

The Effect of Integrative STEM Instruction on Elementary Students' Attitudes toward Science

Radu Bogdan Toma ^{1*}, Ileana M. Greca ¹

¹ Departamento de Didácticas Específicas, Universidad de Burgos, SPAIN

Received 21 September 2017 • Revised 18 December 2017 • Accepted 18 December 2017

ABSTRACT

An inquiry-based integrative STEM education approach was implemented in two fourth grade Elementary Education classes, in Spain, through a module on simple machines. The viability of this science education model in the official Spanish curriculum and its influence on students' attitudes towards science and learning of STEM subjects has been studied through an adapted Test of Science Related Attitude scale, achievement tests, and teachers' interviews. Students participating in the integrative STEM project reported significantly more favourable attitudes toward science than students from traditional classrooms. Although attitude scale and achievement test results seem to show that an integrative STEM education may be feasible in 4th grade of the Spanish elementary education, interviews revealed reluctance among teachers to use integrative STEM education and more directive instructions on implementing such an educational model are demanded. Implications for science education and future studies are discussed.

Keywords: integrative STEM, attitudes toward science, inquiry-based science education, TOSRA

INTRODUCTION

Numerous reports warn of failings in the educational system to provide suitable science and technological training for young people in relation to the employment needs of the 21st (e.g. EC, 2016; UNESCO, 2015). Over recent years, fewer and fewer students appear to be interested in problems of a scientific-technological nature (Osborne & Dillon, 2008). In Europe, the number of students that end their formal studies with no scientific qualification has increased (EC, 2015), and the number of enrolments in scientific courses has fallen (OECD, 2005, 2006). The reasons for this constant reduction have been previously investigated (e.g. Ali, Yager, Hacieminoglu & Caliskan, 2013; Jones, Howe & Rua, 2000; Osborne, Simon & Collins, 2003). Evidence seem to show a failure in reaching the proposal of science education reform; as Osborne and Dillon (2008) pointed out, "The challenge therefore, is to re-imagine science education (...) for the modern world and how it can meet the needs of all students." (p. 5). Apparently, students begin elementary education with a spontaneous interest in nature, however, by the end of this educational stage they perceive science to be irrelevant, boring and too difficult to learn. Thus, while students interest in science is high at 10 years old, regardless of gender (Haworth, Dale & Plomin, 2008), by the time students are 14 years old, their interest has decreased considerably (Osborne et al., 2003). Lindahl (2007), after a longitudinal study with students of 12-to-16 years old, concluded that career aspirations and interest in science became evident at 13 years old and that the probability of engaging students in science related activities at later ages was progressively more difficult.

Although these findings suggest a need for greater emphasis on science education at the elementary education stage, there is little knowledge on how to best do it. Thus, there is a need to develop science education initiatives that address the generalized development of unfavourable attitudes toward science in elementary students. For this reason, the aims of this paper are to present a proposal for integrative STEM education and to assess its impact on elementary students' attitudes toward science and to study its viability in the Spanish education system. The results may be useful in decreasing the gap in the literature related to science education efforts focused on reducing the factors that leads to students' rejection of science, especially in Spain.

Contribution of this paper to the literature

- This paper presents a frame of reference for the design of integrative STEM projects for the elementary level.
- The proposed model seems feasible to be used for science teaching, particularly in the Spanish education system.
- The proposed model seems to improve 4th grade students' attitudes toward science in comparison to a traditional science teaching approach.

BACKGROUND

Attitudes toward Science

Concern over students' attitudes toward science is not new (Osborne et al., 2003) and different factors involved have been investigated. Different studies have established that the environment in which the learning of science takes place has a direct relation with the attitudes that students will develop at a later stage in life (e.g. Aldridge & Fraser, 2000; Puacharearn & Fisher, 2004). Thus, unfavourable attitudes seem to be related to traditional science teaching approaches (Oh & Yager, 2004) and rote learning (Hacieminoglu, 2016). In addition to the methodological factor, other aspects seem to impact students' attitudes, such as academic results, gender, and grade level (Ali et al., 2013). In relation to the first aspect, Caleon and Subramaniam (2008) indicate that students with low performance have shown a more unfavourable attitude towards science in comparison with high achievers. In terms of gender, there are contradictory evidences. While some studies report that boys have more favourable attitudes in comparison to girls (e.g. De Pro Bueno & Pérez Manzano, 2014; Jarvis & Pell, 2005), others have noted similar attitudes towards science among both male and female students (Akpınar, Yildiz, Tatar & Ergin, 2009).

