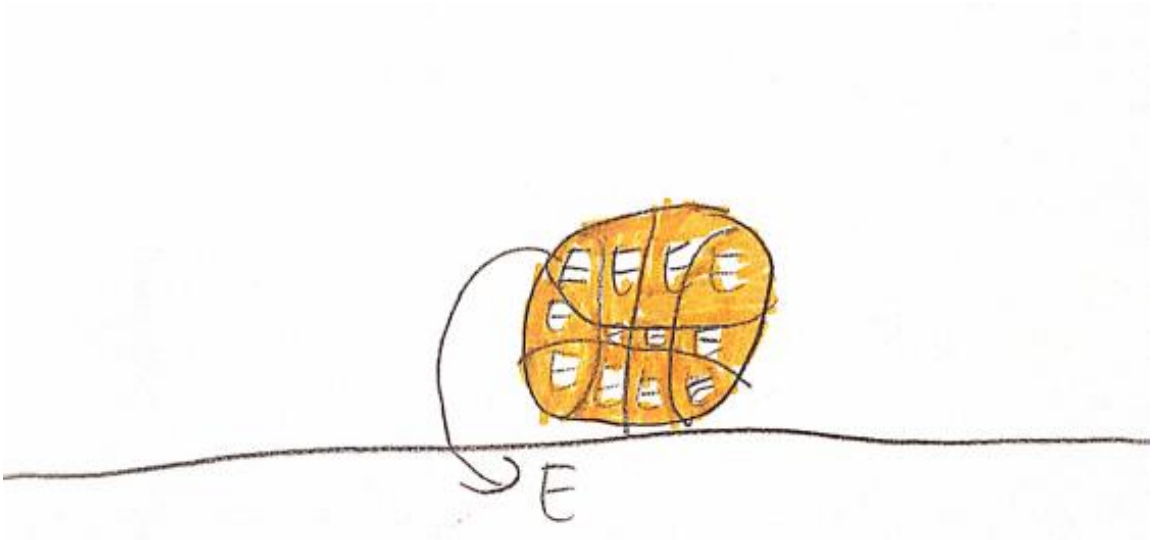
UNIVERSIDAD DE GRANADA

Interdisciplinary intervention for Primary Education: The study of energy through sport



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Abstract

This paper shows the results obtained after an interdisciplinary intervention. The main objective is to develop the concept of energy and its characteristics while improving their skills in basketball and bowling through pre-sports activities.

The study was carried out in a primary school located in the Almanjáyar district of the city of Granada. It involved three groups in the 3rd year of primary school, aged between eight and nine years old, being in total 50 students. It consisted of six sessions: A first one in which the pre-test was done, four sessions in which the contents were worked and a final one in which the post-test was made.

The results obtained, despite the limitations caused by COVID-19, have been very positive. Moreover, its potential is high due to the motivation that the students have maintained during the course.

Justification

Being a Primary School teacher implies working to solve current problems and to improve its teaching methods.

For this reason, this Final Degree Project (FDP) has been carried out in response to a problem present in today's society, interest in science, which is declining among young people. The impact of an interdisciplinary intervention has been studied with the aim of assessing whether it is advisable to implement it during primary school in order to increase interest in science. In addition, energy has been chosen as a content because generally creates a lack of interest among pupils as it is somewhat abstract.

It has been carried out through the subject of Physical Education to contextualise these contents in sport and work on physical activity in a more scientific way.

Key words

Primary Education, Physical Education, Natural Sciences, energy.

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Introduction

Science is the body of knowledge obtained in an objective and verifiable way from everything that surrounds us. Thanks to it, human beings have been able to advance throughout history and, nowadays, even faster, as their progress is exponential. For this reason, having an interest in science is something fundamental that should be developed from an early age.

Currently, there is a "decline" in students' interest for science, which is reflected in the disinterest of adults for the same. "Young people's attitudes decrease from the most positive attitudes expressed by the youngest students (grade 4, 10 years old) to the least positive attitudes expressed by older students (grade 9, 15 years old)" (Vázquez & Manassero, 2008, p. 15). Therefore, it is necessary to seek new methodologies that encourage students' curiosity about the things that make up our universe, from the smallest to the largest. As Vázquez & Manassero (2008, p. 15-16) say in their study, "the aim should be to generate curiosity and motivate learning through an appropriate curriculum and school activities that are both interesting and relevant for students and for society".

This Final Degree Project (FDP) intends to study the students' response after an interdisciplinary intervention in which Natural Science contents will be worked on in Physical Education. Specifically, we work with the *energy*, a content that generally creates disinterest among students because of its "difficulty" and be somewhat abstract. Moreover, it is not only how young people see science, but how is its didactics. According to Doménech et al., (2003), curricula prioritise conceptual contents such as principles and laws, with no relation to the students' reality, but science education should be considered as education for everyone, bringing us closer to aspects that generate interest. "Meaningful understanding of concepts requires overcoming conceptual reductionism and approaching science teaching as an activity, close to scientific research, which integrates conceptual, procedural and axiological aspects" (Duschl & Gitomer, 1991, cited by Doménech et al., 2003, p. 289).

According to Rugarcía (1996, p.7), " interdisciplinary approach refers to the use of at least two disciplines in the search for an answer, it is a kind of force capable of uniting various experiences to deal with the challenges of these times". In other words, in real life, there are no problems that only cover one area of knowledge, so in order to really prepare

students to face the problems that arise outside school, it is necessary to work the contents of Primary School in an interdisciplinary way.

Based on the foregoing, it was decided to carry out an interdisciplinary intervention. Physical Education is an ideal subject to work on other areas at the same time as working on its contents, as it is of interest to almost all students and situations of experimentation and investigation can be created through a wide variety of activities in which they interact with their classmates and the environment. In addition, this provides a context close to the *energy* contents that are going to be worked and the students give a meaning to learn about it while improving their performance in sport.

Objectives and contents

The main objective of the intervention is to identify the energy during basketball and bowling practice. In addition, it is pretended to develop their understanding of mechanical energy and to improve their motor skills in sport. When the intervention is presented, this general objective will be concretised into more specific ones.

During the sessions, the contents that have been worked on in the subject of Physical Education are extracted from the Order of 17 March 2015 (BOJA number 60 of 27 March 2015). The main focus is on block 4, "School game and sport". These contents are:

4.1. Application of basic skills in game situations. Initiation to the practice of sporting activities through pre-sport games and adapted sport.

4.2. Experimentation, investigation and application of the basic skills of handling balls and mobiles, with or without implements, in playing situations.

4.4. Learning and use of basic strategies in situations of cooperation, opposition and cooperation-opposition, in the practice of games and sports.

Also, other procedural and attitudinal contents are worked simultaneously as they are ambiguous and cover many possibilities.

Regarding to the contents that will be worked about the energy, a review has been made of different articles explaining which are the ideal ones for this stage and the best way to work on them. In this way, we will prevent students from learning misconceptions and provide them with a good basis for their future study in subsequent years.

"Numerous studies have highlighted students' serious misunderstandings about the nature of energy" (Pfundt & Duit, 1998; Domenech, 2000, cited by Doménech et al., 2003). Moreover, if we add the fact that "there is no consensus on the definition of energy, neither from a scientific point of view, in the sense of what its physical meaning really is,

nor from a didactic point of view" (Garcia-Carmona & Criado, 2013), the concept of energy is something difficult to define, and, even more, from a beginning. Therefore, according to Domenech et al. (2003), it is not a question of seeking a single and correct conception, but of constructing one's own idea of energy through approximations.

In addition to the concept of energy, its main characteristics appear: conservation, transfer, transformation and degradation. These contents will be worked, not as isolated events, but taking into account the relationship between them.

Even so, although each student constructs his/her own idea, during the sessions, common approximations will be shown to all of them. For the conservation of energy, it is assumed that "the total energy (including thermal energy) of an isolated system remains constant" (J. L. Doménech et al., 2003). This, linked to the degradation that explains that not all the energy used for a work is used in it, that is, as it is explained by Garcia-Carmona & Criado (2013), energy that is degraded is released to the environment, increasing its temperature. Also, energy is transformed and transferred through work and heat. "The transformations that a system undergoes are due to interactions with other systems or interactions between its parts" (Doménech et al., 2007).

Methodology

Participants and context

The intervention was carried out in a public school located between the Almanjáyar neighbourhood and Cerrillo de Maracena. Most of the school's children are from Cerrillo de Maracena or surroundings. The intervention has been done with three groups of 3rd grade of Primary School, a total of 50 students, with 18 in 3rd A, 17 in 3rd B and 15 in 3rd C. Regarding the gender of the pupils, there are 28 girls and 22 boys, even though in this analysis of the results, this variable has not been taken into account. Although the sample with which we worked was 50 pupils, we were only able to analyse the results of 42 because at the beginning of the intervention (pre-test), there was an outbreak of COVID-19 in the centre, causing some participants to be absent, and in the post-test, one more pupil was absent. Therefore, the sample was reduced to: 15 in 3rd A, 13 in 3rd B and 15 in 3rd C.

In general, the socio-economic level of the families at the school is medium-high and their involvement in their children's education is high.

The students' motivation for Physical Education is high, as they consider it to be a different subject from the others because most of the activities carried out in it are games

or sports which they enjoy. Their interest in science is not clear, but they show great curiosity about the things around them, so we could say that they are interested in learning about new things that attract them.

Procedure

The intervention is composed of six sessions: one for the pre-test, four in which the contents are worked and a final session for the post-test. Table 1 shows the objectives of each session.

Specific objectives of each session	
Pretest	
1st Session	1) To identify the energy in the practice of basketball. 2) To relate the different properties of bodies, their mass, speed or position (height) with energy. 3) To justify, in energetic terms, why the basketball court and ball have the characteristics they have. 4) To predict the best way to execute an action in basketball.
2nd Session	1) To associate changes in the motion, trajectory and velocity of basketballs with the transfer of energy in the interactions we perform on them. 2) To identify the transfers and transformations of the energy of the basketball during the game with its surroundings. 3) To justify the conservation of energy in different basketball actions.
3rd Session	1) To predict, approximately, the energy that each ball can have according to its mass and the speed it can reach according to its physical capabilities. 2) To identify the external variables that can influence the speed and trajectory of a rolling ball. 3) To calculate which pins or cones can roll taking into account the characteristics of the ball, the pins and the surface they are on.
4th Session	1) To relate the loss of velocity of the balls to energy degradation. 2) To identify at what times and in what ways the energy of moving balls degrades. 3) To choose the balls and surfaces that involve the least loss of useful energy.
Postest	

Table 1: Specific objectives of each session

All sessions take place during Physical Education hours. The intervention lasts two weeks taking into account that each week has three sessions for the subject of Physical Education.

The sessions have been designed taking into account that there are two teachers, in this case, a teacher and a trainee student. In order to get the students motivated and involved, the intervention has been thematised. The students have been told that they have been chosen for a special training where they will use science to improve in basketball and

bowling. It is not just any training, as it is carried out by the University of Granada in collaboration with Stark Industries (Iron Man's company, a Marvel character) under the name "Project Stark". For this purpose, three videos have been used in which "J.A.R.V.I.S.", Iron Man's artificial intelligence butler, talks to the students. They explain to the children what they are going to do.

- Pretest (video 1): Introduction
- Pretest (video 2): Explanation of the sessions
- Postest (video 3): Review of the challenges and end of sessions

In addition, at the end of each session, they have to overcome a challenge in order to continue the training.

The sessions were planned to take place in the weeks from 19 to 30 April and were distributed as shown in table 2.

Hours	Monday 19	Tuesday 20	Wednesday 21	Thursday 22	Friday 23
9:00 – 10:00				2ª session	2ª session
10:00 – 11:00	Pretest	1ª session	1ª session		
12:00 - 13:00	Pretest	1ª session			
13:00 – 14:00	Pretest				2ª session
	Monday 26	**Tuesday 27**	**Wednesday 28**	**Thursday 29**	**Friday 30**
9:00 – 10:00				Postest	Postest
10:00 – 11:00	3ª session	4ª session	3ª session		
12:00 - 13:00	4ª session	4ª session			
13:00 – 14:00	3ª session				Postest

Table 2: Initial timeline of the intervention per group. Each colour corresponds to a group: 3rd C yellow, 3rd B green and 3rd A blue.

The structure planned for the sessions is very similar. All Physical Education sessions are divided into warm-up, main part and cool-down. In our sessions, in almost all of them, it was divided into these three parts, although the work is done in a different way than usual in each of them.

The only exception is session 4 which is divided into two parts: in class and in the playground. This is an adaptation to one of the school's measures for the prevention of COVID-19, which divides the school break of the three cycles at different times, with the first half hour of class from 12:00 to 13:00 on Mondays and Tuesdays coinciding with

the break of another cycle, with the consequence that this half hour has to be done in class.

Before starting the session, they are given a brief introduction to what we are going to work on and we ask them a question that they will have to answer during the session. In the warm-up, they are prepared for the main part with an introductory or related to the contents game in order to activate the students.

The main part is the important part of the sessions. During this part, the objectives of each session are worked and the activities in which they experiment, test and analyse are realised in order to answer the initial question and other questions that they ask themselves while practising basketball and bowling. To finish this part, always, there is a group challenge related to the skills or contents worked on that they have to overcome. This challenge needs to be something that they can achieve but with a bit difficult. With this, the children will feel fulfilled with the session.

Finally, in the cool-down, the aim is to relax the students so they can go back to class. To do this, they were seated in a semicircle. Once they were seated, they all answered the initial question. Afterwards, an experience related to the contents worked during the session was carried out in order to reflect on what had happened, seek an explanation and clarify any doubts. For a more detailed description of the sessions, see annex II.

In general, the implementation of the activities has been satisfactory. The children were active and participative during all the sessions. Moreover, on many occasions they made interesting interventions with curious questions and very complete answers.

Even so, during the sessions some changes have been made, which will be detailed later in the sections on results and proposals for improvement with new proposals for changes that, according to what has been experienced, can make the intervention more effective.

