Overcoming Misconception through Emotion: Science Education in Elementary Schools in México

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ABSTRACT

It is widely recognized that children can learn science with appropriate teaching. Literature mentions that the main problem in learning science is correcting wrongly held beliefs students had before instruction. In this study, with near 2100 children attending upper elementary school, the objective was to try to see if erroneous preconception inhibited their ability to observe what happens in a scientific experiment correctly. The workshop of 'initiation to science' began with a questionnaire that contained eight hypotheses, followed by instruction consisting eight experiments, and finally the same questionnaire to be responded to once the experiments were over. It is known that children try to explain their surroundings, thus arrive at school with preconceptions about the phenomena of the natural world. Preconceptions that disagree with an accepted scientific theory is after this referred to as 'misconception.' The research questions of this investigation were: Is it more difficult to overcome a misconception than a preconception that does not disagree with scientific theory? Could a misconception affect what a child observes from an experiment? With an odds ratio analysis, it is demonstrated that children whose hypothesis was incorrect due to a misconception and who performed an experiment, had a higher probability of changing their minds to the correct answer than if they did not have the misconception. This suggests that the excitement produced when they are seeing the opposite of what they are expecting, impact their rational level, supporting that cognition processes are linked to emotions.

Keywords: misconception, elementary education, classical physics experiments.

INTRODUCTION

Science is the driving force for the development of a country. Science education in elementary schools has been introduced in scholarly programs in the last two decades because, according to the National Research Council (2007), children are capable of learning science if they receive appropriate instruction. One of the most commonly mentioned problems in learning science is the beliefs students have before enrolling in their first formal science course, referred to as 'preconceptions' (Erlyimaz, 2002). Preconceptions are also termed in the literature as alternative conceptions, alternative frameworks, alternative ideas, conceptual misunderstandings, conceptual prisms, erroneous ideas, errors, false ideas, incomplete or naïve

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notions, intuitive notions, mistakes, misunderstanding, non-scientific beliefs, oversimplifications, preconceived notions, preconceptions, and untutored beliefs. Preconceptions sometimes agree and sometimes disagree with a scientific theory. The former is named anchoring conceptions (Brown and Clement, 1989). Clement, Brown, and Zietsman (1989) named it this way because they could help teach science classes. On the other hand, 'misconception' is a belief that contradicts accepted scientific theory and sometimes persists despite presenting evidence to the contrary (Eryilmaz, 2002).

In general, misconceptions provide quick and superficially reasonable explanations to natural phenomenon; indeed, Coley and Tanner (2015) documented many linkages between intuitive ways of thinking and misconceptions in Biology disciplined reasoning. A study by the National Research Council (2007), proposed that children bring to science class ample knowledge about the world because they always try to interpret and anticipate events and explain their surroundings in ways that can be useful. Thus, the student's preconceptions influence the understanding of science concepts. Nevertheless, misconceptions have been mentioned as they appeared to be tenacious and retained even in the presence of formal instructions (Wandersee, Mintzes, and Novak, 1994; Chi, 2005). An explanation for this is that people refuse to generate evidence or entertain ideas that do not fit with their existing knowledge (Schauble, 1996). Jarvis, Pell, and McKeon (2003) suggested that children's misconceptions persisted because teachers with limited understanding are reinforcing them.

Pine, Messer, and St. John (2001) considered that children's preconceptions (in favour or against scientific theories) commonly emerge in science classes, which suggests that calling children's naive theories to mind, and making them explicit, can help in the acquisition of new concepts. Several methods for identifying misconceptions (against scientific theory) have been proposed: drawings (Köse, 2008), the certainty of response index method (Hasan, Bagayoko, and Kelley, 1999), the method of dominant incorrect answers (Bani-Salameh, 2017a), cartoons (Ekici, and Aydin, 2007), and interviews, among others. Thus, misconceptions have been documented in many scientific disciplines for example Chemistry (Nakhleh, 1992), Biology (Bahar, 2003; Coley and Tanner, 2012), Physical Geography (Nelson, Aron, and Francek, 1992), Geosciences (Francek, 2013), and Physics (Stein, Larrabee, and Barman 2008; Liu and Fang, 2016).

Most studies about misconceptions in science are from students in or after high school because it became evident when a specific scientific topic was taught. For example, Martín-

Blas, Seidel, and Serrano-Fernández (2010) made an inventory of force misconceptions students had in their first year of an engineering degree. The most common misconceptions in Physics are related to force; motion implies active force, impetus dissipation, etc. (e.g. Martín-Blas, et al., 2010; Pine et al., 2001, Liu and Fang, 2016), but there are few studies about the misconceptions and ways of thinking of children in elementary education.