Finally, related to grade level, although traditionally the age of 14-16 years has been established as the focal-age to improve interest in the attitudes toward science, Haworth et al. (2008) suggest that those vocations are already defined at 14 years old. Research into elementary students' attitudes toward science confirmed that girls tend to report more unfavourable attitudes than boys. More specifically, girls enjoy less science lessons (Denessen, Vos, Hasselman, & Louws, 2015) and boys have more aspiration in science than girls (DeWitt & Archer, 2015). Also, it seems that as grade level increase, favourable attitudes toward science decrease drastically (Ali et al., 2013; Said, Summers, Abd-El-Khalick, & Wang, 2016).

STEM Education

In order to increase students' positive attitudes toward science and foster their aspiration for a science related career, STEM (Science, Technology, Engineering & Mathematics) proposals have gained momentum. The idea of STEM education is the conceptualization of these disciplines as a cohesive entity, the teaching of which is integrated and coordinated as they are applied to problem-solving in the real world (Sanders, 2009). Therefore, STEM education is a model that ought to promote and improve the learning of the disciplines to which the acronym refers. Nevertheless, the conceptualizations of what STEM implies often vary between authors. While some proposals focus on the renovation of each STEM subject (Bybee, 2013), others support a multidisciplinary and integrative STEM education in which the teaching of the contents of Science, Technology, Engineering, and Mathematics subjects is similar to the treatment of these disciplines in real life (Ritz & Fan, 2014).

Nevertheless, this approach is complex and there is a lack of consensus over establishing how the content should be organized, taught and evaluated, and at what educational stage its implementation would be more convenient and beneficial (Pitt, 2009). In the comprehensive review of STEM programs conducted by Heil, Pearson & Burger (2013), the authors indicate that there is an absence of empirical studies and theoretical frameworks that guide the design and implementation of STEM programs; that the clear majority of proposals are implemented in an extracurricular schedule; and that STEM proposals are generally designed and implemented in secondary school. In the Spanish educational system, Cañal's (1998, 2007) and Charrier Mellillán, Cañal & Rodrigo Vega's (2006) studies report that teachers are reluctant to implement active teaching methodologies (like inquiry-based Science teaching) in their classrooms. In general, Spanish teachers consider that inquiry teaching is a very slow teaching method and think that it is not viable; teachers consider that it will be impossible to implement the curricula objectives and contents that are necessary if contents are taught according to student's interests. Finally, teachers tend to consider that the quality of the knowledge that students achieve through an inquiry-based education can be low or very low (Cañal, 2007).

At the institutional level, several governments have emphasized the need to develop specialized STEM programmes at all educational stages, with several of them based on the inquiry teaching approach. Thus, for

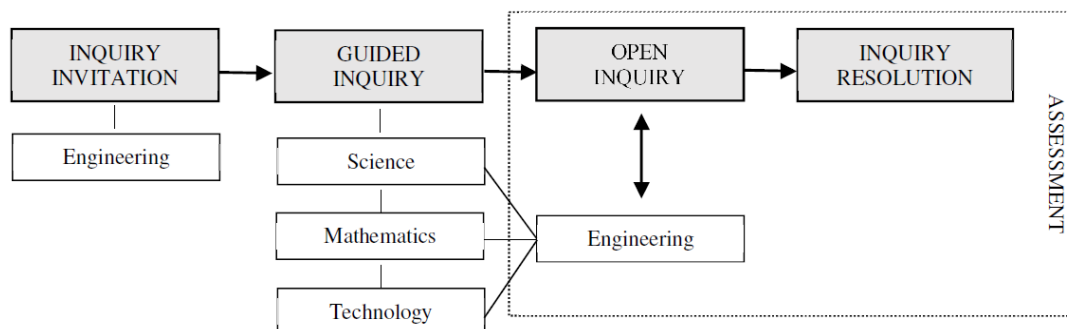


Figure 1. Integrative STEM framework for elementary education

example, Australia (Marginson, Tytler, Freeman & Roberts, 2013) and Scotland (Science and Engineering Education Advisory group, 2012) have published national reports with recommendations for the implementation of STEM education and have proposed an integrated curriculum in the final year of Secondary Education (ASEE, 2011; Ritz & Fan, 2014; Pitt, 2009; Australian Government, 2013). However, for Elementary Education there is an absence of educational projects of these characteristics (Heil et al., 2013).