Also, due to the rain on Tuesday 26th May, the 3rd A and 3rd C sessions were delayed, so that they finished on 3rd June instead of 30th May as planned.

Instruments and data analysis

A mixed quantitative and qualitative analysis has been realised. The quantitative part was carried out with a pre-test at the beginning and a post-test at the end of the intervention. For the qualitative part, a researcher's diary was used to record what happened during each session.

For the pre-test and post-test, the same questionnaire was administered. It consisted of 12 questions: The first one was short answer, the next ten were multiple choice with four

options with only one correct answer and the last one consisted of drawing a picture. All the questions in the test were worked during the intervention (annex I).

With the researcher's diary, a continuous evaluation was made, in which were recorded: the students' attitude, their level of participation, some participation or specific comments that were surprising, the modifications made during the sessions, which aspects of the intervention worked better and which worse. This makes it possible to evaluate, specially, the activities in order to improve the intervention for future implementation (annex III).

For the quantitative data, a descriptive comparative analysis was done using the Excel spreadsheet, version 2016. For the qualitative data, a comparison was made between what was initially planned (sessions, annex II) and what was actually implemented (researcher's diary, annex III). Also, we have compared the performance of each group and, based on this, we observed which aspects caused this difference.

Results

To analyse the results of the pre-test and post-test and to compare them, quantitative techniques were used. It compares the students' answers in the pre-test and post-test by groups and in general.

The answers to the first question, the number of correct answers in the multiple-choice questions and the indicators to facilitate the comparison of the drawings will be analysed.

First part: The word that is most related to energy for you.

We will start by looking at the answers of each group. Figure 1 represents the answers of the 3rd A students.

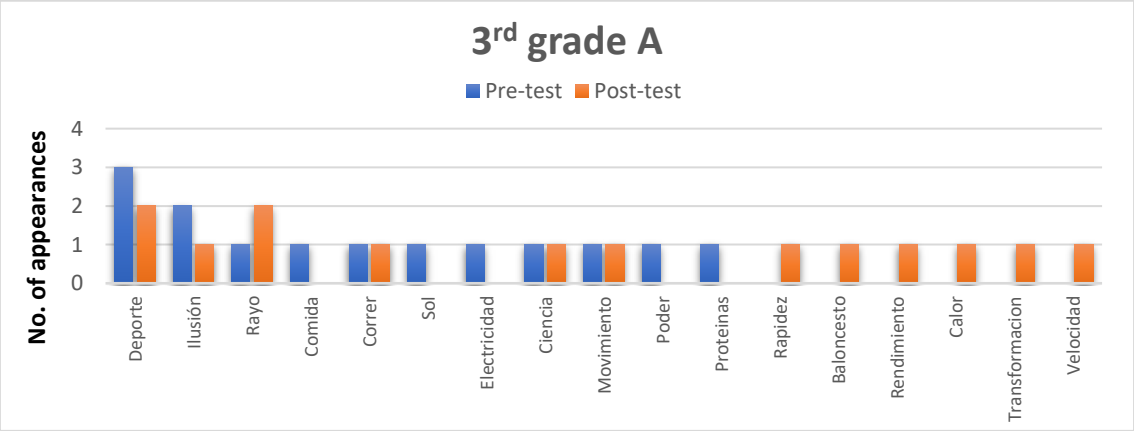

Figure 1: Answers to the first question in 3rd grade A

In the answers of 3rd A, we can observe that the word that is most repeated in the pre-test is "sport", as in the post-test, with "lightning". However, if we look at the words used in

the post-test (fast, efficiency, heat, transformation, speed, motion...), they are related to the contents worked during the sessions, that is, they are related to energy. Also, in the pre-test, there are several words related to energy, but, specially, they refer to energy sources, whereas in the post-test, they are closer to the concept of energy.

Figure 2 shows the answers of 3rd B.

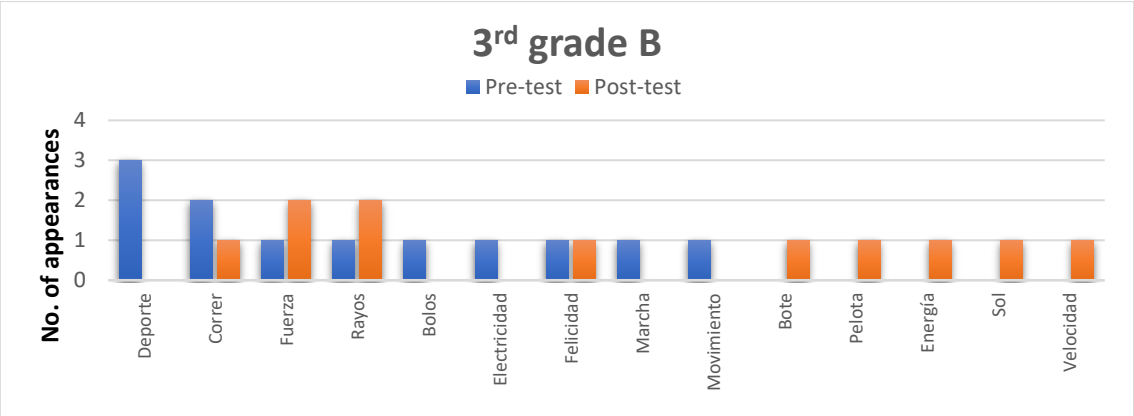

Figure 2: Answers to the first question in 3rd grade B

As in the previous group, the word that stands out most is "sport", followed by "run". In the post-test, the terms change to "strength" and "lightning". Looking at the pre-test, we can see that the general idea of the group is around physical activity except four answers (strength, lightning, electricity and happiness). Then, in the post-test answers, new elements or situations viewed during the sessions appear, such as "bounce" and "ball". In addition, one of the energy variables, "speed", appears, so that, although some words worked on during the intervention are added, no significant change is seen in this question. Also, the frequency of the word "strength" increases, a concept commonly erroneously related to energy. This is discussed below.

Figure 3 shows the answers given by 3rd C.

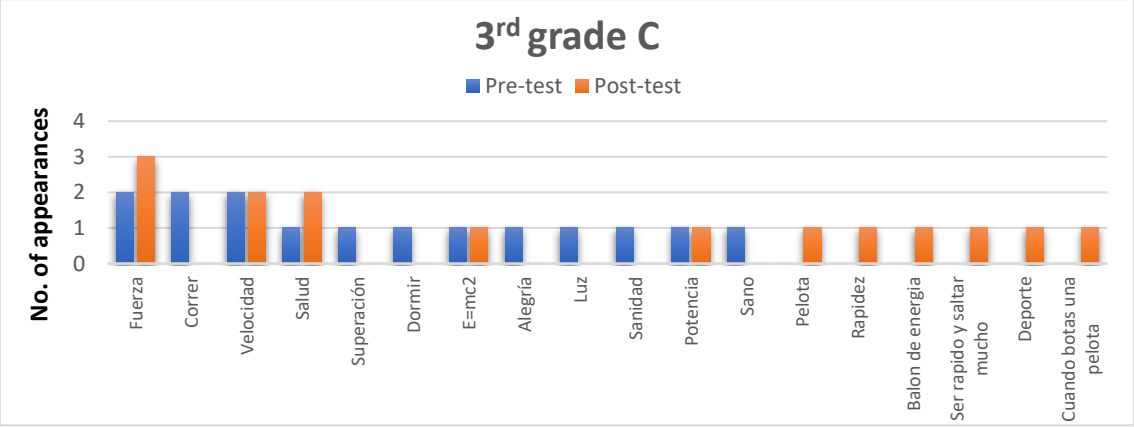

Figure 3: Answers to the first question in 3rd grade C

Finally, in the 3rd C group, in the pre-test, three words stand out equally, "strength", "run" and "speed", while in the post-test, the word that is most repeated is "strength". In this group, as in 3rd B, although there are words related to the sessions carried out, do not approach to the concept or idea of energy as was the case in 3rd A, except for "speed" or "$E = mc^2$". Therefore, with this question, no appreciable change in their idea of energy can be observed either. As a detail to highlight, the answer of "$E = mc^2$" is quite surprising to see that someone knows it and relates it to energy at such an early age.

Figure 4 represents all the answers given by the participants as a whole.

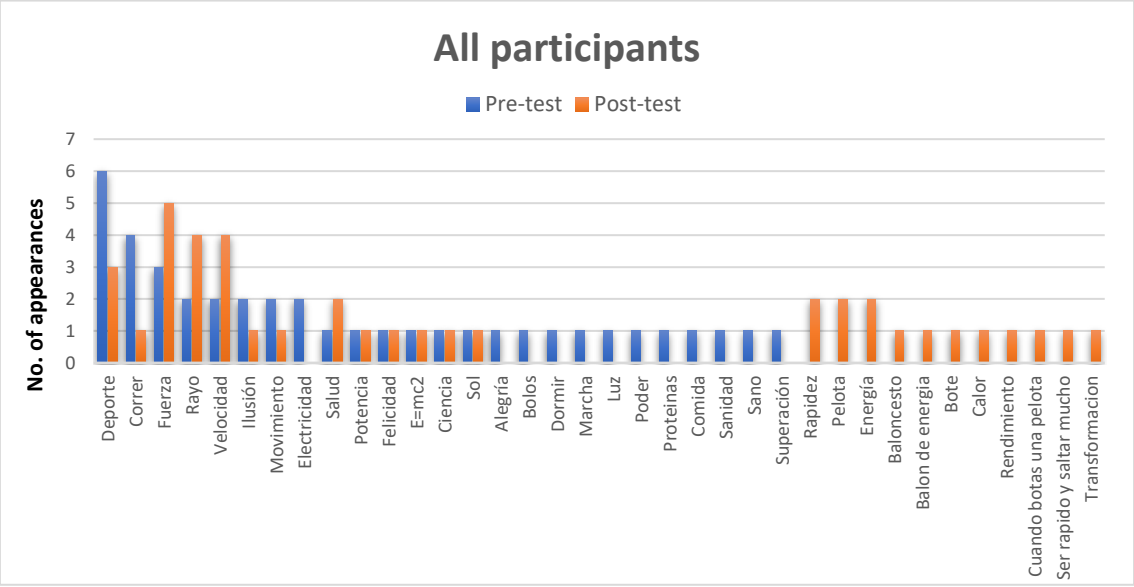

Figure 4: Answers to the first question in general

In general, we can observe that, although it is not a big change, in the post-test appears more terms related to the idea of energy or what was viewed during the sessions, showing that the children have modified their idea of energy. Even so, the increase in the frequency with which "strength" appears is noteworthy, as strength and energy are concepts that are often confused, although, in physical terms, they are completely different. A possible explanation for the increase is that, during many activities, in order to throw the objects faster, they had to apply more strength. Therefore, it is possible that they have confused the strength used to throw the balls with the energy transferred to them.

Second part: Multiple-choice questions

In order to analyse the multiple-choice answers, we will start by looking at the answers of all students in general (figure 5). To see the answers of each student, consult to annex IV.

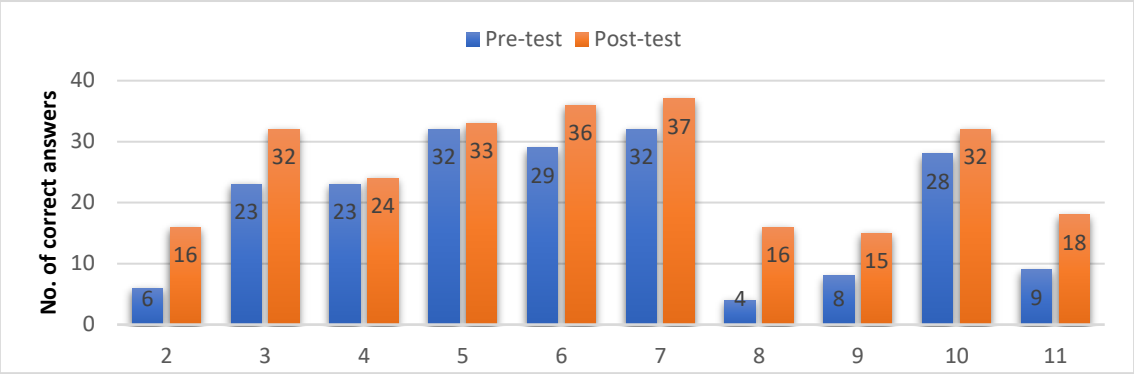

Figure 5: Correct answers in multiple-choice in general

The multiple-choice part is the most important of the questionnaire as it evaluates the contents that have been worked during the intervention. Comparing the results of the pre-test with those of the post-test, we can see if it has had a positive effect on the students.

The first aspect we can see in this comparison is that the number of correct answers in the post-test (254) is considerably higher than in the pre-test (194). Furthermore, if we compare the answers to each question, we can see that, in all of them, the frequency of correct answers has increased, to a greater or lesser extent. The questions in which there has been more difference pre-post-test are: question 8 (+12), question 2 (+10), question 3 (+9) and question 11 (+9).

Looking at each question, we can see that the contents appearing in questions 2, 8, 9 and 11 are the least known by the students, since in the pre-test they have few correct answers. Then in the post-test, in general, knowledge of these contents increases and, although it does not reach the level of the contents most known by the students, they are among the questions with the greatest difference between pre- and post-test.

The questions most commonly known by students before the intervention are: question 5 (32), question 7 (32), question 6 (29) and question 10 (28). Then, once the sessions had been realised, the number of correct answers increased very little in all of them, except for question 7, which increased by five correct answers. In addition, in the post-test, question 3 is added to the best-scoring questions, with a notable difference between the pre-test (23) and the post-test (32).

Although in general, it may seem that the results of all the questions are positive, if we analyse the answers by groups, we can see that in some questions the frequency of correct answers in some of the questions remains the same or even decreases, and varies according to the group.

Figure 6 shows the number of correct answers by each group in the multiple-choice questions.