The researchers in this study wondered what children's preconceptions of natural phenomena were. Champagne and Klopfer (1983) documented a common Physics misconception encountered in elementary education, namely the belief that heavier objects fall faster than lighter ones. Pine et al. (2001) and Laksana, Degeng, and Dasna (2017) documented children's misconceptions based on their teacher's information; they assume that materials with greater mass will fall faster and that objects fall at different speeds. Until 12 year's old, children do not consider the weight of air at all (Galili and Bar, 1997) and there are many student's misconceptions recorded, especially having to do with air pressure (Nelson et al., 1992).

This study aims to prove whether a misconception is more difficult to eradicate than a preconception that agrees with a theory in primary education. To do this, we first identified misconceptions and other preconceptions using a questionnaire that contained hypotheses-statements about eight daily life phenomena. The questionnaire was answered by 2100 fifth and sixth grade students from 26 schools in central México. Then, we analysed which one of the correct answers in the post-test came from an incorrect answer (some are misconceptions) and which ones came from an affirmation that they did not know the answer. Finally, the study compared overcoming of misconceptions in contrast to students that had other preconception items wrong.

The instruction consisted of a specific experiment for each hypothesis. A binary logistic regression was used to see the probability of a child having a correct answer in the post-test having given the incorrect answer in the pre-test. It is presumed that the odds ratio of obtaining a correct answer in the post-test would not favour children that had a misconception.

RESEARCH QUESTIONS

- Is it more difficult to overcome a misconception than to create a new concept?
- Could a misconception affect what a child observes from an experiment?

METHODOLOGY

Two thousand two hundred eighty-six students took part in a science workshop. There were 1114 fifth-grade students from 50 groups and 1172 sixth grade students from 49 groups, attending 24 public schools from Guanajuato state, in México.

The workshop centred around three booklets in the collection 'Easy experiments to understand a complicated Earth' published at the University of México. Students from fifth grade took part in the experiments titled L1. Atmospheric pressure and falling bodies (Alaniz-Alvarez and Nieto-Samaniego, 2007) and L3. Eureka! The continents and oceans float! (Alaniz-Alvarez and Nieto-Samaniego, 2009). The sixth grade students did the experiments L3. Eureka! The continents and oceans float! and L4. The weather hanging by a thread (Alaniz-Alvarez, Nieto-Samaniego, and de Icaza-Herrera, 2010) as stated in the booklets.

Eight researchers/professors and 14 postgraduate students, participated in the workshop as instructors. Four bachelor's students assisted. The workshop lasted three and a half hours and took place in a single school day.

Students from fifth and sixth grade were handed a paper with a list containing several hypotheses. Each child had to choose an option for each one: a) I think it is correct, b) it is incorrect or c) I don't know. Then the students carried out an *ex professo* science experiment for each hypothesis and at the end of the class (after doing the experiments), they had to choose an option for each hypothesis again.

The instruction method is science experiments. This method was chosen because the scientific method includes research, experimentation, evidence evaluation and inferences (Zimmerman, 2007). Experimentation is a fundamental skill to model, reproduce and investigate how several variables intervene in a process or natural phenomenon (Lehrer, Schauble, and Petrosino, 2001). The purpose of an experiment is to ratify or rectify a hypothesis.

This study tries to document whether experimentation can change misconceptions. A comparison was made between pre- and post-tests about hypotheses related to four misconceptions (contrary to a scientific theory) and four related to anchorage conceptions or correct preconceptions (Clement et al., 1989). That means that the hypotheses are about four phenomena that occur against intuition and four in favour of it. All analyses were conducted using IBM SPSS Statistics 19. The statistical analysis was done using a simple binary logistic regression to predict a binary response based on one independent variable. It was labelled ‘0’ for an incorrect answer and ‘1’ for a correct answer. The correct answer in the post-test is the dichotomous criterion variable, and the two non-correct answers in the pre-test (the ‘incorrect’ and the ‘I do not know’ options) are used as a dichotomous predictor variable.

The odds ratio compares the odds of obtaining a correct answer in the post-test between these two predictor variables: incorrect answers are labelled ‘0’ and the ‘I do not know’ option is labelled ‘1’ in the pre-test. If the Exp(B) (odds ratio) is > 1, that means that the odds for obtaining a correct answer in the post-test favoured those who chose the ‘I do not know’ option in the pre-test. If Exp(B) <1, it favoured those who choose the ‘incorrect’ option in the pre-test. Based on the literature mentioned above (Champagne and Klopfer, 1983; Pine et al., 2001; Chi, 2005; Martin-Blas et al., 2010) it was supposed that when analysing the responses that involve a misconception, the Exp (B) will be >1, meaning that the misconception is not overcome; and when analysing the responses that involve an anchorage conception the Exp (B) should be near 1.

Achievement Test

The pre- and post-achievement tests were identical, consisting of eight hypotheses statements, four related to documented misconceptions or phenomena that went against intuition and four related to phenomena in favour of intuition (Table 1). It is analysed by item. They were ordered from those most against intuition to those more in favour of intuition according to our estimation.

