarity, previous studies conducted by Maheady [62] and
13 Robinson and Steers-Wentzell [63] indicated that peer tutoring may lead to significant
14 improvements in the attitudes of mathematics students. Theoretical research on cooperative
15 learning also reports that attitudes of solidarity usually increase after this type of experience
16 [64, 65]. Studies in fields other than mathematics but also involving peer tutoring and
17 attitude of solidarity include those by Miravet, Ciges and Garcia [66] in the college subject
18 of general didactics, and Miravet, Garcia and Ciges in biology [67], which also reported an
19 increase in students’ attitudes of solidarity.
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34 These increases detected in all the analysed constructs coincide with the findings of the
35 meta-analysis conducted by Cohen, Kulik and Kulik [68] which stated that “*tutoring*
36 *benefits both tutors and tutees on both the cognitive and affective levels*”.
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43 With regard to the qualitative information, first we analyzed the degree of satisfaction
44 expressed by the students with the peer tutoring program through the discussion group. It
45 was noted that most of the students were satisfied with this method and they valued it
46 positively. Most of them also said they would be interested in trying other cooperative
47 learning techniques, confirming that they were motivated and interested in this particular
48 technique and in methods that require students to participate actively. This may be due to
49 the friendly environment this type of method generates among the students, and to the
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3 tutors' use of language and examples that are most appropriate for the age of the tutees. [69,
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5 70] In addition, the more relaxed environment and individual attention enabled them to ask
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7 questions without fear and to receive an immediate answer. [13] This is illustrated by the
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9 way all the students were actively involved in solving the problems: the tutors went to great
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11 pains to explain all the exercises to their tutees, and the tutees paid great attention to their
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13 tutors' explanations. Maheady [62] and Topping et al. [71] also reported high levels of
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15 satisfaction with the methodology among the students in their studies.
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20 The students' perceptions of the program were also investigated. Most of them described
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22 it as useful and different to the way they were used to working. We found diverse opinions
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24 regarding the tutees' feelings about their position in the program, although none of them
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26 said they felt uncomfortable or annoyed. All the tutors said that they felt important in their
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28 positions, a feeling that has been observed in other peer tutoring programs with other
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30 subjects, such as Schleyer et al. [72] or Gillies [73]. The tutors in their studies expressed a
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32 feeling of responsibility and importance in their roles during the program. This feeling is
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34 directly related to the tutors' high efforts. None of the tutors wanted to lose their position
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36 and strived to do the exercises to the best of their abilities. This may be due to the fact that
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38 they felt responsible for their peers' learning, they had made a commitment, and they were
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40 given certain "power". Perhaps because all the tutors had to meet together before working
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42 with their tutees, and because everyone would know who had performed their role well and
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44 who had not, peer pressure may have motivated them all to do their best and show the
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46 others that they knew what they were doing.
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53 Finally, we contrast the quantitative information (mathematics self-concept, academic
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55 performance and attitude of solidarity) with the information collected through the
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57 discussion groups and the participant observation. The significant improvement detected in
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3 the test on the mathematics self-concept analysis was contrasted not only with the
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5 interviews with the students, but also with the daily attitude observed toward the subject.
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7 All the students stated that mathematics was a useful subject and most of them said that
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9 they thought it was necessary for almost everything in our lives. Furthermore, they claimed
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11 to feel more confident when tackling the problems and relied more on their own skills to
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13 solve and explain them to their peers than before the peer tutoring program. The daily
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15 attitude observed also chimes with this increase detected in the mathematics self-concept,
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17 as almost all the students wanted to go to the board and solve the problems in class despite
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19 knowing they would have to explain them later to their classmates, reflecting their high
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21 levels of self-confidence. Moreover, the increase detected quantitatively in the academic
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23 performance was also reflected in field diary observations that some of the students who
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25 had previously been more reluctant to work in class were now making great efforts and
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27 seemed truly interested in the subject. Similarly, the increase in the attitude of solidarity
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29 detected in the tests was also seen in the participant observation, where it was noted that
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31 several times students explained exercises to others when a classmate asked for help or
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33 without being asked. All these observations, together with the self-concept, confirms
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35 hypothesis 4 not only because a considerable improvement was detected in the students'
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37 communicative abilities, but also because they felt competent to explain to their classmates
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39 the exercises they had previously solved. These improvements have also been detected in
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41 other studies such as Tsuei [74] and Topping et al. [75].
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51 **Conclusions**