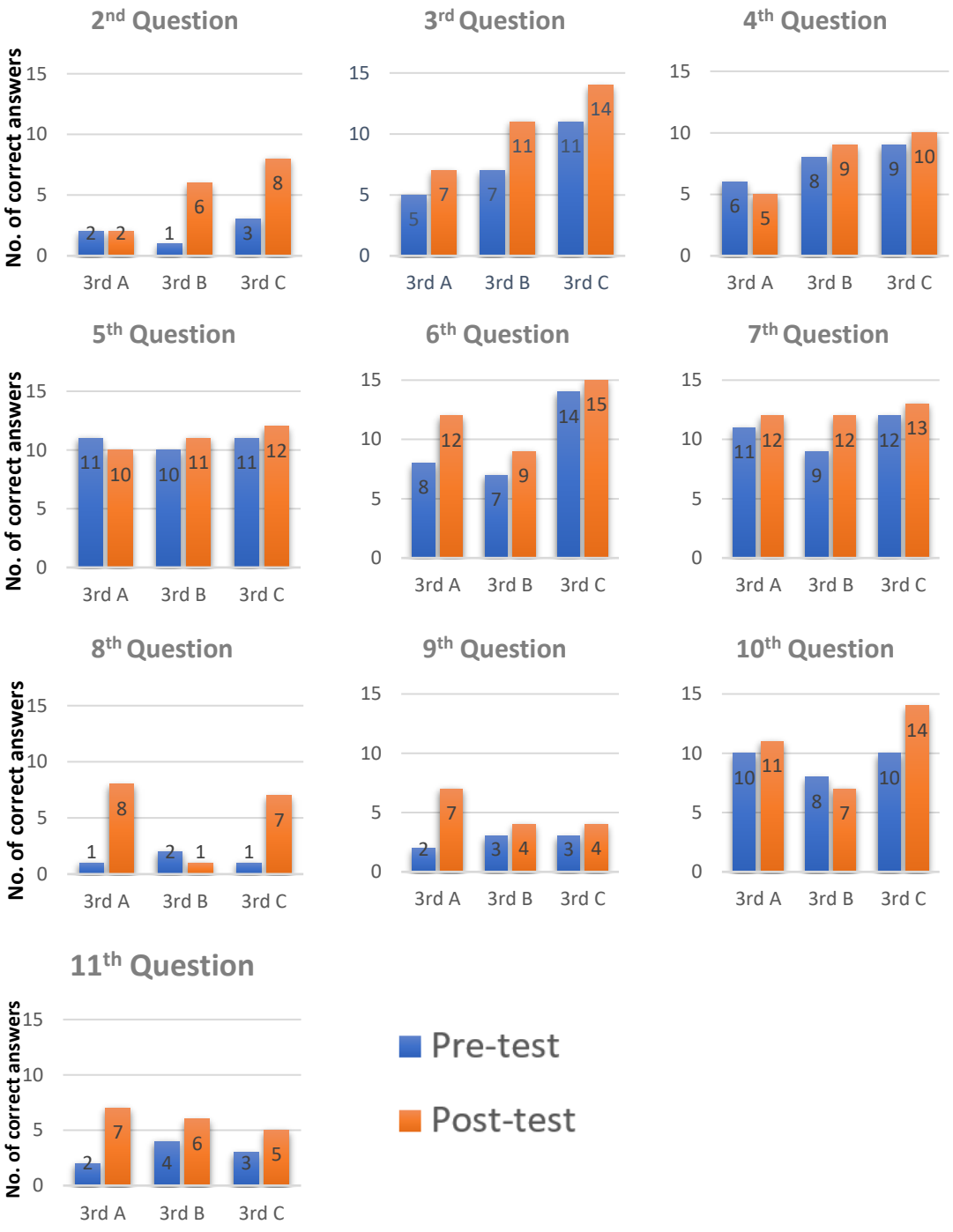

Figure 6: Correct answers of each multiple-choice question by groups

The 3rd A group started with the lowest level with respect to the others, taking into account the number of correct answers in the multiple-choice part with 58 in total. In the post-test, this number has increased to 81, which shows a general improvement in the contents

covered during the intervention. Even so, in some of these questions the number of correct answers has not increased. These are questions 2, 4 and 5.

Questions 2 and 4 may be due to the fact that in the 3rd A sessions, as they were the first to do the session, not enough emphasis was placed on some contents, as it was not considered necessary, but once the session had been carried out with them and seeing the importance of doing so, it was done with the other groups. Question 5 may be due to confusion with the experience of bodies falling at the same time from the same height and under the same conditions because in the post-test, 3 students answered with option D (all three have the same energy) whose answers did not appear in the pre-test.

The 3rd B group had 59 correct answers in the pre-test, one more than 3rd A, even though there were two students less. Afterwards, in the post-test they had 76 correct answers in total, so in this group there was also a general improvement after the intervention. Although the number of correct answers in total has increased, the number of correct answers in questions 8 and 10 has decreased.

These small decreases may be due to the fact that in session 3, in which these contents were worked on, emphasis was not placed on the differences in playing in different fields (question 10) or simply the students were paying attention to other things during the activities and, in the final experiment (question 8), maybe we didn't show well what was important or they didn't give the corresponding importance to it because in the other groups they have improved in these questions.

The 3rd C group started with the highest number of correct answers in the pre-test with 77 and is also the group that obtained the best result at the end of the intervention with 102 correct answers. In this group, the results for all questions have improved. Moreover, although it was the group that started with the best result in the pre-test, it was also the group that improved the most in comparison to the others.

To see all the answers given by the students, please consult annex V.

To conclude this section, in relation to the questions in which the number of correct answers dropped, it was only a difference of one, so, if it is not due to the explanations given above, it may be due to a mislead or simply to answering quickly, without thinking, in order to finish and go out to the playground as soon as possible.

Third part: Draw how you imagine energy

This last question was an open question. In it, the objective was that students could show how they understand energy through a drawing, with total freedom to express what they

imagine when they think about energy. Therewith, we pretend to know their concept/image of energy.

In order to be able to analyse the drawings quantitatively, a set of indicators was defined (annex VI). They were used to define the drawing, its relation with the energy and, if it has one, what characteristics it has.

We will begin by analysing the dichotomous criteria (yes/no). In these, we simply observed whether the criterion appeared or was fulfilled. The criteria used are:

- Clear drawing: If it is possible to clearly identify what the drawing represents.
- Objects and people: If objects or people appear, respectively.
- Relation with Q1: If the drawing is related to the answer given in question 1.
- Relationship Phy-Act: If the drawing is related to physical activity.
- Relation with E: If the drawing is related to energy or is represented in some way.
- Fantasy: Those drawings that represent cartoon characters or objects or if they have more relation with fantasy than reality.

Figure 7 shows the number of times that appears each of the dichotomous indicators.

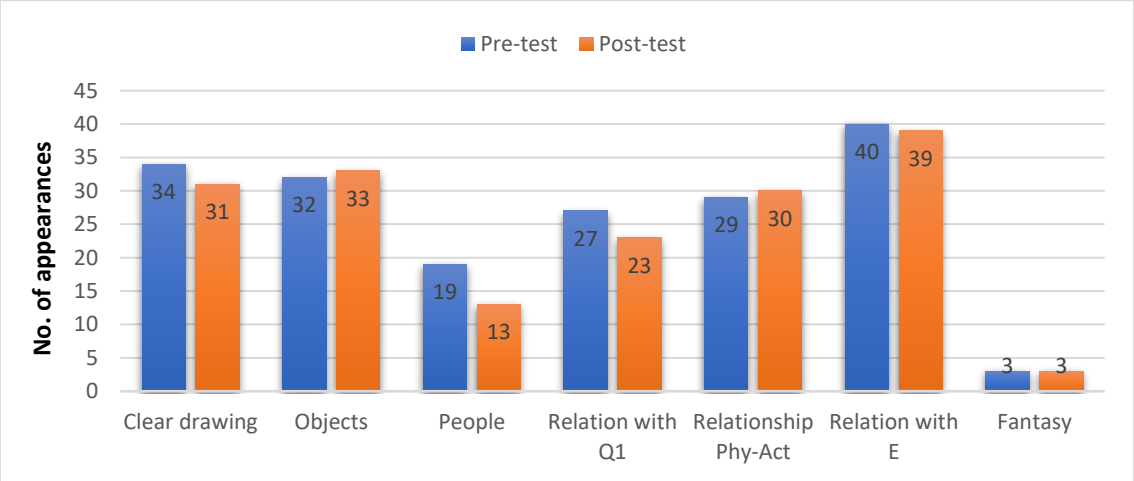

Figure 7: Number of affirmative dichotomous indicators in drawings

In most of the drawings it is clearly identifiable what is depicted. We can see that the majority relate energy to physical activity and the vast majority have at least some relationship with energy. Also, objects are represented in more than 75%. These criteria vary very little in a pre-post-test comparison.

In those where there is a visible variation, almost half of the students in the pre-test represent people and, in the post-test, it is reduced with a difference of six drawings. It seems that after the intervention they relate energy less to people. In addition, the

relationship with the first question was reduced in the post-test to 23, while in the pre-test it was 27.

In the data by groups, the results are similar to those of the data in general (annex VII). Even so, in the indicators of whether people appear and the relationship with Q1, there are notable variations depending to the group. Figures 8 and 9 show these indicators by groups.

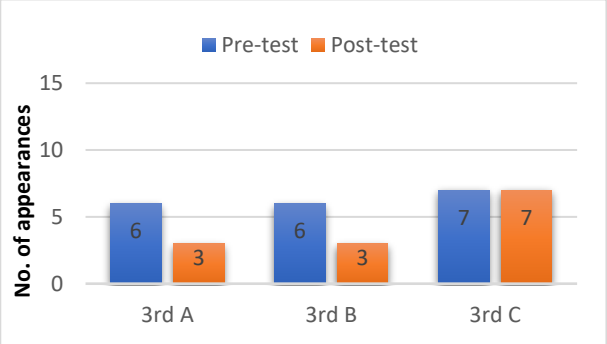

Figure 8: Number of drawings with people depicted by groups

In the section of people, the groups of 3rd A and 3rd B have reduced the number of drawings in which people appear by three, while in 3rd C the number has remained the same.

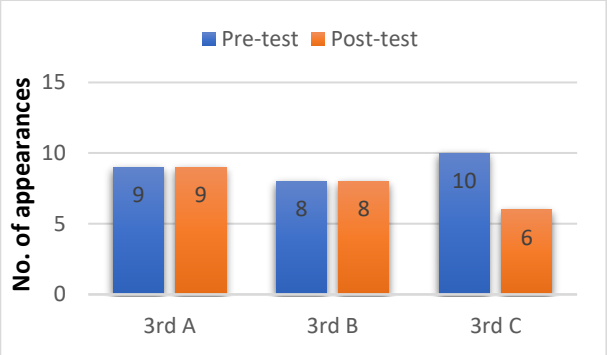

Figure 9: Number of drawings related with the answer in Q1 by groups

In the relationship between the drawing and Q1, only the number has changed in the 3rd C group, while the other two groups have not changed in this aspect.

Then, the elements that appear in the drawings are analysed. In figure 10, we will observe the elements that are repeated more than once in the pre-test or in the post-test because there are many that appear only once. The elements identified can be consulted in annex VII.

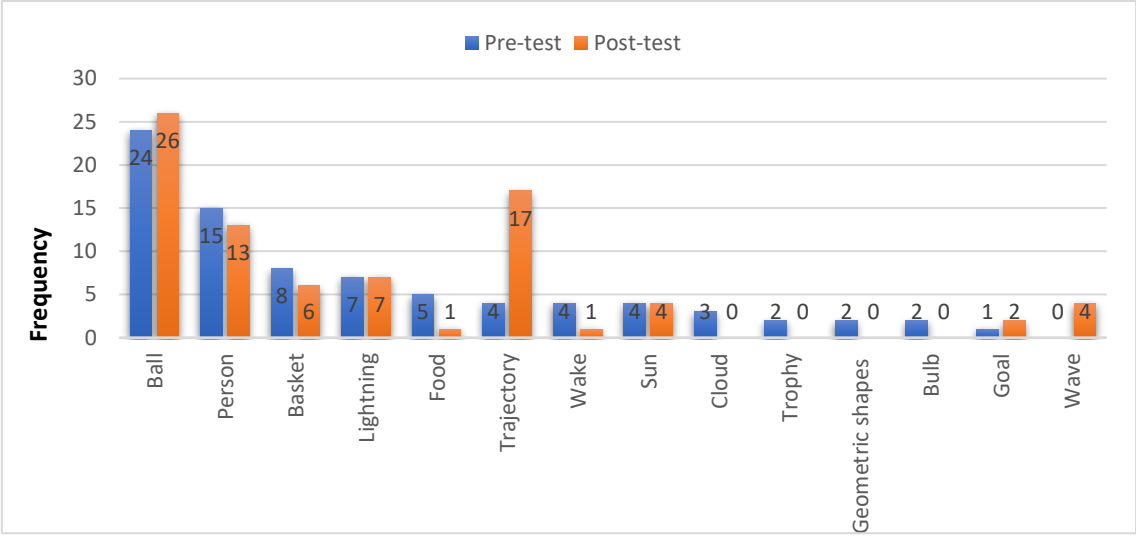

Figure 10: Elements appearing in the drawings that are repeated more than once in general

The elements that are most repeated between the pre-test and post-test drawings are very similar except for two elements that are added after the intervention: trajectory (+13) and wave (+4). Trajectory is by far, the one that has increased the most from pre-test to post-test. Also, wave, an element that did not appear in the pre-test, appears in four drawings in the post-test, being the second most changed.

This is an indicator that the intervention has brought these changes. From these data, it can be deduced that, at the end of the sessions, they relate energy with motion, mostly of balls or objects used during the sessions.

Regarding those elements that have also varied, there are those that have decreased in frequency such as food (-4), wake (-3), person (-2) and basket (-2), and among the others that have increased are ball (+2) and goal (+1). These small changes may be due to the fact that the drawings are more related to what we have done during the sessions and this has changed the drawings of the pre-test, which came from previous basketball sessions and therefore, the relationship with this sport.