HYPOTHESIS AND EXPERIMENTS

H1. A Candle Can Be Lit Without Directly Touching It With an Open Flame

This study was started with this statement because it was thought to be the most counter-intuitive notion where most children would answer that this hypothesis is incorrect. The instructor told them how to perform the experiment: 1) Light the candle with a match. 2) Extinguish the candle but not the match.3) Put the match on top of the candle, in the smoke thread formed by the evaporated wax and observe.[1] After that, a simple explanation about how combustion works is given: there is a chemical reaction which obtains heat from fuel and oxygen to produce the flame. After the experiment, they realised that it is possible for a candle

[1] Video of the experiment is shown in slow motion on YouTube: https://www.youtube.com/watch?v=63Pr9Yshs1Q

to be lit without touching the wick with a flame. The question here is if the preconception that 'it is not possible' could affect what the child observes from this experiment in real-time.

H2. Heavier Objects Fall Faster Than Lighter Ones

This statement is a documented misconception (Champagne and Klopfer, 1983; Pine et al., 2001; Laksana et al., 2017): when a very light object falls, the air resistance slows it down; thus, our perception is that the weight has to be a factor that influences its downward velocity. It is known that this hypothesis is incorrect because of the 'falling bodies' and 'inclined plane' experiments performed by Galileo. The instructions to perform the experiment were: 1) Take two plastic bottles, one empty and the other one filled with water (or anything else). 2) Drop the bottles at the same time. 3) Observe which of the two falls first.[2] After that, an explanation is given about how objects accelerate as they fall and that this acceleration is independent of the weight. The experiment shows that both bottles fall at the same time, although the bottle with water weighs approximately one thousand times more than the one with just air. The question here is if the preconception that 'heavier objects fall faster than lighter ones' affects the interpretation of what the child observes from this experiment in real-time.

H3. Air Has No Weight at All

This statement was chosen because of misconceptions about air (mostly regarding its weightlessness and about air pressure) as mentioned above; and because many teachers told us that the children asked them if air has weight. It is known that this hypothesis is incorrect because the molecules that compose air have mass which is affected by gravity; thus, the air must have weight. The instructions to perform the experiment were: 1) Build a weighing scale by tying a thread in the middle of a straw. 2) At the ends of the straw, hang deflated balloons with adhesive tape in such a way that the scale is balanced. 3) Change one of the deflated balloons to an inflated one. The scale should be tilted to where the inflated balloon is, proving that the air has weight. After that, an explanation is given about the composition of air and how its molecules have mass. The problem with this experiment is that the balloon is very susceptible to electrostatic forces, and many times the balance is not inclined to the inflated balloon, but statically charged clothes attract it. The question is if this distractor affected the observation of the experiment.

[2] Video of the experiment is shown in slow motion on YouTube: https://www.youtube.com/watch?v=63Pr9Yshs1Q

H4. Dawn Is Hotter Than Early Morning

This statement was chosen as a hypothesis because many teachers and children told us that they feel colder when they go out of their houses between 2 am and 5 am. It is known that this hypothesis is incorrect because the sun is the heat source to warm the day. For this hypothesis, there is no experiment involved, only the explanation of the concepts of diathermancy, albedo, duration of the day because of inclination of the rotation axis, among other concepts.

H5. A Kilo of Wood and a Kilo of Iron Weigh the Same Underwater

This statement was chosen as a hypothesis because the concept 'kilo' is the colloquial name of kilogram-force and the weight, according to the Archimedes principle, changes underwater. Besides the scientific concept of weight, it is assumed that this hypothesis could be intuitively incorrect because if we use a hook as a scale, the children could visualize that wood floats thus the scale will tip towards the iron. The instructions to perform the experiment were: 1) Hang a necklace made of metal at one end of a hook and hang a necklace made of wooden beads on the other end. The hook will serve as a low precision weighing scale and must be even. 2) Place two containers with water under the necklaces in such a way that they are suspended. The scale will lean towards the densest object. See an example of how this experiment was carried out in the classroom.[3]

H6. Water Heats up Faster Than Soil

This statement was chosen as a hypothesis because temperature and heat are present in our daily vocabulary. When water heats up in a metal bowl, it is evident that the metal heats quickly; thus, it is assumed that it can be easy to transport the analogy to the soil instead of metal. It is supposed that this hypothesis will be chosen incorrectly because when we walk barefoot on a sunny day, the soil is hotter than the water on the floor. The instructions to perform the experiment were: 1) Fill a small glass with water, put some soil in a second glass of the same size. 2) Put the two glasses in the refrigerator. 3) Remove them after ten minutes and compare them to find out which is colder by using a thermometer or by touching them. 4) Then put other glasses that have water and soil (initiating at the same temperature) in the sun for 15 minutes and with a thermometer measure the temperature of the glasses. Be aware that the glasses must be small, the mass (in grams) must be the same, and the content of the two

[3] Video of the experiment is shown on YouTube: https://youtu.be/fNQ4aM3EjsY

glasses must be at the same temperature. The soil must change its temperature faster than water because the heat capacity of water (the energy needed to change the temperature) is greater than the soil. Thus, the hypothesis is false.