THEORETICAL UNDERPINNINGS OF THE PROPOSED MODEL

In this article, we propose an integrative STEM education model for elementary school. We consider that an integrative STEM education is more pertinent for elementary school because disinterest in science among students starts in this level (Keeley, 2009), especially in girls (Abell & Lederman, 2006). Moreover, a strong positive relationship has been found between students' science-related experiences at elementary school and the choice of future studies in STEM disciplines (Tai, Qi Liu, Maltese & Fan, 2006). Regarding viability, in elementary education, teachers teach most of the subjects to the same class. So, an interdisciplinary and integrated treatment would not be a drastic change at that educational level. At least in Spain, it would be more difficult to implement an integrative STEM model in secondary education, due to the curricular organization and, even though teachers at this level possess a higher conceptual knowledge of the subject matter, all the necessary teaching and pedagogical skills to implement an integrative STEM education at that stage may be lacking.

The proposed model of integrative STEM education uses, as a main teaching methodology, an inquiry-based science teaching approach. The term "inquiry teaching" has been used to characterize good practices in both the teaching and the learning of STEM disciplines (NRC, 2011, 2012; Rocard et al. 2007), and science teachers and researchers have scattered various interpretations of the effective forms of inquiry-based science education. In our model, we understand inquiry teaching as defined by the National Research Council (NRC, 2012): as a set of activities that seek to assimilate the learning of science and the processes and strategies that scientists follow to resolve problems in real world situations. It is a strategy that seeks to facilitate self-learning through students' interactions with the objects of the environment that stimulate them, awake their curiosity, and drive the development of thoughts of a higher order and problem-solving skills, which are competencies demanded in many science curricula reforms and in the Spanish educational system (LOMCE, 2013). For us, learning science and about science requires inquiry teaching that should involve activities that include the analysis of scientific questions through the use and development of numerous skills (identification of variables related to the problem that needs to be investigated; design and realization of experiments; data interpretation; development of explanations, and the communications of results and conclusions). More specifically, our proposal is based on a coupled inquiry (Martin-Hansen, 2002) that combines a guided and an open inquiry investigation. Through this model, different aspects of Science, Mathematics, Technology and Engineering are addressed (Figure 1). It begins with an invitation to inquiry in which teacher select a first problem to investigate that is connected to a specific science standard or content. Next, an open-inquiry is implemented where students generate questions related to the first problem and "specific concepts can be explored in a more didactic fashion allowing students to connect their concrete experiences to abstract concepts" (Martin-Hansen, 2002, p.35).

The proposed model consists of four phases that seeks to encompass each STEM discipline. Thus, in the first phase (inquiry invitation), the teacher proposes an engineering-based real-world problem that serves as a context to teach science-related content matter. During the second phase students perform a guided inquiry in which they conduct different experiments using scientific practices, technology, and interpret data using mathematics. The third phase consists of an open inquiry during which students should discuss the results obtained in the guided inquiry and propose new research questions necessary to solve the initial problem. The fourth and final phase (inquiry resolution) requires the design or implementation of a solution which could be technological in nature. In

this way, students begin to explore engineering design, linking engineering and science, as proposed in NRC (2012). **Table 1** report how STEM disciplines are emphasized during the four phases of the proposed model.

Table 1. Integrative STEM phases and its relationship with STEM disciplines

Coupled inquiry	STEM disciplines
INQUIRY INVITATION Science content is introduced through a real world problem	SCIENCE - ENGINEERING Real world problem related to an engineering challenge
GUIDED INQUIRY Students perform guided experiment following teacher instruction	SCIENCE Application of scientific methodologies in order to address the scientific concepts needed to solve the problem MATHEMATICS Data analysis and interpretation TECHNOLOGY Handling of devices and instruments for the design of experiments, data gathering and analysis
OPEN INQUIRY Students keep addressing the initial problem through experiments that are not guided by the teacher	SCIENCE, TECHNOLOGY, ENGINEERING, MATHEMATICS Students discuss the results obtained and they identify better ways to improve their design in order to solve the initial problem
INQUIRY RESOLUTION Solving the initial problem	ENGINEERING Students design or implement the technological device that solves the initial problem, using the scientific concepts developed previously and, in this way, linking engineering and science TECHNOLOGY Students propose possible technological applications in real world situations of the scientific concepts addressed throughout the inquiry. Students communicate their results and offer a possible resolution of the initial problem

Programme Description: The Proposed Model as Applied to Simple Machine Unit for 4th Graders

The following is an example of the application of this model on the topic of simple machines, as designed for fourth graders.

1st phase: Invitation to inquiry. The teacher introduces the following engineering-based problem: How did the Egyptians transport the stone blocks for building the pyramids without using modern machines?