In relation to the answers of each group, there are no significant differences between the most repeated elements, although the number of times they appear varies. In the pre-test, the most repeated words in 3rd A were balls, people and baskets; in 3rd B they were ball, wake and lightning; and in 3rd C they were person, balls and trajectory, in that order respectively. We can see how the initial idea of energy in each group was different. Then, in the post-test, in 3rd A they are balls, trajectory and lightning; in 3rd B they are ball, trajectory and sun/person; and in 3rd C they are balls, trajectory and person, in that order respectively. The three most repeated elements in each group are almost the same, only

the third most repeated changes, so it can be seen that at the end of the intervention, their idea of energy has changed and towards the same concept, approaching what has been worked in class. To see the most repeated elements in each group, see annex VII.

The form of energy and the source of energy in the drawings has been analysed, too. Since the mechanical energy of a body is due to the motion or potential motion of objects, it has been deduced whether or not there is any, taking into account the general idea of the drawing represented. In those where trajectories appear, it is clearer, but, especially in the pre-test, even if they do not appear, in all those that show some activity, sport or it can be deduced that there is motion (taking into account if they represent a moment of activities done in Physical Education), it has been identified as kinetic energy. Figure 11 shows the forms of energy that appear in the drawings.

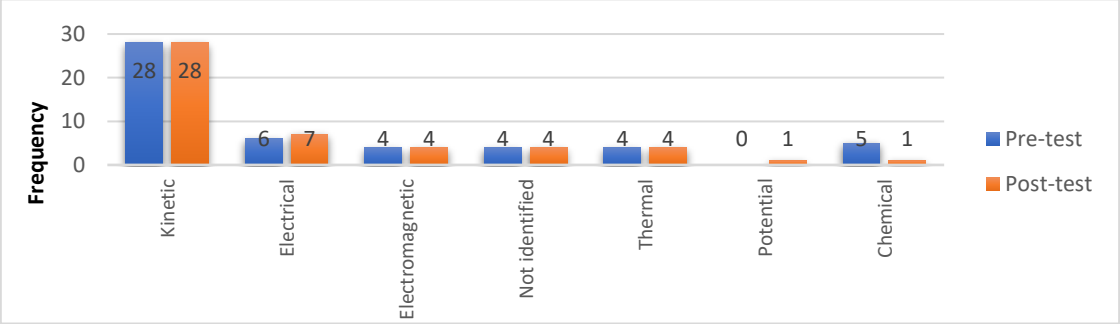

Figure 11: Forms of energy represented in the drawings in general

The most frequently appearing form of energy is kinetic energy. This may be due to the fact that it is the predominant form of energy in the subject Physical Education. The other forms of energy are less represented by a wide difference, except for chemical energy, which drops significantly in the post-test. In this section, there was almost no variation between the pre-post-test answers.

The sources of energy were also observed in the drawings, although in most of them they do not appear. These are shown in figure 12.

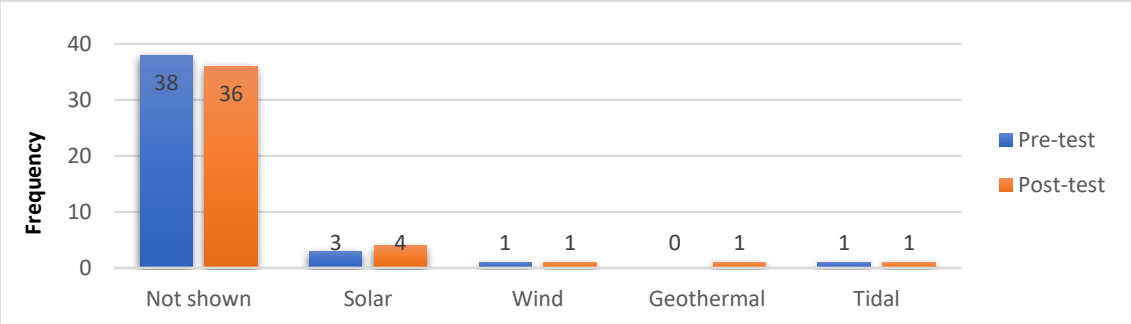

Figure 12: Sources of energy represented in the drawings in general

In these last two sections there is hardly any difference between the answers of each group and their analysis is very similar to the general one.

Researcher's diary analysis

Once the intervention had been carried out, as well we have evaluated the students' progress, it was possible to assess the sessions and the children's participation in them. In this way, data was collected about what worked, what did not work and proposals for improvement for future implementation of the intervention.

All of them have been collected in the researcher's diary and the proposals are based on experience. Their implementation depends on several factors, including the characteristics of the students, school, teachers, etc. Therefore, it is important to carry out an evaluation each time it is realised.

During the implementation, there have been changes in the activities that have been done due to contingencies or because it was considered a better option. In the researcher's diary (see annex III), all the changes made, the reasons for them and proposals for improvement for each session were recorded. The proposals are:

- Pre-test and post-test sessions:
  - **1)** Prepare activities in case there is time left over after the test.
  - **2)** Explain and clarify the videos or prepare them so that the information appears more slowly.
- 1st Session:
  - **3)** Add to the experiment the question: what would happen if you put the tennis ball on the bottom and the basketball on the top?
  - **4)** Modify the bouncing activity to make it more enjoyable. Make it shorter or add an objective that motivates the students.
  - **5)** Do the first activity in groups instead of pairs. It works and can be better controlled.
- 2nd Session:
  - **6)** Have the material ready before the session if possible.
  - **7)** Use the basket activity as a challenge. Before they start the activity, make it clear that they are starting it so that they are more motivated during the activity.
  - **8)** Set aside more time for the final experiment so that they can experience it themselves.
- 3rd Session:

9) Prepare the material before the session.

10) For each round of bowling, use only 2 minutes at the most.

11) Instead of having a competition as a second activity, continue with throwing the maximum score, but with the other ball to see the difference in points using one or other.

- 4th Session:

12) Leave the material ready before going to the playground. In this way, curling can be played on different surfaces as in the 3rd session.

13) After the activities in the playground use the last five minutes to reflect on the relationship between curling and degradation.

Conclusions

From the results we can conclude that the intervention has achieved the established objectives and has been beneficial for the students in both subjects. The three participating groups have improved their knowledge about energy while practising basketball and bowling. In addition, the students were motivated and curious to discover new concepts during the sessions, which is very positive as it may mean that it has awakened the interest of many for science.

During the sessions, it has been possible to observe these improvements in their learning. The pupils were able to compare the moments of different bodies (speed, mass or height) and identify which of them had more energy quite correctly, especially in the last sessions. Also, they were able to explain where the energy was transferred to during the activities, for example, when bouncing a basketball, they explained how the energy was transferred from their arm to the ball and then from the ball to the ground. Even, some children were more specific, saying that it warmed up the floor due to the degradation of energy. In addition, some students individually reflected and tried to explain other more complex events such as air friction, why from the hand to the ball motion is transferred to the ball and then heat to the ground, etc. Regarding their skills in sports, in only two weeks no significant changes can be observed in any sport, but it has been observed how they have been able to perform complicated exercises with ease that they could not do before in basketball. In basketball, a change can be seen because they have been working on it in previous weeks.

Even with these good results, in future implementations, when the COVID-19 prevention measures that limit the possibilities in the classroom are reduced and with more time and

coordination with the teaching staff of the subjects involved, in this case Natural Sciences and Physical Education, the contents could be worked in a richer and more extensive way. Therefore, the potential for interdisciplinary work in these subjects is high, as the possibilities offered by physical education and the benefit of personal experimentation in science complement each other perfectly. Even so, more studies are required to know its impact in depth in other contexts, with other ages and even with proposals for improvement previously mentioned.

I would like to end this conclusion with a quote from Galileo Galilei in which he mentions what has been done in this intervention and how I think science education should be worked. For me, science is not taught, it is discovered, and for this, personal experimentation should be encouraged in each student, and with a little guidance, they build their own knowledge.

"You cannot teach a man anything, but you can help him to discover it for himself" Galileo Galilei (1564-1642) (Palomo, E., 2013).

Limitations, proposals for improvement and future lines of action

Before carrying out the intervention, the limitations and facilities available at the centre must be taken into account. Based on these, the sessions are adapted to achieve the greatest possible positive impact on the participating students.

This intervention was carried out during the pandemic caused by COVID-19, so we had to take into account the centre's prevention measures and protocols to avoid contagion. In this situation, one of the risks was that, during the intervention, several pupils were likely to be absent due to quarantine. Among the measures that most limited the intervention was the washing of hands after each session, which had to end five minutes earlier to allow enough time. In addition, a distance of one and a half metres between students should be respected as far as possible. The gym could not be used for activities either, as it was agreed at the beginning of the course not to use it as it is an enclosed space with poor ventilation. Finally, as three breaks have been created (one for each cycle), when it was time for Physical Education in the 4th hour, it wasn't possible to go out to the playground for the first half hour because it was occupied by the children of other cycle.

Although there were some limitations, there were also facilities that allowed the sessions to be implemented. To carry out the sessions, there were two teachers in total (tutor and trainee student). This was a great help to organise the sessions, the material, managing

the class... Also, another measure that has been positive for the intervention has been the splitting of the classes, thus reducing the number of students per group.

The ideal moment to do the intervention is when the students are working the energy in Natural Sciences. Thus, the Science and Physical Education sessions can complement each other and probably lead to better results for the pupils. During our intervention this has not been possible due to lack of time.

Nevertheless, the intervention had promising results for future implementation. With the proposals described before in the section of results and, if more resources or other facilities are available, I believe that better results can be obtained. Furthermore, by making the appropriate adaptations, it could be implemented in higher grades to study the impact on students of other ages.

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Annexes

Annex I: Questionnaire used for the pre-test and post-test

Test: Energy in sport

1) Escribe la palabra que, para ti, esté más relacionada con la energía.

_____

2) ¿Por qué las pelotas de baloncesto botan tanto?

a) Por ser grandes.
b) Por ser pesadas.
c) Por ser elásticas. (CORRECT ANSWER)
d) No depende de la pelota, depende sólo de la fuerza con la que se bote.

3) ¿Por qué las bolas de bolos son capaces de derribarlos con tanta facilidad?

a) Por ser grandes.
b) Por ser pesadas. (CORRECT ANSWER)
c) Por ser elásticas.
d) La facilidad para tirar los bolos no depende de la bola.

4) ¿Qué crees que pasaría si cada bolo tuviera una masa de 1000kg?

a) Podríamos tirarlos igual que si pesaran menos.
b) Sería mucho más difícil tirarlos. (CORRECT ANSWER)
c) Sería completamente imposible tirarlos.
d) Sería más fácil tirarlos.

5) Tres compañeros tiran hacia arriba, en vertical, lo más fuerte que pueden, una pelota de baloncesto. La pelota de Juan llega alcanzar 5m de altura, la pelota de Victoria los 7m de altura y la de Jose Luis alcanza los 3m de altura. ¿Cuál de estas pelotas tiene más energía y, por lo tanto, tocará el suelo a mayor velocidad?

a) La pelota de Juan.
b) La pelota de Victoria. (CORRECT ANSWER)
c) La pelota de Jose Luis.
d) Las tres tienen la misma energía.

6) ¿De qué material harías tú el suelo de las canchas de baloncesto para que la pelota bote mejor?

a) De madera o cemento. (CORRECT ANSWER)
b) De césped.
c) De arena.
d) Da igual la superficie, en todas ellas la pelota bota igual.

7) Tenemos 3 pelotas. Una bola de bolos de 5kg, una de gomaespuma de 0,5 kg y una de goma de 1 kg. Si lanzamos las tres pelotas a la misma velocidad hacia una fila de bolos ¿cuál de ellas tiene más energía permitiendo así tirar más bolos?

a) La bola de bolos. (CORRECT ANSWER)
b) La pelota de gomaespuma.
c) La pelota de goma.
d) Las tres pelotas tiran los mismos bolos.

8) Si dejamos caer una pelota de tenis, una de baloncesto y una de bolos, ¿cuál crees que llega antes al suelo en igualdad de condiciones?

a) La de baloncesto.
b) La de tenis.
c) La de bolos.
d) Las tres a la vez. (CORRECT ANSWER)

9) Cuando dejamos caer una pelota desde una altura determinada, podemos ver que cada vez alcanza menos altura en cada bote hasta que termina parada en el suelo. ¿A qué se debe esto?

a) Va botando menos porque se le gasta la energía.
b) Cada vez que bota, utiliza su energía para subir de nuevo hasta que se queda sin energía.
c) Se debe sólo a la gravedad.
d) En cada bote, parte de la energía se degrada. (CORRECT ANSWER)

10) Si lanzamos, a la vez, una pelota rodando en cada una de estas superficies, ¿en cuál de ellas se detendrá antes?

a) Un suelo de cemento.
b) Un suelo de arena. (CORRECT ANSWER)
c) Un suelo de madera.
d) En todas a la vez.

11) ¿Qué pasa con la energía que tiene una pelota de baloncesto cuando la estamos botando?

a) La pelota gasta energía en cada bote y cada vez que le empujamos la recargamos de energía.
b) En cada bote y cada vez que empujamos la pelota, no varía nada su energía.
c) En cada bote la pelota transfiere energía al suelo y cuando la empujamos con la mano, le proporcionamos energía. (CORRECT ANSWER)
d) En cada bote, la pelota se recarga de energía.

12) Dibuja cómo imaginas la energía.

Annex II: Sessions

Pre-test session

1) Introduction of what is going to be done.
2) Play the introductory video.
3) Explanation of the test and doubts.
4) Pre-test (30 minutes).
5) Play the second video presenting the sessions.
6) Final doubts.

If there is a lot of time left over, students can go to play a basketball game.

If time is short, a video on the concept of energy can be shown.