H7. The Air Pressure Inside a Balloon Is Higher Than the Pressure Outside It

This statement was chosen as a hypothesis because one of the aims of this study is to analyse what happens when there are no misconceptions related to a phenomenon. Indeed, this phenomenon happens very much in line with our intuition. It is known that this hypothesis is correct because the air inside the balloon tends to go outside, given the opportunity. The instructions to perform this experiment were: 1) Inflate one balloon. 2) Pierce the balloon through any of its ends. When you pierce the balloon on either end, nothing seems to happen. If you get close, you will notice the air is escaping slowly through the hole you made with the pin. The air always flows from high to low pressure.

H8. When Air Is Heated, Its Volume Increases

This statement was chosen as a hypothesis because there are no misconceptions related to this phenomenon. It is discerned that this hypothesis is correct because a rise in the temperature increases the kinetic energy and speed of the particles causes the molecules of air to move faster and farther apart increasing the volume that the same mass of air occupies. The instructions to perform the experiment were: 1) Stretch the balloon to cover the top of a bottle. 2) Fll the container with hot water. 3) Place the bottle inside of the container. It is evident that the balloon expands.

RESULTS

Gain and Odds Ratio

H1. A Candle Can Be Lit Without Directly Touching It With an Open Flame

The responses from fifth and sixth grade students were collected. One thousand one hundred ninety-six students (1196) answered the pretest, but only 1136 answered the posttest. In the pretest 542 answered that the hypothesis is true (the response is correct), 481 that the hypothesis is false (incorrectly answered), and 173 that they did not know the answer (Figure 1). After the experiment, 1003 answered correctly, 115 incorrectly and 18 admitted to not knowing the answer. The Hake gain g= (Final Score -Initial Score) / (Max Score-Initial Score) g= 0.77 (approximate because of a difference of 60 students between the pre and posttest). According to Hake (1998), a low gain is <0.29, a medium gain is between 0.3-0.69, and a high gain is >0.7.

The odds ratio Exp (B) compares the odds of obtaining a correct answer in the post-test between the options in the pre-test: incorrect (labelled '0') and 'I do not know' (labelled '1'). The analysis shows that the children that chose the 'incorrect' option had significantly more chances to get the correct response in the post-test than those who chose the option 'I do not know' (Exp(B)=0.509, SE=0.285, Wald=5.616, p=0.018). The predictions had an overall success rate of 82.6%. Considering the inverse of Exp(B)<1, 1/0.509=1.96 for better appreciation (Wuensch, 2014), it can be interpreted that the children that answered incorrectly in the pre-test had a 1.96 higher chance of answering correctly after the experiment and that it is significant (Figure 2).

H2. Heavier Objects Fall Faster Than Lighter Ones

The responses of 1090 students from fifth grade were collected. Seven hundred thirty-five answered that the hypothesis is correct (the answer is incorrect), 295 that it is false (the answer is correct), and 60 that they do not know. After the experiment, 630 answered correctly, 419 incorrectly and 41 that they did not know. The Hake gain was g= 0.42, which, according to Hake (1998), is a medium gain (Figure 1).

The number of students that did not answer correctly in the pre-test and responded the post-test was 657. We calculated the odds ratio of getting the correct answer in the post-test (as the dependent variable) between the two non-correct answers in the pre-test (as the independent variable), the incorrect select labelled '0' and the 'I do not know' labelled '1'. The odds ratio obtained Exp (B)=0.538 (SE=0.304, Wald=4.327, p=0.038) supports that the children that answered in the pre-test that the misconception 'heavier objects fall faster than lighter' is true had significantly more chances to get the correct answer, in the post-test. In considering the inverse, it is interpreted that the children who answered incorrectly in the pre-test had a 1.85 higher chance of answering correctly after the experiment and that it is also significant. The overall success rate of the model was 51.8%.

H3. Air Has No Weight at All

The responses of 1195 students from fifth and sixth grade were collected. In the pretest 690 answered that the hypothesis is true (incorrect answer), 426 that it is false (correct answer) and

79 that they did not know. After the experiment, in the posttest, 837 answers were correct, 285 were incorrect, and 14 confessed that they did not know (Figure 1). The Hake gain was g=0.58.