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3 This research appears to show that peer tutoring has a high influence on emotional,
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5 attitudinal and academic factors and on students' communicative abilities, as well as having
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7 positive effects in the classroom. The results have shown how the students themselves can
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9 become a powerful teaching-learning resource for their classmates. In addition, this
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11 methodology affords the teacher the opportunity to exploit this potential by turning the
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13 interactions between the students into learning situations.
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17 Peer tutoring is therefore a dynamic, enjoyable methodology that encourages
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19 participation and offers an alternative way to learn. It also raises students' awareness of the
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21 importance and utility of helping between classmates, both for other students and for
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23 themselves.
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27 The results in this research are promising, although the study has certain limitations that
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29 must be taken into account. The first of these concerns the number of sessions. The students
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31 participated in only 10 peer tutoring sessions. On one hand, the fact that only a few sessions
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33 produced such significant outcomes is a good sign that the methodology can be effective
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35 even in short-term programs. Nevertheless, a longer period of analysis, together with more
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37 sessions and more than one test may have yielded a more reliable analysis of this
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39 methodology. In addition, we had no control group, which would have allowed a broader
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41 and more reliable analysis of the quantitative constructs. However, given its
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43 aforementioned potential, we consider peer tutoring to be an appropriate cooperative
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45 learning method for working with mathematics. In addition, the results should be
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47 interpreted with caution. The fact that this program was held during the third term—a
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49 period students always regard as crucial and stimulates them to work harder due to the
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51 proximity of the end of course exams—may have produced results that would not have
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53 been achieved had the program been run in the second or first term. Moreover, the scores
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3 before the program showed this was already an academically competent, confident and
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5 supportive group of students before the peer tutoring program. Hence their positive
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7 attitudes and cognitive competence facilitated the development of the program.
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10 Furthermore, the mere fact that the teaching method was entirely different in the third term
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12 could also have contributed raising the students' academic performance, regardless of the
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14 type of learning methodology implemented. The fact that students took the mathematics
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16 self-concept questionnaire for the second time (after the intervention) after the third term
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18 exam may also have influenced the scores of this test. After taking the third term exam the
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20 students may already have known their marks would be better than previous terms, which
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22 may have led to higher answers on the mathematics self-concept questionnaire. The lower
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24 academic performance of two students must also be taken into account, especially
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26 considering they had achieved passing grades in the previous terms. Their attitude during
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28 the program was poor compared to their classmates and they did not express a great deal of
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30 confidence in this methodology. This shows that although peer tutoring may be beneficial
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32 for the students, it can have no effect if they do not perceive it as useful and trust it as a
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34 beneficial way of learning.
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40 Reliability tests (Cronbach's alpha, Guttman and Spearman Brown coefficients) for the
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42 mathematics self-concept and the attitude of solidarity questionnaires showed values that
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44 may be considered acceptable, but not excellent. Caution is needed when interpreting the
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46 reliability analysis, especially taking into account the elevated number of items in the two
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48 questionnaires (52 and 23 items each). [76] The fact that the sample was small (only 19
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50 students) must also be considered. [77, 78] Future research using these questionnaires
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52 should run reliability tests.
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This research is a further illustration of how to teach in diversity and inclusive education in secondary school classrooms.

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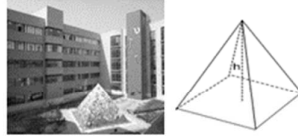
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Worksheet number 6

Unit 9 – Geometric shapes

THE UJI PYRAMID

At the University of Castellon there is a square pyramid made of ceramics. It was built inside the teachers' department at the School of Technology and Experimental Sciences. The Dean wants to varnish the pyramid. A painter asks for 50 £ per m^2 . Calculate how much it will cost if we know the following dimensions of the pyramid:



Dimensions of the pyramid:

Height of the pyramid: 5 meters

Side of the base: 4 meters

Figure 1. Worksheet number 6 and the extra material delivered for this session

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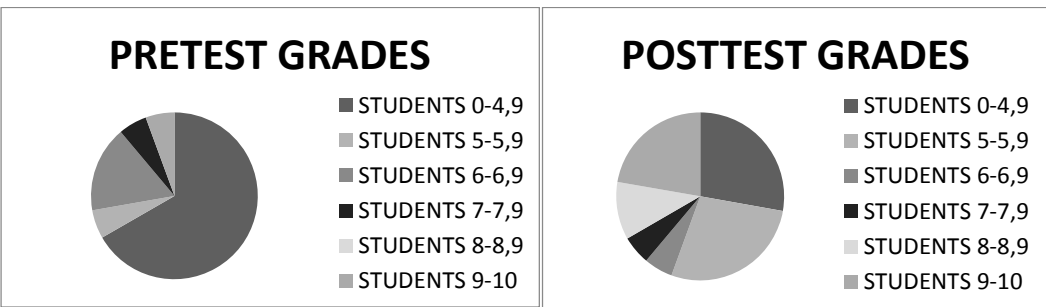


Figure 2. Students' marks before and after the peer tutoring program.