Session 1: Starting with "energy" in basketball
Objectives: 1) To identify energy in basketball practice. 2) To relate mass, speed or position (height) to energy. 3) To justify, in terms of energy, why the court and the basketball have the characteristics they have. 4) To predict the best way to execute an action in basketball.
Materials: **1) Warm-up:** • Basketballs • Foam rubber balls • Small beach balls or footballs **2) Main part:** • Basketballs • Foam rubber balls • Small beach balls or footballs • Two basketball baskets or basket boxes • Medium cones **3) Calm down:** • Tennis ball • Basketballs

Question: Where do you think we can find energy during today's session?		**Session time:** 45 min
Warm-up	**Passing and movement** **Organisation**: In pairs. **Development**: Each pair will move around the court with the ball while making passes. First, they will do it with a rubber ball. They will have to make chest passes and bouncing passes, as they prefer, but doing both. Later on, they will change balls and do the same activity with different balls until they reach the basketball ball. 1) Foam rubber ball 2 min. 2) Beach ball 2 min 3) Basketball 2 min	**10 min**
Main part	**Organisation:** 2 large groups (one with each teacher). **Development:** For these activities the class will be divided into two groups (one for each teacher). Each group will work on one part of the track.	**20 - 25 min**
	Displacements with boats: In the first activity they will be placed in 2 rows depending on the number of students. They will be placed one in front of the other and will start with a foam ball. They will move with boats in a straight line and later in a zigzag pattern. 1) Foam ball 2) Beach ball 3) Basketball	10 min
	Throws of choice: For this activity, a line will be placed in front of each basket. Throws to the basket will be made where they will be able to choose the ball, they will try to make a basket with.	5 - 10 min
	Group challenge: To overcome this challenge, they have to overcome a number of baskets in the time given by the teacher. It must be one that is challenging but that they can achieve. For example: Make 10 points with the basketball, 5 with the foam basket and 8 with the beach basket.	5 min

Cool-down	**Experiment, reflections and explanations** **Organisation:** Large group. Seated in a semicircle. 1) Carry out the experiment. https://www.youtube.com/watch?v=j1PBUhNiJyg 2) Answer the initial question. With their contributions and with what they have done in the session, they will explain the concept of energy. 3) Questions about what happened in the session: Examples: • Which ball was the best for the exercise, why? • What does what we have just done have to do with energy? • Why do you think some were more difficult than others?	**10 min**

Session 2: Conservation of energy in basketball

Objectives:

1) To associate changes in the motion, trajectory and speed, of basketballs with energy transfer.
2) To identify the transfers and transformations of the energy of the basketball.
3) To justify the conservation of energy.

Materials:

1. **Warm-up:**
   - One or more basketballs.
2. **Main part**

   2.1. First game:
   - Basketball

   2.2. Second game:
   - Basketballs.
   - Large boxes (4).
   - Baskets.
   - Hard wall.
   - Hoops.
   - Barrier made of sticks and cones.
3. **Cool-down:**
   - Balloons.

	• Pins.	
Question: What does it mean: "energy is neither created nor destroyed, it is only transformed"?		**Session time:** 45 min
Warm-up	**Basketball Pac-Man** **Organisation:** Large group **Development:** In this activity, one or more children will keep the ball. They have to move around while they are bouncing the basketball. The participants can only move along the lines painted on the floor.	**10 min**
Main part	**Organisation**: Large group (2 groups, one per teacher). **Development:** Each group will be a team. They will have to score as many points as possible and they will write them down or remember them in order to compare both results later.	**20 - 25 min**
	Attack in superiority: With the basketball. They will attack the basket with defence. The attacks will be 3vs1, 3vs2 or 4vs2, depending on the performance of the children.	10 min
	Shooting baskets or boxes with different trajectories: In this activity, there will be three baskets available for shooting: - The first one, will be near to the wall where the shooter will have to make a throw where the ball bounces off the wall and basket in the box without touching the floor. - The second must be made with a dive shot aimed at the inside of a hoop, bouncing only once and basket in the box. - - The third one will be made over the top of a barrier with a pumped shot. Once they have shot in a row, they move to the next one, passing through all the posts.	10 min
	Group challenge: They have to pass all the balls from one box to another in the time indicated. They will go one by one as if it were a relay race. If they drop the ball, they must return the ball to the box at the start.	5 min

Cool-down	**Balloon experiment with pins** **Organisation:** Large group, seated in a semicircle. 1- Realization of the experiment: https://www.youtube.com/watch?v=orXZgrqOUkU 2- After that, the pupils will give some of their answers to the initial question. 3- Finally, questions will be asked about the session in which the children will contribute their reflections on what they have experienced in relation to energy during the session.	**10 min**

Session 3: Influencing variables on bowling energy

Objectives:

1) To estimate the energy each ball can have according to its mass and the speed it can reach.
2) To identify the external variables that can influence the speed and trajectory of a rolling ball.
3) To calculate which pins or cones can be knocked down taking into account the characteristics of the ball, the pins and the surface on which they are located.

Materials:

1. Warm-up

- Foam rubber balls

2. Main part

2.1. First game

- Foam rubber footballs.
- Mats.
- 30/36 spins/cones - 12 heavy spins, 12 normal spins and 12 light spins.

2.2. Second game

- Foam footballs
- Beach/light balls
- Medicine or heavy balls
- 30/36 spins

3. Calm down

- Medicine ball

	- Tennis ball - Wooden/plastic board (optional) - Paper - Book or similar	
Question: How do you know that one body has more energy than another?		**Session time:** 50 min
Warm-up	**Play tag (Pilla-pilla) with a ball** **Organisation:** Large group **Development:** To start the session we will play a small introductory game with throws where we will play tag with a ball. One or more students will catch with the ball. To catch the others, they will have to hit with the ball. Once they have hit one, he or she will keep the ball and the one who has caught will run away.	**5 min**
Main part	**Organisation:** Two large groups and, within each group, small groups (4 or 5 students). **Development:** Both groups will work simultaneously.	**30 - 35 min**
	Throwing on different surfaces: In each large group there will be 3 "corridors" with a floor of different material (concrete, mat, earth/grass). The groups will rotate and each group will do the activity at least once in each position. The activity will consist of knocking down all the objects at the end of the "corridor". It will not be a competition; it will be teamwork. Two members of the group will be the throwers who will have to take turns in each throw and the other two members will be the spins collectors who will be in charge of placing the spins that have managed to pull. Their aim is to score as many points as possible. Each pin and object will have a score. It is up to them to decide whether it is better to quickly throw the lowest scoring and easiest pins or to go for the highest scoring pins. They have 1-2 min (depending on the time available) to score as many points as possible. The start and finish signal will be given by the teacher.	10 min (2 min. approx. each post)

	Throwing with different balls: For the next activity, we will change the posts. Now in each of them, there will be a different type of ball. As in the previous activity, there will be three posts on each side. Each group will work simultaneously on each post, but this time, each group will have a competition in pairs (2 vs 2). They will spend about five minutes on each post. The teacher will give notice of the change.	15-20 min
	Group challenge: The whole class, or each large group, should agree and a spokesperson from each group will answer the question: Which surface and ball are the best for bowling, and why? To decide the question, they can experimentally try it themselves to draw conclusions. They have 5 minutes to get an agree.	5 min
Cool-down	**Gravity experiment** **Organisation:** Large group **Development:** 1- Realization of the experiment with the balls, using a sheet of paper and a book: https://www.youtube.com/watch?v=mrVT3r2Yonc 2 - The pupils will give some of their answers to the initial question. 3 - Finally, the children will share their reflections on what they have experienced in relation to energy during the session and may be asked questions to help them think.	**10 min**

Session 4: Degradation in bowling
Objectives: 1) To relate the loss of speed of the balls with the degradation of the energy. 2) To identify when and in what ways the energy of moving balls is degraded. 3) To analyse the balls and surfaces with the lowest loss of useful energy.
Materials **In class:** - Computer and projector. - Links to videos and websites.

- One or two balls. **In the playground:** - Foam rubber balls or similar. - Ropes/hoops. - Different surfaces (cement, grass, mat...).		
Question: Do all movements produce heat?		**Session time:** 55 min
In class	**Experiment of the degradation of mechanical energy into heat**: We will start the class with this experiment. To relate it to sport, we will also use one or more balls.	10 min
	Show video that it is possible to cook a chicken or steak by pounding, exaggerating the energy degradation: https://www.youtube.com/watch?v=LHFhnnTWMgI	5 min
	Afterwards, they will be shown a simulation of how energy varies with friction and how it degrades as heat to the environment, completing the previous explanation. **Skate Park**: https://phet.colorado.edu/en/simulation/energy-skate-park-basics **Pendulum**: https://phet.colorado.edu/en/simulation/pendulum-lab	5 min
	With this, we will be able to explain the reason why balls stop rolling when we throw them or stop bouncing when they fall.	5 min
In the playground	**Organisation:** Two large groups. Small groups will be formed in each group. **Development:** Different posts so that as many groups as possible work at the same time.	**25 min**
	Curling with bowling balls: In this activity, they will throw the balls at a target on the ground. The targets will be made with ropes or hoops. It is a variant of curling. They will play in trios or in pairs and all at the same time, if it is possible. They will not play on the same surface. They will be in different fields spread over different surfaces that can be found in the playground. After each game, they will go to another surface with a different surface.	10 - 15 min

	Group challenge: In this challenge, the whole class will join together to meet the challenge set by the teacher. The whole class will stand behind a line with a ball each one. The teacher will indicate or place an area where the balls should stay. The children have to throw the ball as in the previous activity, making sure that the ball stays in the designated area. They will pass the challenge if the number of balls in the area exceeds the number of balls indicated by the teacher. There can be several attempts.	5 - 10 min
Cool-down	Finally, in a semicircle, the children will reflect about what they have done during the session. They will relate what was said in class with what they have experienced. Also, there will be time to ask questions about the topic.	**5 min**

Post-test session

1) Explanation that the sessions have finished.
2) Explanatory video of the last test and review of the sessions done
3) Explanation of the test and doubts.
4) Realization of the post-test (30 minutes).
5) Final questions.

If there is a lot of time left over, they can choose a game to play.

If there is not much time left, they can select and play a related video.

Annex III: Researcher's diary

Pre-test session

The sessions took place in all three groups. They all received the initiative with curiosity, but with the videos and explanation they could not grasp much of what the training was about, or at least that was my feeling.

In general, they understood that they were going to do some special sessions that would bring science and sport together. Some were disappointed with the initial test, but that's because they think Physical Education classes would be done in the classroom.

All those who attended took the test. Several were absent due to quarantine due to COVID contact in the school. They will not take the initial test, but will take the final test.

Aspects to improve from pre-test session:

1) To prepare introductory activities in case there is time left over after the test.
2) Explain and clarify things in the videos or prepare it to give information more slowly and better.

Session 1: Concept of energy - Basketball

In general, the three groups were very involved in the session. They all paid attention to what they were doing because of themselves and because of questions asked by the teachers during the activities.

Tuesday 20th. 3rd A. Very well. The zigzagging activity at the end, they were getting a bit bored, but we changed quickly before the class was bored.

They did the zigzag activity only with the basketball and the rubber ball because with the beach ball it could be very frustrating because it is hardly to bounce.

The experiment went very well. It was fun and they reasoned very well what happens. For example, how energy passes from the basketball to the tennis ball, why one ball has more energy than the other and more reflections on what they have done during the session.

During the experiment they wondered what would happen if instead of putting the basketball down, they put it up, they made hypotheses and one child was able to predict what was going to happen.

Tuesday 20th. 3rd C. Very well. The first activity was done in groups instead of pairs.

The activity of displacements, as before, was a bit long for some of them.

The experiment was also very good. Everyone was very impatient and curious to know what was going on and, moreover, they were able to explain on their own what happened

and other situations that appeared during the session. They have also asked themselves what would happen if instead of putting the basketball down, they put it up.

Wednesday 21st. 3rd B. Very well. The first activity was done in groups instead of pairs as it worked better with the previous group. They were better organised and it was easier to control.

The class was very involved in the session and enthusiastic. They even asked questions and tried to explain them during the activities.

In the experiment everyone was especially participative and with very clear ideas. Almost everyone answered at the same time and wanted to contribute new ideas. They managed to explain the experiment and other characteristics of the energy-related bodies they worked with during the session. They did not ask what would happen if the balls were turned upside down at the time of the experiment, but on the way back to class in the line, they commented on it, but they could not see it.

Aspects to improve from session 1:

1) Add in the experiment the question: what would happen if you put the tennis ball at the bottom and the basketball at the top?
2) Vary the bouncing activity a bit to make it more enjoyable.
3) To do the first activity in groups instead of pairs. It works better and they can observe what is happening while the other children are doing it.

Session 2: Conservation of energy. Transformation and transfer - Basketball

Thursday 22nd. 3rd C. Very well. We started with the initial question. Everybody was very curious and tried to answer the question afterwards.

The warm up was good. It was used to prepare all the material for the following activities.

In the attack defence, it went well. At the beginning it was a bit difficult for them but after a while, they did the activity well without help. It was a bit longer while we were preparing the material.

They liked the baskets with different shots. The activity seemed slow but they didn't get bored during the activity.

There was not enough time for the planned challenge, but they were challenged to score more than 100 points in the same activity.

Afterwards, they have been providing good reasoning about what the initial question meant and about the conservation of energy. After the experiment, some of them predicted

what was going to happen and others doubted, but they checked that what some of their classmates said was true and they finally found why between all of them.

Friday 23rd. 3rd B. Very well. We started with the initial question and some of them already knew the sentence: "Energy is neither created nor destroyed, it is only transformed".

Warming up well. Preparation of materials.

Attack-defence was difficult to understand at the beginning, but as time went by and with the help of the teachers, they improved in the activity. They were separating to receive the ball, defending each other, etc.

Then the different baskets went very well. It was a challenge for many of them and some of them were trying different ways of shooting until they managed to make more baskets. We didn't do the final challenge as the other class didn't do it and we did the same. To get over 100 points between all of them.

Finally, they tried to answer the question at the beginning and they said interesting things like "energy always comes from somewhere", referring to the fact that things only move if something transfers energy to them.

Then the experiment, some of them had already seen it but did not have the full explanation. After the performance, they managed to explain it. One child explained that "the energy of the balloon is shared with all the pins, making each one has less energy". From this, most of them have reasoned why with one pin it explodes and with many it does not.