Taking into account the 707 children that answered the post-test and did not answer correctly in the pre-test, we used binary logistic regression to build a model that would predict what had more influence in getting a right answer in the post-test: children that chose in the pre-test that the 'air has no weight' hypothesis is true, or the option 'I don't know'. The odds ratio obtained is Exp(B)=0.620 (SE=.252, Wald=3.61, *p*=0.057). Considering the inverse 1/0.62=1.61 for better appreciation (Figure 2), it can be interpreted that the children that thought that air had no weight before the experiment had a 1.61 higher chance of answering correctly after the experiment than those that do not know, and that it is also significant. The overall success rate of the model was 67.5%.

H4. Dawn Is Hotter Than Early Morning

Four hundred four responses were collected from the sixth grade students. Two hundred sixty-eight answered that the hypothesis is true (incorrect answer), 114 that it is false (correct answer), and 22 that they do not know. After the experiment, 267 students answered correctly, 127 incorrectly, and nine confessed that they did not know. The Hake gain was 0.529.

A binary logistic regression was used to build a model to predict what had more influence in getting the right answer after the explanation (instead of an experiment); children who in the pre-test said that the 'early morning is colder than dawn' hypothesis is true, or who said 'I do not know.' The odds ratio found is Exp (B)=0.704 (SE=0.478, Wald=0.541, p.=0.462). Considering the inverse 1/0.704=1.42 for better appreciation (Figure 2), it can be interpreted that the children who answered incorrectly in the pre-test had a 1.42 higher chance of answering correctly after the experiment and in this case, it is not significant. The predictions had an overall success of 60.6%.

H5. A Kilo of Wood and a Kilo of Iron Weigh the Same Underwater

The responses of 1196 students from fifth and sixth grade were collected. Three hundred seventy-four answered that the hypothesis is correct (incorrect response), 581 that it is false (correct response), and 241 that they do not know. After the experiment, 831 students answered correctly, 255 incorrectly, and 48 said that they did not know. The Hake gain was g=0.452.

The odds ratio obtained Exp (B)=1.334 (SE=0.187, Wald=2.375, *p*=0.123). The children that answered 'I do not know' in the pre-test had a 1.33 higher chance of answering correctly after the experiment, but that is not significant (Figure 2). The predictions had an overall success of 64.4%.

H6. Water Heats up Faster Than Soil

The responses of 404 students from sixth grade were collected. In the pretest, 158 answered that the hypothesis is correct (incorrect answer), 180 that it is false (correct answer), and 66 that they do not know. After the experiment, 347 students answered correctly, 43 incorrectly, and 12 confess that they did not know. The Hake gain was g=0.752.

The odds ratio obtained Exp (B)=0.642 (SE=0.408, Wald=1.179, p=0.278). The children that answered incorrectly in the pre-test had a 1.55 higher chance of answering correctly after the experiment, but that is not significant (Figure 2). The predictions had an overall success of 82.5%.

H7. The Air Pressure Inside a Balloon Is Higher Than the Pressure Outside It

The responses of 1092 students from fifth grade were collected. In the pretest, 830 answered that the hypothesis is true (correct response), 107 said that the hypothesis is false (incorrectly answered), and 155 responded that they do not know. After the experiment, 924 students answered correctly, 112 incorrectly and 53 that they do not know. The Hake gain g=0.36.

The odds ratio obtained is Exp (B)=1.030 (SE=0.302, Wald=0.009, p=0.923). The children that answered incorrectly and those who answered ‘I do not know,’ in the pre-test, had almost the same chances of answering correctly after the experiment (Figure 2). The predictions had an overall success of 67.5%.

H8. When Air Is Heated, Its Volume Increases

The responses of 1092 students from fifth grade were collected. Six hundred seventy-nine answered that the hypothesis ‘When the air is heated, its volume increases’ is true (correct answer), 202 that it is false (incorrect answer), and 211 that they did not know. After the experiment, 991 students answered correctly, 66 incorrectly, and 33 declared that they did not know. The Hake gain was g= 0.759.

The odds ratio obtained is Exp (B)=1.055 (SE=0.275, Wald=0.038, p=0.845). The children that answered incorrectly and those who answered ‘I do not know’, in the pre-test, had almost the same chance of answering correctly after the experiment (Figure 2). The predictions had an overall success of 81.4%.

DISCUSSION

According to research, misconceptions are stable, robust, and resistant to instruction (Anderson and Smith, 1987; Bahar, 2003; Chi, 2005; Laksana et al., 2017; Bani-Salameh, 2017b). As mentioned in the introduction, many research methods document the main misconceptions in secondary education. This study considered a simple method of detecting misconception, with a sample of children between 9 to 12 years old. Firstly considered were statements that related to a natural phenomenon that occurred in daily life with an explanation using scientific theory. If the incorrect pretest responses constitute more than 50%, and the 'I don't know the answer' is < 10%, it is considered a misconception. But if the correct answer constitutes more than 50% and the 'I don't know' answer is greater than the incorrect answer, it is considered an anchorage conception. According to the study's results, the misconceptions are: H2, H3 and H4, and the anchorage conceptions are H7 and H8 (Figure 1).