2nd phase: Guided inquiry. After the discussion, the teacher indicates students how to construct three simple machines (pulleys, inclined planes and levers) using LEGOTM material. To perform the experiments, students tie a small-sized bag into each simple machine. Then, they insert small-sized coins until the block to be transported is raised. Next, students determine the force applied by the coins to move the stone block using a dynamometer. The experiment is repeated changing the size and the weight of the stone block, the fulcrum in the case of the lever, the angle of slope in the case of the inclined plane, and the type of pulley (fixed or mobile and its size). In each case, students have to predict what will happen. The experiments are conducted three times with each simple machine, in groups. When the experiments are done, students discuss the results obtained and the laws that govern each machine are deduced with teacher facilitation. It's worth stressing that in this unit the mathematical concepts are adding, subtracting, multiplying, and dividing decimals.

3rd phase: Open inquiry. Students report their results and discuss new variables that might have an impact on the force that is necessary to move the pyramid block using simple machines, such as the ruggedness of the inclined plane surface, the length of the inclined plane, or if a simple or compound pulley is used. Afterwards, in groups, they propose new hypotheses, design and complete experiments, and formulate their conclusions.

4th phase: Solution of the initial problem. With the results of the coupled inquiry and other support materials (e.g. class textbook), students create a model with LEGOTM materials in which the route of a stone block from its origin to the hypothetical pyramid is shown, pointing out the way in which simple machines would have been used. This solution implies an engineering thinking process, where students have to apply the scientific concepts studied and give a reasoned answer.

DESIGN AND METHODS

Purpose

The purpose of this study is to implement and evaluate, through a quasi-experimental study, the viability of the proposed integrative STEM model in the elementary stage of the Spanish educational system, and to assess its impact in 4th year students' attitudes toward science. Therefore, the following research questions were proposed:

1. What effect does the proposed STEM model have on girls' and boys' attitudes toward Science?
2. Is the proposed STEM model feasible in the Spanish educational system?

It's worth stressing that for answering this second question it is necessary to address two aspects. One is related to student's science achievement when science is being taught using a hands-on approach, and the other is related to the main objections placed by Spanish teachers for not implementing active-teaching approaches (e.g. time consuming and student's low achievement).

Participants and Procedure

The research was carried out in two elementary schools from a metropolitan area situated in northern Spain (n = 96 students; 42% girls). Two classes have formed the treatment group (n = 55) and two classes the control group (n = 41). The treatment group was selected using convenience sampling and control group was selected based on similarities with the treatment school in terms of science teaching methodology, materials used, and students' performance.

All students included in this study passed science subject during the first trimester and most students were Spanish (foreign students were less than 10% in each school). Also, both schools followed similar science teaching approaches, mainly via traditional teaching strategies using textbooks: students neither conducted experiments, nor were engaged in problem solving activities.

The content of simple machines was selected. The treatment group studied this content through the proposed integrative inquiry-based STEM model (as detailed in the previous section), and the control group through traditional science teaching methodology. Teachers from treatment group were assisted by the first author of this study during the whole implementation. Both treatment and control group simple machine unit lasted for 12 sessions (60 minutes each), as initially expected.

Measures

Adapted Test of Science Related Attitudes (TOSRA)

An attitudinal scale adapted from Fraser's (1981) TOSRA instrument was used to assess the influence of the proposed model on students' attitudes toward science. Originally, TOSRA was designed to assess seven attitudes' dimensions through a total of 70 Likert-type items. For this study, we adapted the scale to fit our specific context and to be more viable for its application with four grade elementary students. Thus, items were reduced to a total of 14, two for each dimension. All items formulated negatively were discarded because of Spanish language characteristics, in which negatively worded sentences reduced understanding. Of the remaining positive items, authors selected four items per attitude sub-dimension until reaching complete consensus. Next, items were translated into Spanish by two bilingual translators using direct and back-translation (Callegaro Borsa, Figueiredo Damásio & Ruschel Bandeira, 2012). A pilot study was performed using a 28 Likert-type scale (n = 24; 4th graders). Preliminary results indicated student's fatigue and scale administration was time demanding. Thus, items with low reliability were excluded ($\alpha < .60$) and a final scale of 14 items was developed, two per dimension. Cronbach's α of the finale scale administered in this study was .78. The adapted TOSRA assess social implication of science (i.e. It is worth spending money on science; Science can help to make the world a better place), normality of scientists (i.e. Scientists are normal people who look like anyone else; Scientists are just as friendly as other people), attitudes toward scientific inquiry, (i.e. If I want to know something about science I prefer to do an experiment instead of receiving the answer from another person; It is better to discover things by experimentation rather than asking the teacher), adoption of scientific attitudes (i.e. I am curious about the world in which I live and the things surrounding me; I find it interesting to debate and hear opinions that are different than mine), enjoyment of science lessons (i.e. Science is the most interesting subject; I would like to have more science classes each week), leisure interest in science (i.e. I would like to receive scientific materials to do experiments at home; I like to talk about science during my leisure time), and career interest in science (i.e. When I grow up: I would like to work with people who makes scientific discoveries; I would like to study something related to science). A Spanish version of the scale is included in the Appendix 1.