Friday 23rd. 3rd. Well. We started a bit late and we were short of time. Before going out to the playground we did the initial question in class.

The warm up went well. They did the activity with one more child because one child was not doing well.

The defence-attack was difficult at the beginning, and when they were improving, because of the time, we had to stop the activity earlier than in the previous classes.

Then in the baskets, it went well. It was a challenge for everyone to put the ball in the different baskets. This activity was also shorter than the other classes to allow time for the children to calm down. They did the same challenge as the previous classes.

When it came to answering the initial question, at the beginning, they had problems relating what they had done to the energy, but later, with some clues, they were able to give some answers. In the experiment, some of them managed to predict what was going to happen and later, they got the explanation with the key contribution of a pupil "as there

are many pins, it is distributed among all the pins, it transfers the energy to all the pins, as if it were distributed among all of them".

The fuss at the end and the difficulty of reasoning was probably due to the fact that it was late on a Friday, a time when children are usually more excited.

Aspects to improve from session 2:

1) Use the basket activity as a challenge. Before they start the activity, make it clear that they are starting the challenge so that they are more motivated during the activity.
2) To have the material prepared before the session if it is.
3) Set aside more time for the experiment so that they can experience it themselves, although in one hour it is difficult to do everything at once.

Session 3: Variables that determine the energy of a body - Bowling

Monday 26th. Class 3º C. Very well. Although we were short of time, we had to modify the session a bit. At the beginning we have asked them about things from previous sessions to review a little bit what we have to do in order to make the session better. Then, they were asked the question about which variables determine the energy of a body.

The warm-up went well. Time to prepare the material for the next activity.

In the next activity they were very motivated all the time. At the beginning, I had given three minutes for each track, but it was too much time as they got tired so I reduced it to 2 min. They kept count, more or less, the points they were making.

In the next game they were going to do competitions between the members of the group, but we decided to just change the ball and do the same activity so that they could see the difference in points they made with one ball and the other.

In the final reflections, they came up with several interesting reflections and, in response to the question at the beginning, they came up with the following variables: speed and weight (mass). Later, in the experiment, they were unable to predict what was going to happen. It was difficult for them to understand why they fall at the same time if one weighs more than the other, but in the end, I got the feeling that they were able to understand that gravity affects all bodies equally, it does not depend on mass.

Monday 26th. Class 3rd A. Very well. We had more than with 3rd C, but we did the same session so that everyone did the same activities.

The warm up went well. Time to prepare the material for the next activity.

The next activity was very good, everyone liked it and they were all very motivated. The difference in points between one ball and another was very noticeable and even the children said it during the game.

In the final reflections, they made several reflections why it was more difficult with one ball and less with another, and in answer to the question at the beginning, the following variables were mentioned: speed, weight (mass) and height (explaining that the higher the ball is, faster it reaches the ground). In the experiment, everyone was surprised to see that all the bodies reach the ground at the same time, but they saw that this is because it does not depend on the mass.

Wednesday 28th. 3rd B. Very well. We didn't warm up the class to have more time to go. The activity went very well and dynamic. Everybody participated and kept motivated during the activity. The change of balls was taken as a challenge and they kept the same enthusiasm during the whole session. They were able to clearly see the difference between one ball and another through their experience and by counting the points obtained in each round.

Answering the question at the beginning, they have learned that the variables that determine the energy of a body are: speed and weight (mass).

The experiment went very well, everyone was surprised to see that all things fall at the same time regardless of their mass. After the experiment, they deduced that another variable of energy is height.

Aspects to improve from session 3:

1) Prepare the material before the session because a lot of time is wasted in preparing the material.
2) For each round of bowling, use only 2 minutes at the most.
3) Instead of doing a competition as a second activity, continue with throwing the maximum number of pins, but with another ball to see the difference in points of using one ball or another.

Tuesday 27th, session postponed due to rain.

Session 4: Energy Degradation - Bowling

Monday 26th. 3rd B. Very well. In class, most of the children participated in the activities and questions we asked about energy degradation. They have experimented and made good reflections on what was happening.

The video caught their attention and the simulation, too. In the simulation, they drew good conclusions and by themselves they got interesting facts that I didn't mention, such as that the potential and kinetic energy varied depending on where they were and, “the harder the blow, the hotter it was ".

In the playground it went very well, too. They have been able to do mini-competitions among themselves, but it has been done on the same surface due to lack of time. Finally, the challenge was completed successfully.

Thursday 29th. 3rd C. Well. It seemed that they didn't feel like being in class or that they thought it was difficult and they stopped paying attention in some moments.

In the experiment of warming up the hand, everyone could see that movement causes heat, but it was difficult for them to relate that any movement of anything "produces" heat, that is, that part of its energy is degraded.

The video attracted their attention and they asked several questions about the video. In the simulation, they saw more about the degradation of energy, observing how when bodies slow down it is because their mechanical energy is degraded by heat.

Then, in the playground, went well. They did the activity in pairs and competed against each other. Later, they liked the challenge, although they needed several attempts and it lost a bit of difficulty and motivation for some of them.

Friday 30th. 3rd A. Well. Some children were a bit nervous, especially one boy who kept shouting, which was disrupting the class a lot. Even so, several children participated and, at the end, I felt that they had grasped the main idea that energy degrades by heat. They said interesting things like "if something goes faster and collides, it heats up the wall more than something that goes slower" or also, during the Skatepark simulator, they realised that the sum of mechanical energy plus thermal energy resulted the total energy of the system (the energy at the beginning).

Then in the playground session it went better. They got into trios and played curling before the challenge. They managed to overcome the challenge and all the time maintaining their motivation.

Aspects to improve from session 4:

1) To leave the material ready before going down to the playground. If there are two teachers, one should go down to set up the materials. This way, they can play curling on different surfaces as in session 3.

2) Even if it is spent half an hour in class, after the activities in the playground, try to have at least five minutes to talk about how what we have seen in class relates to what we have done.

Post-test session

Friday 30th. 3rd B. Well. I had the feeling that they have done the exam too fast or without motivation because there were wrong answers from children that during the sessions they had said correctly and reaching good conclusions.

Monday 3rd. 3rd A and C. In the other groups more emphasis has been put on them concentrating on the test so that they get it as good as possible.

Aspects to improve from post-test session:

1) Give them free play after the post-test as a reward or prepare activities that review what was given during the sessions (something to motivate them to do the test the best as possible).

Annex IV: Tables with Q1 and multiple-choice answers of each participant

3rd A group

Pre-test

P\Q	1	2	3	4	5	6	7	8	9	10	11	Correct answers
1	Ciencia	D	D	C	A	A	A	C	B	B	C	4
2	Poder	D	D	C	B	D	A	A	D	B	D	4
4	Sol	C	B	C	B	A	A	C	A	D	A	5
6	Ilusión	D	D	B	B	D	D	C	A	B	D	3
7	Deporte	D	D	A	C	A	D	A	C	B	A	2
8	Deporte			B		A	A	B		C		3
9	Comida	A	B	B	C	D	A	D	A	D	D	4
10	Deporte	D	D	A	B	D	A	B	C	B	D	3
11	Electricidad	D	D		B	D	C	B	B	B	A	2
12	Rayo	D	A	A	B	A	A	C	B	B	D	4
13	Proteínas	D	B	C	B	D	C	C	D	A	A	3
14		C	B	B	B	D	A	C	A	B	A	6
15	Movimiento	A	B	C	B	A	A	A	C	A	A	4
16	Correr	D	D	B	B	A	A	B	B	B	A	5
17	Ilusión	D	D	B	B	A	A	C	B	B	C	6

Post-test

P\Q	1	2	3	4	5	6	7	8	9	10	11	Correct answers
1	Ciencia	D	B	C	D	A	A	C	D	B	C	6
2	Velocidad	D	D	C	B	D	A	C	B	A	C	3
4	Energía	C	B	C	B	A	A	D	D	B	C	9
6	Rendimiento	D	D	B	B	A	A	D	A	A	A	5
7	Rayo	D	D	A	D	A	A	D	D	B	C	6
8	Deporte	B	B	B	B	A	D	D	D	B	C	8
9	Baloncesto	A	B	B	B	B	A	D	B	C	A	5
10	Deporte	D	D	C	B	A	A	D	D	B	A	6
11	Rapidez	D	D	C	B	A	C	A	B	A	C	3
12	Rayo	D	A	A	C	A	A	C	A	B	A	3
13	Transformación	D	B	C	B	A	B	C	D	B	A	5
14	Calor	D	D	B	B	B	A	D	A	B	A	5
15	Movimiento	C	B	C	B	A	A	D	A	B	C	8
16	Correr	D	B	B	C	A	A	B	D	B	A	6
17	Ilusión	D	D	C	D	A	A		B	B	A	3

3rd B group

Pre-test

P\Q	1	2	3	4	5	6	7	8	9	10	11	Correct answers
2	Fuerza	D	B	C	B	A	A	C	A	B	D	**5**
3	Rayos	D	B	B	C	A	A	C	C	B	C	**6**
4	Felicidad	D	B	B	B	D	A	B	A	C	C	**5**
5	Movimiento	D	B	B	B	A	A	C	C	B	A	**6**
8	Bolos	D	B	C	B	A	A	D	C	A	C	**6**
10	Correr	D	D	B	D	D	D	D	A	B	D	**3**
11	Marcha	D	A	C	B	D	A	C	B	D	A	**2**
12	Correr	D	B	B	B	A	A	C	D	A	C	**7**
13	Deporte	B	D	B	B	D	A	A	D	B	D	**5**
15	Deporte	C	B	B	B	A		B	D	B		**7**
16	Deporte	B	D	A	B	B	C	B	A	B	B	**2**
18	Electricidad	B	A	B	B	A	A	C	A	B	D	**5**

Post-test

P\Q	1	2	3	4	5	6	7	8	9	10	11	Correct answers
2	Fuerza	C	B	B	B	A	A	C	A	B	C	**8**
3	Rayo	C	B	B	B	A	A	D	D	B	C	**10**
4	Felicidad	D	B	B	B	D	A	B	D	C	C	**6**
5	Sol	C	B	B	B	A	A	C	A	B	A	**7**
8		D	B	C	B	A	A	C	B	B	D	**5**
10	Correr	D	D	B	B	D	A	C	A	B	A	**4**
11	Rayo	C	B	A	C	D	A	C	B	D	C	**4**
12	Energía	C	B	D	B	A	A	C	B	A	A	**5**
13	Velocidad	B	B	B	B	A	A	A	A	A	A	**5**
15	Bote	D	B	B	B	A	A	C	D	B	C	**8**
16	Pelota	B	B	B	B	A	A	C	A	A	A	**5**
18	Fuerza	C	B	B	B	A	A	C	D	B	C	**9**