Nevertheless, even if the number of children that answered 'I do not know' is very low, the odds ratio is useful because it compares the odds for each one of the predictor variables considered, independent of the number of samples of each of them.

The odds ratio for the misconceptions H2, H3 y H4 shows that children that answer incorrectly in the pre-test have a higher chance of getting the right answer after performing the experiment. This in contrast to the anchorage conceptions (H7 and H8) where the odds of getting the right answer after the experiment is in favour of the children who recognised that they do not know in the pre-test, but the odds ratio is near one.

This finding contrasts with the previous assertion that misconceptions are robust and resistant to instruction mentioned by many authors (e.g. Chi, 2005). However, other authors (National Research Council, 2007) recognised that with proper instruction, the misconceptions could be overcome. In this case, the experiments were a useful method of instruction because the purpose of a scientific experiment is to ratify or rectify a hypothesis. The gain was medium to high, ranging between g_{H8}=0.363 to g_{H1}=0.77. In all cases, except in H8 in which the score of the pre-test was high, thus the gain was low. The line score-trends of the pre- and post-test were very similar. It is not surprising that the lower percentage of right answers in the post-test (57.8%) was concerning H2 'heavier objects fall faster than lighter ones' which is a common misconception mentioned in the literature. The second-lowest of 66% is related to the H4

'Dawn is hotter than early morning' that does not have an experiment but an explanation.

Considering the odds ratio of all the hypotheses, five were in favour of the incorrect responses in the pre-test; of which four are related to the total of the phenomena against the intuition considered. In three, the differences were significant ($p< 0.05$) (Figure 2). To better appreciate the odds ratio, we transformed the odds ratios <1 to the inverse and the incorrect choice was labelled as negative, and the 'I do not know' option positive. The researchers also subtracted or added '1' respectively to the values (Figure 2). The H1 was representative of the surprise that children get when the experiment is run. Thus, it is easy to explain that the emotion of seeing the opposite of what is expected influences their retention of the phenomena. This happens with all the other counter-intuitive phenomena experiments, in contrast with the intuitive phenomena experiments.

Seeing vs Performing an Experiment

Chinn and Malhotra (2002) studied four cognitive processes (observation, interpretation, generalisation and retention) in which the conceptual change is blocked when children encounter anomalous scientific data. The anomalous data reported by them are referred to as the children's beliefs based on their experiences, that conflict with a scientific theory; like heavy objects should fall faster than lighter objects, and that electrical current wears out as it progresses around a circuit. The anomalous data presented by Chinn and Malhotra (2002) are very similar to the phenomena we named as counter-intuitive. They conclude that the cognitive process that impedes more conceptual change is at observation. They expected and explained their results because, in the philosophy of science, the observations are said to be 'theory-laden', that means theoretical presumptions influence them. Observation is significant because others' cognitive processes (interpretation, generalisation and retention) depend directly on it.

In this paper, the focus was on the observation process in children doing an experiment in contrast to Chinn and Malhotra's (2002) study, where the instruction consisted of showing the experiment. Many steps in our procedures are similar to theirs: 1) children answered a questionnaire before and after the experiments; 2) children received information regarding what the science experiment is about, had to annotate their predictions and record what they saw after the experiment; 3) the anomalous data was presented as a science experiment, one of them was the same as ours. This study differ in several ways: 1) The questionnaire had only one question per hypothesis, 2) the multiple-choice had true, false or I do not know options, 3) children performed their own experiment, in contrast to the Chinn and Malhotra study where an instructor performed the science experiment; 3) the explanation was presented after the children performed the experiment and not before.

The results of Chinn and Malhotra's (2002) research and our study are compared. The results from Chinn and Malhotra (2002) and ours are very similar. Table 2 shows the results about prediction in which object hit first, prediction, observation with an explanation before the experiment (From Chinn and Malhotra, 2002), and observation with an explanation after the experiment, and uninformed (*children only saw two objects drop). The results of Experiment 1 of Chinn and Malhotra (2002 p.329-321) show that the conceptual change is impeded at the observation level. Children that predicted that the heaviest object would hit first reached only 26%, χ^2 (2, N=95) = 5.45, p>0.05. In contrast to our results in which children that predicted that the heaviest object would hit first reached at observation level 51%, χ^2 (2, N=325) = 4.44, p=.035 (Table 3). The results of children that did not know the weight of the object (last row of Table 3) were almost the same in the three questions.

This example is useful for comparing the conceptual change at the observation level in children of the same age that 'see' an experiment and children that 'perform' the experiment. The surprise that we witnessed when children perform a counter-intuitive experiment and realise that what they expected did not occur, strongly suggests that there is a greater impact on the observation level than in the case when the child only sees the experiment. This surprise should generate emotion in the cases when children perform an experiment and observe that the result is contrary to their beliefs (H1, H2, H3 and H4), but not in the case when the children have an anchorage conception (H5, H6, H7, H8) (Figure 4). In the case of misconception, the odds ratio was significantly in favour of the incorrect answer, whereas in the anchorage conception, the odds ratio was almost one.