During the post-test, once students complemented TOSRA scale, they were asked two open-ended questions (i.e. What are your thoughts about school science subject? Can you explain your feelings and thoughts about school science subject?)

Students achievement test

An achievement test with 25 questions was prepared following teachers' criteria and standards of evaluation. Two items asked for theoretical definition and the remaining were problem solving-based items that were answered through multiple choice or true/false answer. Examples of these questions are attached in Appendix 2.

Teacher structured interview

In order to know the vision of the regular teachers of the treatment group, a structured interview was prepared to gather information about what they believed to be important factors for science teaching and learning in elementary education (i.e. What factors do you consider to be essential for science teaching and learning in elementary education based on gender variables?), what methodology, materials and activities they used to develop for science teaching (i.e. How would you describe your approach to science teaching and what materials and activities do you use most?), and their thoughts about teaching science through an integrative STEM approach (i.e. Discuss the use of integrative STEM approaches for science teaching).

Data Collection and Analysis

The implementation of the proposal and data collection were carried out during the second semester of the 2015-2016 academic years. Data for the 1st research question (i.e. What effect does the proposed STEM model have on students' attitudes toward science?) were intended to be gathered using a control group pre-post-test design. However, because of school time restriction, the control group didn't allow pre-test data collection. Thus, available data for this research question were obtained based on a comparative post-test design using the adapted TOSRA scale. The actions adopted in order to prevent threats to internal validity were related to the context. The proposal was implemented in the same context as usual for students: time, teachers, classroom organizations, and the written support (the usual textbook).

In order to categorize students' attitudes toward science, cut-off points were established with equal percentages based on the cases explored ($n = 96$), obtaining three categories describing their attitudes (favourable, indifferent and unfavourable). Next, a statistical Student t-test for each TOSRA dimensions was used to determine differences in attitudes toward science between control and treatment group students.

Data for the second research question (i.e. Is the proposed STEM model feasible in the Spanish educational system?) were collected administering to the treatment group ($n = 55$) an achievement test (pre and post implementation) and by performing structured interviews with teachers ($n = 2$; only post-implementation). For analysing the achievement test, cut-off points were established (fail: correct answers <12 ; below average: 13-15 correct answers; average: 16-18 correct answers; better than average: 19-21 correct answers; excellent: correct answers > 22). Descriptive statistics and paired samples t-tests were used to analyse achievement test results. Interviews were analysed through conventional content analysis, which is a technique generally used for describing a phenomenon without imposing any existing theory (Hsieh & Shannon, 2005), in this case teacher's perception of the feasibility of the proposed STEM model. To do so, interviews were transcribed and edited to allow analysis at the sentence level. Interviews transcripts from both teachers were read comprehensively several times to get an overview of their answers. Next, transcripts were read in detail and key words that capture teachers' key opinions to each interview question were highlighted and codes were derived. Continuing this process, related codes were sorted into more general categories that reflect more than one linked key opinion. To ensure that the analyses was reliable, both authors discussed the coding scheme and categories derived, and the few discrepancies were solved by consensus after in-depth analysing the transcript jointly.

RESULTS

What Effect does the Proposed STEM Model have on Girls' and Boys' Attitudes toward Science?

Student t-student test indicated that students' attitudes from the treatment group differed significantly from students in control group, as measured post-test by the adapted TOSRA scale. On average, the treatment group reported better attitudes toward science (80% favourable; 18.2% indifferent; 1.8% unfavourable) than control group (19.5% favourable; 60.9% indifferent; 19.5% unfavourable; $p < .05$). More specifically, students studying simple

machines through the integrative STEM approach proposed reported more favourable attitudes in five TOSRA sub-dimensions (Table 2) than students studying simple machines unit through a conventional approach. Up to 83.7% of the students from the treatment group expressed positive opinions about science subject, indicating that they saw science as useful (60%) and that they were able to use imagination and creativity during experiments (73.3%). On the contrary, 80.5% of control group students reported negative feelings about science subject, considering it was too hard because of many exercises and homework (82.2%) and boring due to continually reading from the textbook (46.3%).