3rd C group

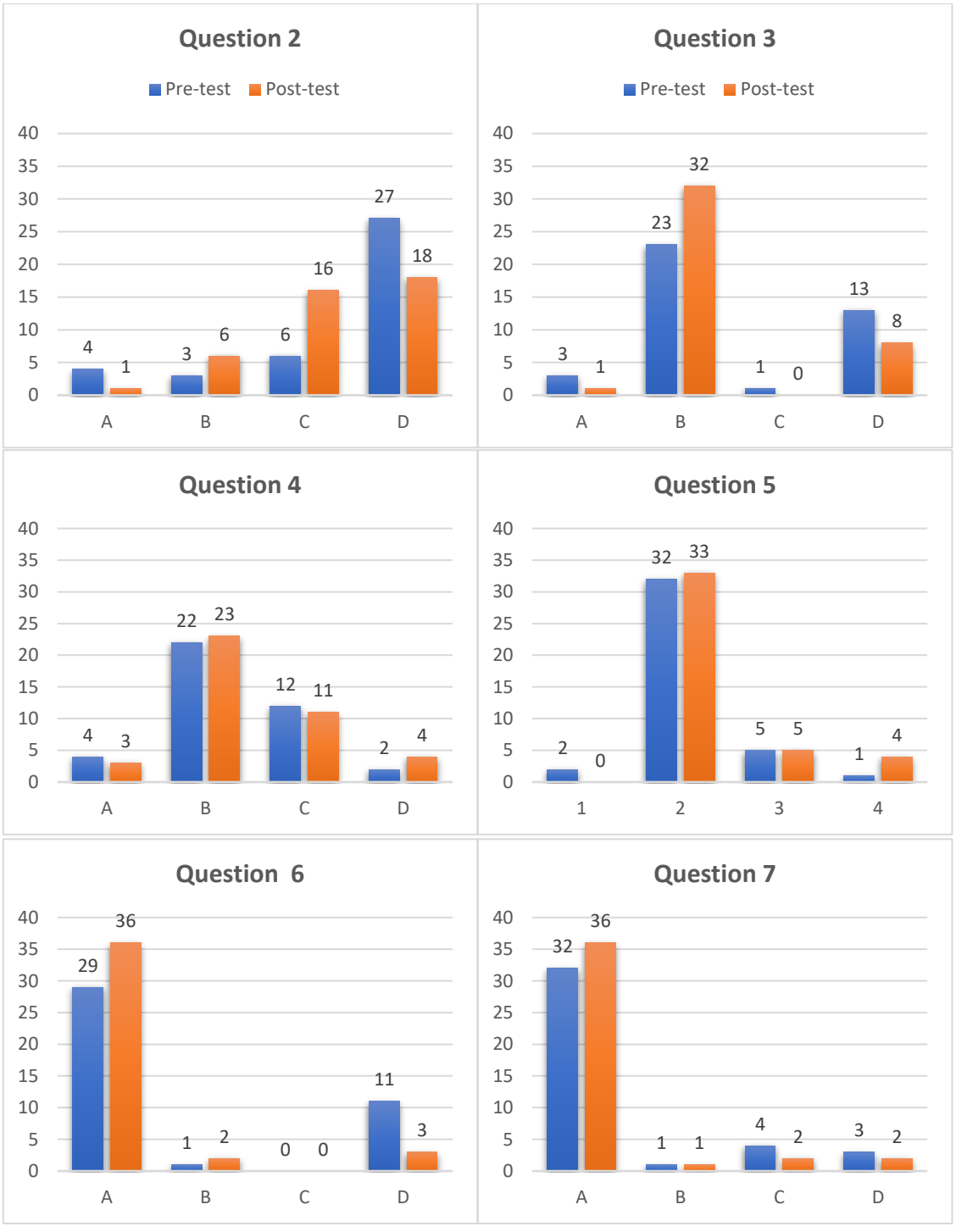
Pre-test

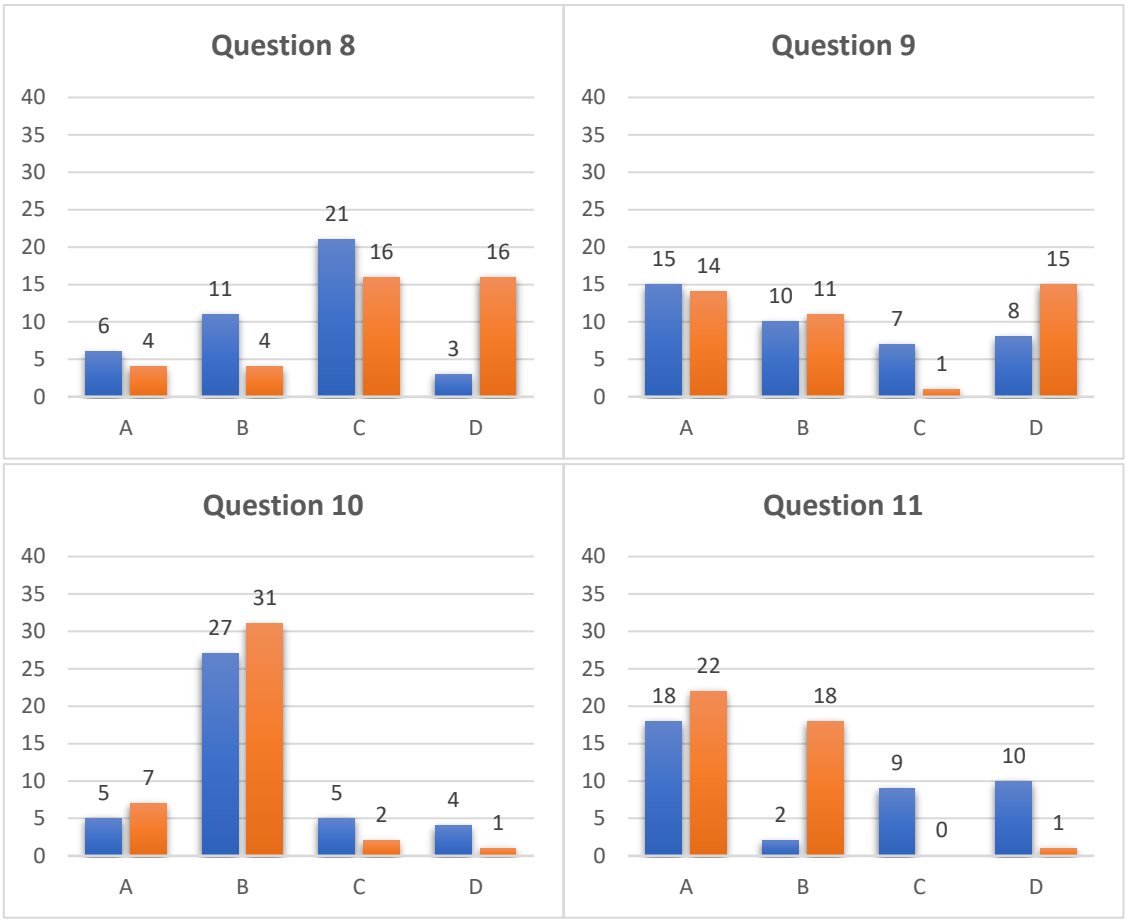
P\Q	1	2	3	4	5	6	7	8	9	10	11	Correct answers
1	Salud	D	B	C	C	A	A	C	D	B	A	**5**
2	E=mc2	D	B	B	B	A	A	B	A	B	B	**6**
3	Alegría	D	B	B	D	A	A	C	D	B	C	**7**
4	Correr	D	D	C	B	A	A	C	B	B	C	**5**
5	Dormir	C	B	D	B	A	C	B	C	D	D	**4**
6	Sano	D	B	B	B	A	A	C	B	B	A	**6**
7	Potencia	D	B	B	B	A	A	C	B	B	D	**6**
8	Luz	C	D	C	A	A	A	C	A	C	A	**3**
9	Velocidad	A	B	B	B	A	A	C	A	B	A	**6**
10	Correr	D	B	D	C	A	A	B	D	C	C	**5**
11	Velocidad	D	D	B	B	D	D	B	B	B	A	**3**
13	Superación	C	B	B	B	A	A	A	A	B	A	**7**
14	Fuerza	D	C	B	B	A	B	D	A	B	A	**5**
15	Sanidad	D	B	B	B	A	A	C	A	A	A	**5**
16	Fuerza	A	B	C	B	A	A	A	A	C	A	**4**

Post-test

P\Q	1	2	3	4	5	6	7	8	9	10	11	Correct answers
1	Salud	C	B	D	C	A	A	D	D	B	A	**7**
2	E=mc2	D	B	B	B	A	A	D	D	B	C	**9**
3	Potencia	B	B	C	C	A	A	C	A	B	A	**4**
4	Cuando botas una pelota	D	B	B	D	A	D	C	D	B	A	**5**
5	Balón de energía	D	D	D	B	A	A	A	A	B	C	**5**
6	Salud	C	B	B	B	A	C	B	B	B	A	**6**
7	Rapidez	B	B	B	B	A	A	C	B	B	A	**6**
8	Pelota	C	B	C	B	A	A	D	A	B	A	**7**
9	Velocidad	C	B	B	B	A	A	D	C	A	C	**8**
10	Ser rápido y saltar mucho	D	B	D	B	A	A	B	B	B	A	**5**
11	Velocidad	C	B	B	B	A	A	D	B	B	C	**9**
13	Fuerza	C	B	B	B	A	A	D	D	B	C	**10**
14	Fuerza	C	B	B	B	A	A	C	A	B	A	**7**
15	Deporte	C	B	B	B	A	A	D	A	B	A	**8**
16	Fuerza	B	B	B	B	A	A	A	A	B	A	**6**

Annex V: Graphs of the answers to each multiple-choice question in general




Question 8
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Question 10
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Question 11
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Annex VI: Tables with the results of drawings

Pre-test

	Student	Clear drawing	Objects	People	Relation with Q1	Relation Phy-Act	Relation with E	Fantasy	Description
3rd A	1	0	1	0	1	1	1	0	Ball that shoots lightning bolts on impact with the ground
	2	1	1	1	0	1	1	0	Shooting to a basket with bounces
	4	0	1	0	1	0	1	0	Sun
	6	0	0	0	1	0	1	1	Two purple and yellow bars
	7	1	0	0	0	0	1	0	Lightning storm
	8	1	1	1	1	1	1	0	A bouncing basketball
	9	1	1	0	1	0	1	0	Hamburger and fries
	10	1	1	0	1	1	1	0	Basket shooting
	11	1	1	0	0	1	1	0	A bouncing basketball
	12	1	0	0	1	0	1	1	Pikachu
	13	1	1	1	1	1	1	0	Boy eating fruit while bouncing a ball
	14	0	1	1	0	1	1	0	Bouncing ball
	15	1	1	0	1	1	1	0	Bouncing ball
	16	0	1	1	0	1	1	0	Girl with dumbbells
	17	1	1	1	0	1	1	0	Bowling ball throwing
3rd B	2	1	0	0	0	0	1	0	Sun
	3	1	0	0	1	0	1	0	Lightnings
	4	1	1	1	1	1	1	0	Children playing basketball
	5	1	1	1	1	1	1	0	Girl shooting at goal
	8	1	1	0	0	1	1	0	Ball on fire with a load bar 0-200
	10	1	1	1	1	1	1	0	Ball moving, girl running and the sea
	11	0	0	1	1	1	1	0	A child marching
	12	0	0	0	0	0	1	0	A thrown object
	13	1	1	0	1	1	1	0	A bouncing basketball
	15	1	1	1	1	1	1	0	Solar panel, a spinning windmill and two children playing basketball.
	16	1	1	1	1	1	1	0	Girl playing basketball
	18	1	1	0	0	1	1	0	A bouncing basketball
3rd C	1	1	1	0	1	0	1	0	Apple and lightning
	2	1	1	0	1	1	1	0	Ball on one hand with energy represented inside with "E".
	3	1	1	0	0	1	1	0	Basket shooting
	4	1	0	1	1	1	1	0	Teacher running
	5	0	0	0	0	0	1	1	Spirals, circle wrapped in a cloud with lines around it forming figures
	6	1	1	1	1	0	1	0	Girl eating an apple
	7	1	1	0	0	1	1	0	Ball in motion
	8	1	1	0	1	0	1	0	A light bulb on

	Student	Clear drawing	Objects	People	Relation with Q1	Relation Phy-Act	Relation with E	Fantasy	Description
	9	1	0	1	1	1	1	0	Child running
	10	1	1	0	0	1	1	0	Ball in motion
	11	1	1	1	1	1	1	0	Athletic race between two girls
	13	1	1	0	1	1	0	0	A scoreboard next to a cup and a basket
	14	1	1	1	1	1	1	0	Boy shooting to basket attached to a lightning by two wires
	15	1	1	1	1	0	1	0	A child eating fruit
	16	1	1	1	0	1	0	0	A girl with a basketball

	Student	Elements	Forms of energy	Source of energy
3rd A	1	Ball, lightning	Electrical, mechanical	Not shown
	2	Ball, basket, girl	Mechanical	Not shown
	4	Sun	Thermal, electromagnetic	Solar
	6	Illusions	Not identified	Not shown
	7	Clouds, lightning, rain	Electrical	Not shown
	8	Ball, basket, child	Mechanical	Not shown
	9	Food	Chemical	Not shown
	10	Ball, basket	Mechanical	Not shown
	11	Ball	Mechanical	Not shown
	12	Pikachu (Pokemon)	Electrical	Not shown
	13	Ball, food, child	Mechanical, chemical	Not shown
	14	Ball, child	Mechanical	Not shown
	15	Ball	Mechanical	Not shown
	16	Dumbbells, girl	Mechanical	Not shown
	17	Ball, bowling, girl	Mechanical	Not shown
3rd B	2	Sun	Thermal, electromagnetic	Solar
	3	Lightnings	Electrical	Not shown
	4	Ball, basket, sun	Mechanical	Not shown
	5	Ball, goal	Mechanical	Not shown
	8	Ball, fire, loading bar	Mechanical	Not shown
	10	Ball, sea, path	Mechanical	Tidal
	11	Lightning, wake	Electrical, mechanical	Not shown
	12	spiked ball, wake	Mechanical	Not shown
	13	Ball, wake	Mechanical	Not shown
	15	Solar panel, windmill, ball	Mechanical, thermal, electromagnetic	Solar, wind
	16	Ball, basket, girl	Mechanical	Not shown
	18	Ball, trajectory, impact	Mechanical	Not shown
	1	Food, lightning	Chemical, electrical	Not shown
	2	Arm, ball, "E "s inside the ball	Mechanical	Not shown

	Student	Elements	Forms of energy	Source of energy
3rd C	3	Ball, trajectory, basket	Mechanical	Not shown
	4	Teacher, trajectory	Mechanical	Not shown
	5	Spirals, circle surrounded by squares and cloud	Not identified	Not shown
	6	Girl, food	Chemical	Not shown
	7	Ball, trajectory, lightning	Mechanical	Not shown
	8	Bulb	Thermal, electromagnetic	Not shown
	9	Child	Mechanical	Not shown
	10	Ball, trajectory	Mechanical	Not shown
	11	Girls, goal line, trophy, poster, athletics	Mechanical	Not shown
	13	Scoreboard, trophy, basket	Not identified	Not shown
	14	Ball, basket, lightning, child	Mechanical	Not shown
	15	Table, food, child	Chemical	Not shown
	16	Ball, child	Not identified	Not shown

Post-test

	Student	Clear drawing	Objects	People	Relation with Q1	Relation Phy-Act	Relation with E	Fantasy	Description
3rd A	1	0	1	0	1	1	1	0	Basketball thrown with lightning bolts to the hand and the ground
	2	1	1	0	1	1	1	0	A bouncing ball
	4	1	1	0	1	0	1	0	Earth's core
	6	0	0	0	0	0	0	1	Two bars
	7	1	1	0	0	1	1	0	Experiment tennis ball with basketball
	8	1	1	0	1	1	1	0	Basket shot
	9	1	1	0	1	1	1	0	Basket shot
	10	1	0	0	0	0	1	0	Lightning
	11	1	1	0	1	1	1	0	Bouncing ball
	12	0	1	0	1	1	1	0	Experiment tennis ball with basketball
	13	0	1	1	0	0	1	0	Two people playing with a ball while a bigger one falls with lightning bolts.
	14	1	0	0	0	0	0	0	Dog barking
	15	0	1	1	1	1	1	0	Boy with a balloon
	16	1	1	1	1	1	1	0	Person running to a goal
	17	1	1	0	0	1	1	0	Experiment tennis ball with basketball
3rd B	2	1	0	0	0	0	1	0	Sun
	3	1	0	0	1	0	1	0	Lightning
	4	1	1	1	1	1	1	0	Girl playing basketball
	5	1	1	0	1	0	1	0	Phone, television, batteries, sun
	8	1	1	0	0	1	1	0	Ball on fire