The relationship between surprise and emotion, and emotion and cognition, documented recently (Foster and Keane, 2015; Pessoa, 2015; Babayan et al., 2019) could be a trigger for the conceptual change that is needed to remove a misconception that in other circumstances is difficult to eradicate.

CONCLUSIONS

This study presents an analysis of prediction and observation of children in fifth and sixth grade, about eight physical phenomena, performing an experiment for each one. Four of the experiments were counterintuitive, and four were intuitive. The purpose was finding out if doing a scientific experiment could help overcome a misconception.

- The <10% in the predicted (pretest) choice of 'I do not know' answers, in the eight hypotheses-statements, agree with the idea that children anticipate events and try to explain their surrounding world.
- The children whose belief contradicts accepted scientific theory has had a higher probability of overcoming a misconception than those that did not know the answer.
- It is easier for children that have a misconception to change beliefs by performing an experiment rather than only seeing it.
- In performing a scientific experiment, the surprise and emotions to obtain a different result than expected favoured overcoming a misconception.

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TABLES AND FIGURES

Table 1. Hypotheses considered in the achievement test

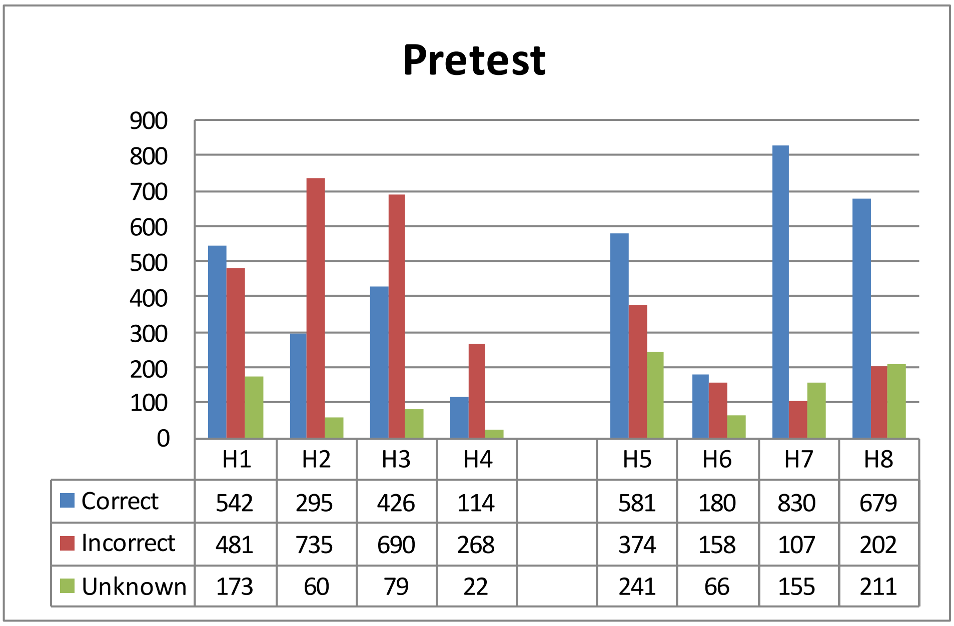
Item	Statement/hypothesis	True/False	Scientific theory related
Phenomena against intuition			
H1 L3-4	'A candle can be lit without directly touching it with an open flame'	True	Combustion
H2 L1-5	'Heavier objects fall faster than lighter ones'	False	Law of gravity-acceleration
H3 L3-3	'Air has no weight at all'	False	Atomic-molecular theory
H4 L4-1	'Dawn is hotter than early morning'	False	Rotation of Earth around Sun
Phenomena in favor of intuition			
H5 L3-3	'A kilogram of wood and a kilogram of iron weigh the same underwater '	False	Buoyancy Archimedes principle
H6 L4-4	'Water heats up faster than soil'	False	Heat capacity- Specific heat
H7 L1-3	'The air pressure inside a balloon is higher than the pressure outside the balloon.'	True	Air pressure
H8 L1-1	'When air is heated, its volume increases'	True	Boyle's law
L1-, L3-, L4- corresponds to the booklet with that number. The number after dash is the item in the database.			