Table 2. TOSRA sub-dimensions' results. Comparison between treatment and control group

	SIS ¹	NS	ASI	ASA	ESL	LIS	CIS
p value	.193	.008*	.000*	.001*	.000*	.000*	.082

* Significant at a level of .05 in favour of treatment group.

¹ Social implications of science (SIS); Normality of Scientist (NS); Attitude to Scientific Inquiry (ASI); Adoption of Scientific Attitudes (ASA); Enjoyment of Science Lessons (ESL); Leisure Interest in Science (LIS); Career Interest in Science (CIS)

Thus, the proposal seems to foster more favourable attitudes towards scientists, scientific inquiry, adoption of scientific attitudes, enjoyment of science lessons, and leisure interest in science. No significant differences regarding gender were obtained between and within each treatment or control group ($p > .05$).

Is the Proposed STEM Model Feasible in the Spanish Educational System?

The achievement test supports the integrative STEM model proposed in this study in fostering learning in students: all students improved their knowledge about simple machines, as shown in Figure 2.

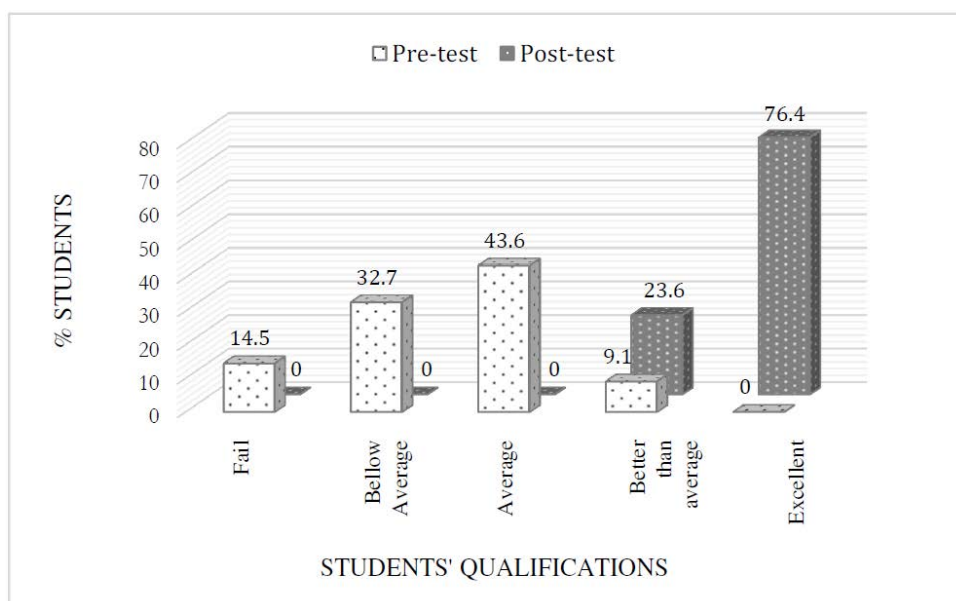


Figure 2. Treatment group achievement test results

Three questions reported significant differences between pre and post-STEM implementation (Table 3). No significant gender differences were obtained between boys' and girls' achievement results ($p > .05$).

Table 3. Achievement test questions that were correctly answered by most treatment group students

Achievement test questions	Pre-test		Post-test		P value
	% wrong answers		% wrong answers		
	Girls	Boys	Girls	Boys	
Only living beings have force	78.3	78.1	4.3	3.1	.03
The weight of an object influences the speed of its fall	95.7	87.5	34.8	15.6	.04
Don't know how to define simple machines	100	96.9	17.4	25	.02

Related to the interviews, both teachers interviewed were females with more than 20 years of teaching experience at elementary level. None of them had specific background or training in science. In relation to the important factors for science teaching, two themes emerged: practical approach, and teacher-student's interaction. Both teachers reported that science teaching needs to be practical to foster understandings of abstract concepts. One teacher discussed the importance of a positive teacher-student interaction, concluding that teachers must create a space of dialogue in which students can solve all their misunderstandings.