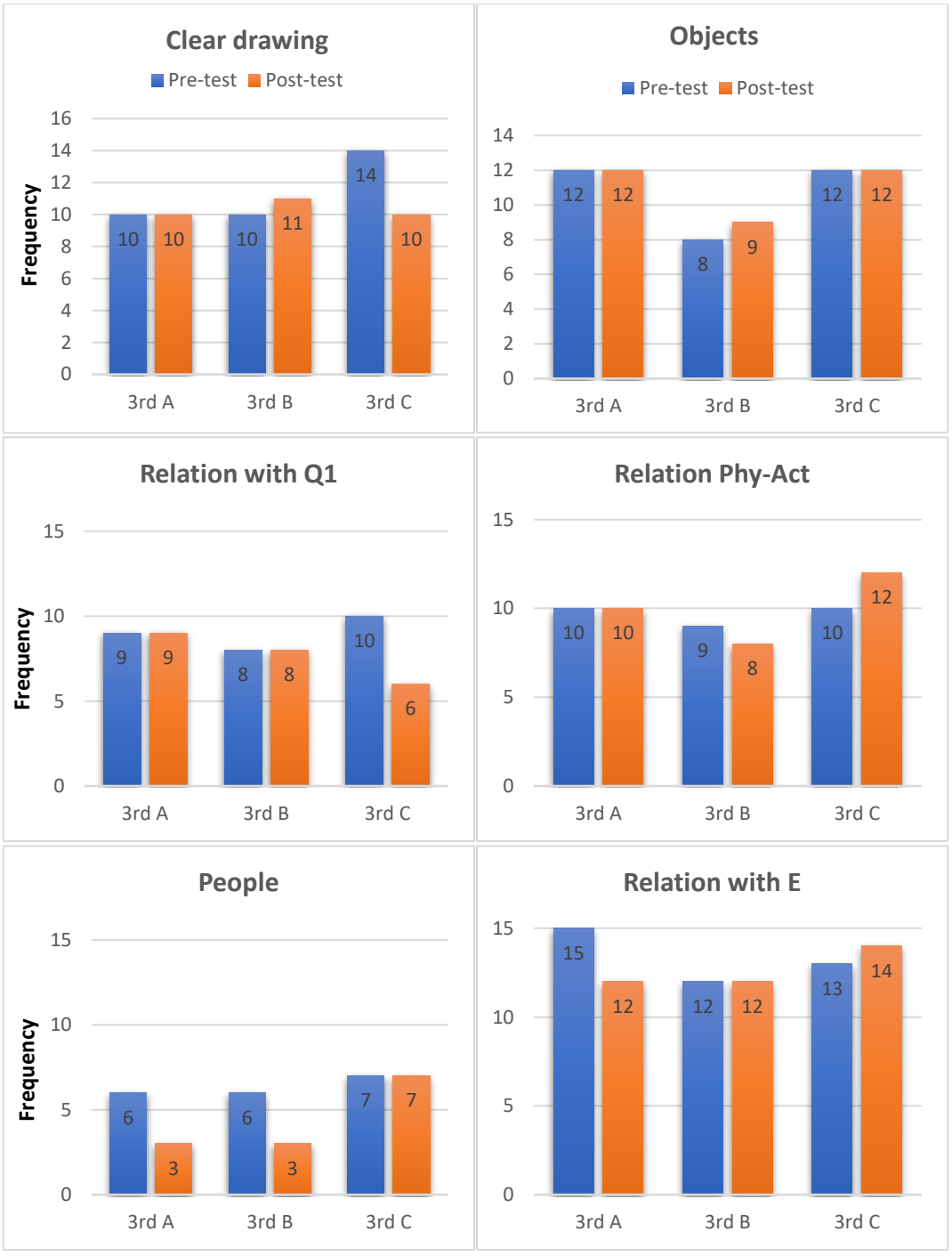
	Student	Clear drawing	Objects	People	Relation with Q1	Relation Phy-Act	Relation with E	Fantasy	Description
	10	1	1	0	0	1	1	0	Sea and a ball in motion
	11	0	1	0	1	1	1	0	Balls with lightning inside
	12	1	0	0	1	0	1	0	Sun
	13	1	1	0	1	1	1	0	Bouncing a ball
	15	1	1	1	1	1	1	0	Solar panel, spinning windmill and girl bouncing a ball
	16	1	1	1	1	1	1	0	Boy playing basketball
	18	1	1	0	0	1	1	0	Experiment tennis ball with basketball
3rd C	1	1	0	0	0	0	1	0	Vibrating lightning
	2	1	1	0	1	1	1	0	Ball transferring energy to the ground
	3	1	1	0	0	1	1	0	Ball going to a basket
	4	1	0	1	0	1	1	0	Girl doing karate
	5	0	1	0	1	1	1	0	Machines throwing balls against walls
	6	1	1	1	1	0	1	0	Girl eating vegetables
	7	0	1	0	0	1	1	1	Lightning and a talking ball
	8	1	1	0	1	1	1	0	Experiment of three balls falling at the same time
	9	0	1	1	0	1	1	0	Boy playing with two balls
	10	0	1	0	0	1	1	0	Two balls moving in the air upwards
	11	1	1	1	1	1	1	0	Two girls arriving at the finish line of a race
	13	1	1	0	0	1	1	0	Explanation of the contents worked (transmission and degradation of energy)
	14	1	1	1	0	1	1	0	Children playing basketball
	15	1	0	1	0	0	0	1	Goku (Character of Dragon Ball)
	16	0	1	1	1	1	1	0	Girl ready to lift a barbell

	Student	Elements	Forms of energy	Source of energy
3rd A	1	Ball, arm, lightning	Mechanical, electrical	Not shown
	2	Ball, trajectory	Mechanical	Not shown
	4	Earth's core	Thermal	Geothermal
	6	Bars	Not identified	Not shown
	7	Basketball, tennis ball, trajectory	Mechanical	Not shown
	8	Ball, basket, waves	Mechanical	Not shown
	9	Ball, basket	Mechanical	Not shown
	10	Lightning	Electrical	Not shown
	11	Ball, trajectory	Mechanical	Not shown
	12	Basketball and tennis ball, lightning	Mechanical	Not shown
	13	Balls, people, lightning, trajectories	Mechanical, electrical	Not shown

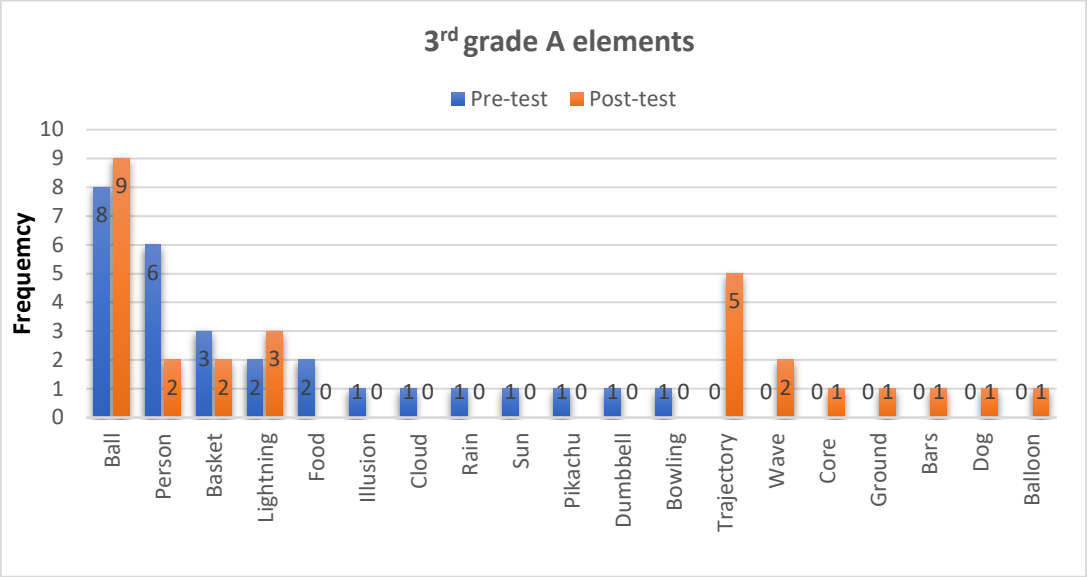
	Student	Elements	Forms of energy	Source of energy
	14	Dog, waves	Not identified	Not shown
	15	Balloon, child	Mechanical	Not shown
	16	Person, goal	Mechanical	Not shown
	17	Basketball and tennis ball	Mechanical	Not shown
3rd B	2	Sun	Thermal, electromagnetic	Solar
	3	Lightning	Electrical	Not shown
	4	Ball, basket, girl	Mechanical	Not shown
	5	Phone, television, batteries, sun	Electromagnetic, electrical	Solar
	8	Ball, fire, wake	Mechanical	No Not shown
	10	Sea, ball, trajectory	Mechanical	Tidal
	11	Balls, lightning	Mechanical (potential)	Not shown
	12	Sun	Thermal, electromagnetic	Solar
	13	Ball, arm, trajectory	Mechanical	Not shown
	15	Solar panel, sun, windmill, girl, ball, trajectory	Mechanical, thermal, electromagnetic	Solar, wind
	16	Ball, basket, child, trajectory	Mechanical	Not shown
	18	Basketball and tennis ball, trajectory	Mechanical	Not shown
3rd C	1	Lightning, waves	Electrical	Not shown
	2	Ball, "E "s, ground, arrow	Mechanical	Not shown
	3	Ball, basket, trajectory	Mechanical	Not shown
	4	Girl, waves	Mechanical	Not shown
	5	Ball throwing machine, balls, trajectory, walls	Mechanical	Not shown
	6	Girl, food	Chemical	Not shown
	7	Ball, lightning, dialogue (text)	Electrical	Not shown
	8	Bowling ball, basketball and tennis ball, trajectory	Mechanical	Not shown
	9	Child, two balls, trajectories	Mechanical	Not shown
	10	Two balls, trajectory	Mechanical	Not shown
	11	Girls, goal	Not identified	Not shown
	13	Ball, text, trajectories	Mechanical	Not shown
	14	Children, ball, basket, trajectory	Mechanical	Not shown
	15	Goku (Dragon Ball)	Not identified	Not shown
	16	Girl, dumbbell	Mechanical	Not shown

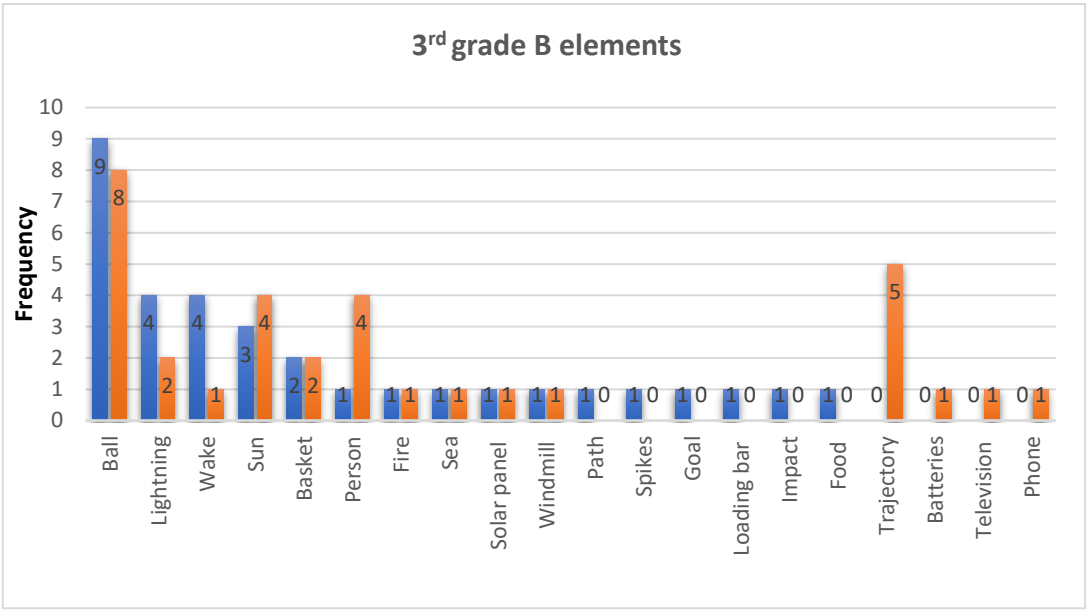
Annex VII: Graphs of the results of the drawings

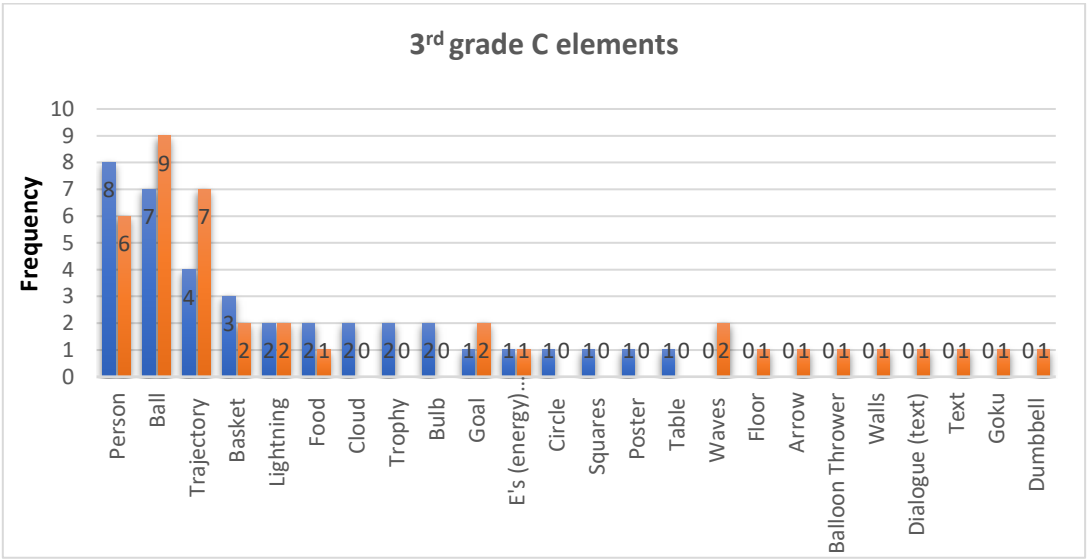
Dichotomous indicators (Yes) per group



Elements appearing in the drawings in each group







Elements appearing in the drawings in general