Table 2. Prediction from Chinn and Malhotra 2002, and this study

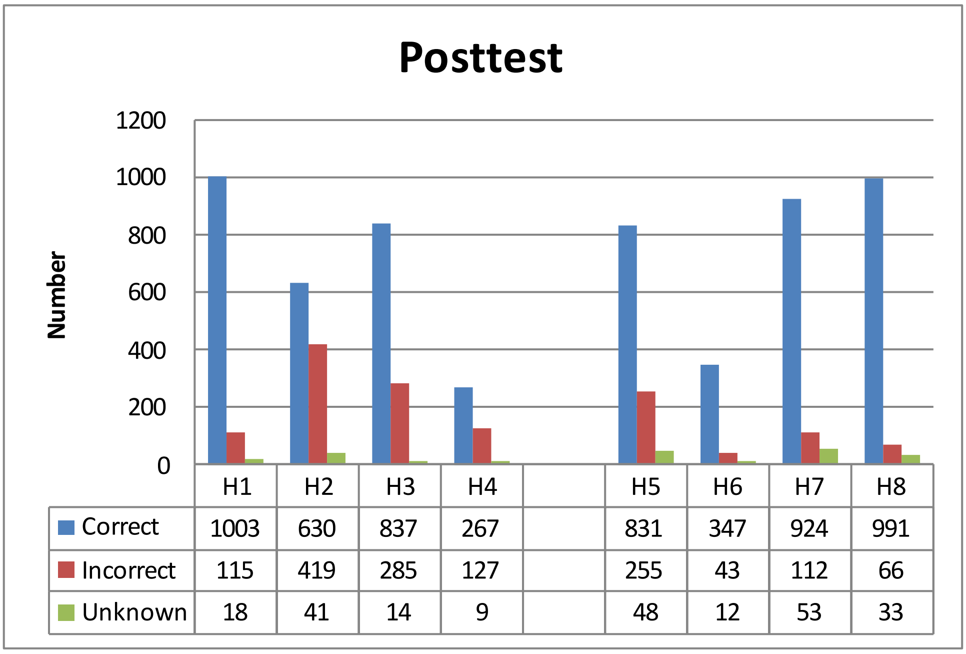
	N	Science experiment	Children know that the objects weigh differently
Chinn and Malhotra (2002)	76	Heavy and light rocks dropped simultaneously	Heavy object would hit first: 65% Light object would hit first: 15% Two objects would hit at the same time: 20%
This work	885	'Heavier objects fall faster than lighter ones'	True-Heavy object would hit first: 68% False-Two objects would hit at the same time: 26% I do not know: 6%

Table 3. Comparison of predicted vs observation between seeing and doing an experiment

	*	Observation (in percentages)*		
Prediction status	N	Heavy object hit first	Two objects would hit at the same time	Light object hit first (I do not know)
Heavy object hit first	95 (606)	46% (287-47%)	26% (307-51%)	31% (12-2%)
Both objects would hit at the same time	29 (231)	28% (73-32%)	72% (151-65%)	0% (7-3%)
Light object would hit first (Do not know)	74 (51)	39% (15-30%)	35% (18-35%)	26% (18-35%)
Uninformed no prediction*	74	39%	35%	26%
*Data from Chinn and Malhotra, 2002 (in parentheses data from this study).				



	H1	H2	H3	H4		H5	H6	H7	H8
Correct	542	295	426	114		581	180	830	679
Incorrect	481	735	690	268		374	158	107	202
Unknown	173	60	79	22		241	66	155	211



	H1	H2	H3	H4		H5	H6	H7	H8
Correct	1003	630	837	267		831	347	924	991
Incorrect	115	419	285	127		255	43	112	66
Unknown	18	41	14	9		48	12	53	33

Figure 1. Number of children that answer each one of the three options of the questionnaire, before and after the instruction

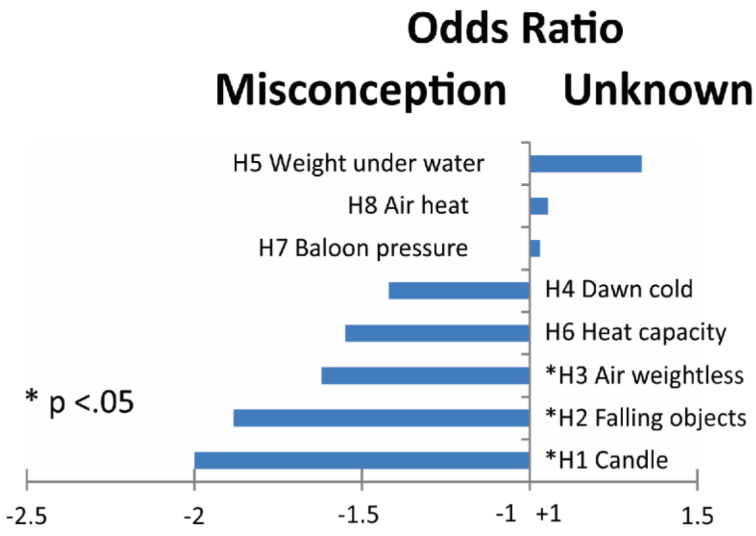


Figure 2. Values of Exp(B) (odds ratio) obtained for each hypothesis. See text for details.