However, these teachers' conceptions weren't used during science lessons. Analysis of the second interview question (i.e. How would you describe your approach to science teaching and what materials and activities to you use most?) revealed that neither the teaching approach, nor the materials used to enhance students' understanding were practical in nature. Thus, both teachers mentioned the textbook as the principal material for science teaching and individual and group written activities as the most habitual practice during science lessons. Three themes emerged as reasons for these choices: educational authorities' demand, usefulness, and convenience. Relating to educational authority's demand, both teachers alluded that textbooks were imposed: "Textbooks are imposed by the school board"; "Given that parents spent a lot of money buying these books, we must use it and we cannot demand parents to buy extra material [that is necessary for performing experiments]". Also, textbooks were considered useful: "Using textbooks we can complete more easily the study program, and this is something that parents value most". Finally, regarding the convenience aspect of using textbooks as the main material, teachers said that "It is the only way to make sure that students don't make a lot of noise."; "Class management is easier [using textbooks]"; "It hardly requires a lot of preliminary preparation", "The publisher provides enough activities to accomplish the study program", and finally, that "parents want to see what their children learn in class. So, by having a textbook, they can review what have been taught each day".

In relation to the third interview question (i.e. Discuss the use of integrative STEM approaches for science teaching) both teachers argued that, although they were surprised by students' results and the classroom atmosphere during the STEM project, they wouldn't use it as the main approach for science teaching. Two themes emerged for this decision: lack of knowledge, and time demanding for the teachers. Thus, one teacher said that "I would be encouraged to use this kind of methodology if class lessons would be provided like the textbooks that we use. I need to know what to do in each moment and how to teach content". Also, both teachers agreed that "I see possibilities to use this approach as a complement to the textbook, but I can't imagine teaching science using STEM [referring to the approach introduced in this study]"; "I simply have no time for preparing experiments at home and then bring them to the classroom."; "I think that this kind of teaching is only viable in the case of having a program-guide and materials already prepared, like the textbook we use". So although the proposal seems to be feasible in Spanish educational, teachers went on being reluctant about its use.

DISCUSSION AND CONCLUSION

Results of this study reinforce the advantages of an integrative STEM education which uses inquiry teaching methodology. In general, it appeared to improve students' attitudes toward science and fostered science content learning. However, although the use of this approach has indicated to be viable in 4th grade of elementary education, teachers remained reluctant about its use and demanded more directive instructions, which requires future studies.

As shown by TOSRA results, students engaged in an integrative STEM approach reported more positive attitudes toward science than those studying science through a conventional (e.g. textbook-based) approach. These results confirm those from earlier studies stating that an active science teaching methodology improves students' attitudes (Hacieminoglu, 2016; Oh & Yager, 2004). Gender didn't have any significant influence in both treatment and control students' attitudes towards science, differing from the tendency showed in previous studies (i.e. Denessen et al. 2015; DeWitt & Archer, 2015; De Pro Bueno & Pérez Manzano, 2014; Jarvis & Pell, 2005), but being similar to those obtained by Akpınar et al. (2009). Overall, these results seem to indicate that the model proposed – using a coupled inquiry and clearly defining each of the phases needed for integrating the different STEM subjects – may be useful for the design of other STEMs teaching units for the elementary level.

This study has also shown positive results regarding the viability of an integrative STEM approach for elementary education. Thus, none of the limitations reported by Spanish teachers in Cañal's (2007) were identified. More specifically, the integrative STEM proposal was implemented without any need to make large-scale changes in the classroom distribution, subjects timing, nor school centre organization, contradicting common belief that "Inquiry teaching is a very slow teaching method. It is not viable"; "If content is taught according to students' interests it will be impossible to implement the curricula objectives and contents that are necessary" (Cañal, 2007, p. 10). Additionally, achievement test results seemed to show that students did learn the science-content proposed by following scientific and engineering practices instead of rote-learning, which clearly show that the common beliefs about the quality of knowledge achieved through active-teaching approaches being low, as reported by teachers in Cañal's (2007) study, doesn't seem to be true. However, the interviews showed that although teachers

initially considered that science teaching and learning needs a practical approach, which tends to be a common conception within science teachers (Ireland, Watter, Brownlee & Lupton, 2012), they remained reluctant about the implementation of the STEM model presented in this study. Specifically, teachers reported to prefer a textbook based approach for science teaching due to convenience and logistical reasons, and they conceived the proposed STEM model as a complement to the theoretical lessons, which is similar to Spanish pre-service teachers' conceptions that consider practical activities to be used for clarifying and reinforcing the theoretical content (Hamed, Rivero & del Pozo, 2014).