For Peer Review Only

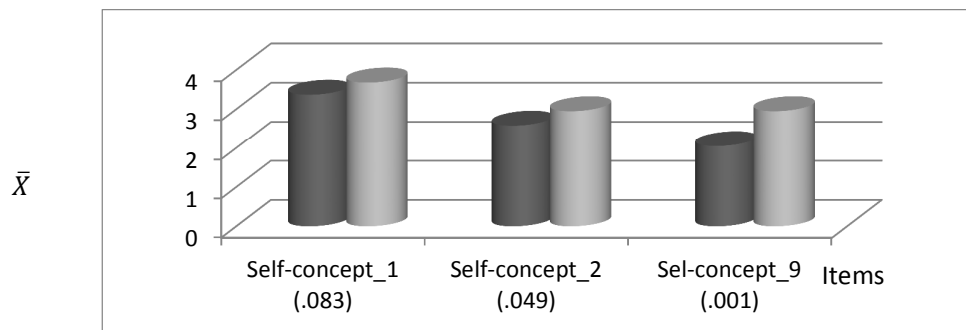


Figure 3. Averages before and after intervention of items 1, 2 y 9 from the mathematical self-concept questionnaire.

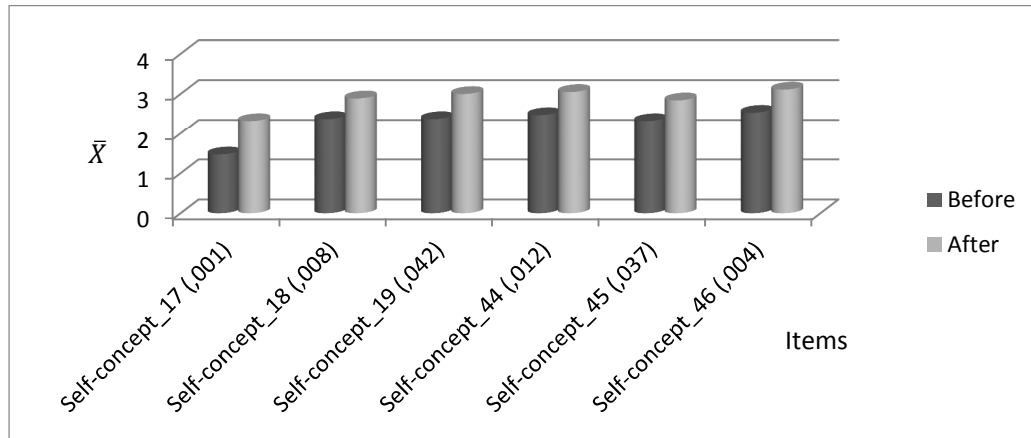


Figure 4. Averages before and after intervention of items 17, 18, 19, 44, 45 and 46 from the mathematical self-concept questionnaire.

Peer Review Only

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Academic Performance	Marks before intervention			Marks after intervention		
	Mean	SD	n	Mean	SD	n
Significance level (.00, $p < .05$)	4.25	2.38	18	6.01	2.68	18

Table 1. Students' grades before and after the peer tutoring program.

For Peer Review Only

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Academic Performance (tutors)	Marks before intervention			Marks after intervention		
	Mean	SD	n	Mean	SD	n
Significance level (.03, p<.05)	6.01	2.07	9	7.54	2.46	9

Table 2. Tutors' grades before and after the peer tutoring program

For Peer Review Only

Academic Performance (tutees)	Marks before intervention			Marks after intervention		
	Mean	SD	n	Mean	SD	n
Significance level (.02, $p < .05$)	2.49	0.87	9	4.48	1.96	9

Table 3. Tutees' grades before and after the peer tutoring program

For Peer Review Only

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Mathematical self-concept	before intervention scores			after intervention scores		
	Mean	SD	n	Mean	SD	n
Significance level (.01, p<.05)	2.72	0.24	19	2.89	0.23	19

Table 4. Mathematics self-concept questionnaire scores

For Peer Review Only

Mathematical self-concept (tutors)	before intervention scores			after intervention scores		
	Mean	SD	n	Mean	SD	n
Significance level (.04, $p < .05$)	2.85	0.21	9	2.97	0.22	9

Table 5. Tutors' self-concept scores before and after the peer tutoring program

For Peer Review Only

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Mathematical self-concept (tutees)	before intervention scores			after intervention scores		
	Mean	SD	n	Mean	SD	n
Significance level (.09, p<.1)	2.59	0.23	9	2.79	0.22	9

Table 6. Tutees’ self-concept scores before and after the peer tutoring program

For Peer Review Only

Solidarity attitude	scores before intervention			Scores after intervention		
	Mean	SD	n	Mean	SD	n
Significance level (.00, $p < .05$)	3.35	0.37	19	3.62	0.39	19

Table 7. Attitude of solidarity questionnaire scores (before and after the program)

For Peer Review Only

Solidarity Attitude (tutors)	Scores before intervention			Scores after intervention		
	Mean	SD	n	Mean	SD	n
Significance level (.01, $p < .05$)	3.35	0.36	9	3.60	0.31	9

Table 8. Tutors' solidarity scores before and after the peer tutoring program

For Peer Review Only

Solidarity Attitude(tutees)	Scores before intervention			Scores after intervention		
	Mean	SD	n	Mean	SD	n
Significance level (.04, $p < .05$)	3.39	0.39	9	3.67	0.50	9

Table 9. Tutees' solidarity scores before and after the peer tutoring program

For Peer Review Only