The results of this study should be interpreted considering the following limitations. The application of the achievement test to both treatment and control groups could have provided more information about the relationship between scientific content learning and the teaching approach used. However, this was not an issue to be investigated in the present study. Another limitation is related to the study design. Although comparative post-test design can report useful results, its main downfall is not controlling the variables that could have impacted post-test results. Thus, it is not clear to what extent treatment students' attitudes toward science were more favourable due to the integrative STEM approach used or due to an already existing positive attitude prior to the project implementation. However, to counteract this downfall we selected schools with similar characteristics and, most importantly, that used the same teaching method and materials.

Results and limitations of this study point to more questions that are worth investigating. The extent to which this model could be adapted to other science content needs to be studied. Additionally, studies using this approach in higher or lower grades than 4th grade are encouraged. Finally, it is necessary to deepen in teacher's hesitation of shifting to a more active-based methodology for science teaching. If science teaching reforms are intended to be achieved, especially in the Spanish educational system, there seems to be an urgent need to study teacher's intention to use integrative STEM approaches and to meet their demands for more directive instructions, trainings and communities of practices (El-Hani & Greca, 2013) or mentoring programmes for the implementation of inquiries (Yoon, Kim, Kim, Young & Park, 2013) that guide science teaching at elementary level through integrative proposals. Additionally, there is a need for science textbooks to include coupled-inquiry laboratory activities. By this inclusion, teachers may be more likely to implement this particular hands-on learning strategy.

In conclusion, this study has sought to design, implement and assess an integrative STEM approach for science teaching at 4th grade elementary school level. The results of this study show that the model proposed may foster favourable attitudes toward science and offer a frame of reference for the design of integrative STEM projects.

REFERENCES

- Abell, S., & Lederman, N. G. (2006). *Handbook of research on science education*. New Jersey: Lawrence Erlbaum Associates.
- Akpınar, E., Yildiz, E., Tatar, N., & Ergin, Ö. (2009). Students' attitudes toward science and technology: an investigation of gender, grade level, and academic achievement. *Procedia Social and Behavioral Sciences*, 1(1), 2804-2808. <https://doi.org/10.1016/j.sbspro.2009.01.498>
- Aldridge, J. M., & Fraser, B. J. (2000). A cross-cultural study of classroom learning environments in Australia and Taiwan. *Learning Environments Research*, 3, 101-134. <https://doi.org/10.1023/A:1026599727439>
- Ali, M. M., Yager, R. E., Hacieminoglu, E., & Caliskan, I. (2013). Changes in student attitudes regarding science when taught by teachers without experiences with a model professional development program. *School Science and Mathematics*, 113(3), 109-119. <https://doi.org/10.1111/ssm.12008>
- ASEE (American Society for Engineering Education). (2011). Preparing future engineers around the world. *PRISM*, 21(5), 26-34.
- Australian Government. (2013). *Science, Technology, Engineering and Mathematics in the National Interest: A Strategic Approach*. Retrieved on 21 August 2017 from <http://www.chiefscientist.gov.au/wp-content/uploads/STEMstrategy290713FINALweb.pdf>
- Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunities*. National Science Teachers Association Press.
- Caleon, I. S., & Subramaniam, R. (2008). Attitudes towards science of intellectually gifted and mainstream upper primary students in Singapore. *Journal of Research in Science Teaching*, 45(8), 940-954. <https://doi.org/10.1002/tea.20250>
- Callegaro Borsa, J., Figueiredo Damásio, B., & Ruschel Bandeira, D. (2012). Cross-Cultural Adaptation and Validation of Psychological Instruments: Some Considerations. *Paidéia*, 22(53), 423-432. <https://doi.org/10.1590/1982-43272253201314>

- Cañal, P. (1998) El origen de la investigación escolar: una alternativa se síntesis frente a la enseñanza tradicional. In G. Travé & F. J. Pozuelos (Eds) *Investigar en el aula*. Aportaciones para una didáctica innovadora. Universidad de Huelva: Servicio de Publicaciones.
- Cañal, P. (2007). La investigación escolar, hoy. *Didáctica de las Ciencias Experimentales*, (52), 9-19.
- Charrier Mellillán, M., Cañal, P., & Rodrigo Vega, M. (2006) Las concepciones de los estudiantes sobre la fotosíntesis y la respiración: una revisión sobre la investigación didáctica en el campo de la enseñanza y el aprendizaje de la nutrición de las plantas. *Enseñanza de las Ciencias*, 24(3), 401-410.
- De Pro Bueno, A., & Pérez Manzano, A. (2014). Actitudes de los alumnos de Primaria y Secundaria ante la visión dicotómica de la Ciencia. *Enseñanza de las Ciencias*, 32(3), 111-132. <https://doi.org/10.5565/rev/ensciencias.1015>
- Denessen, E., Vos, N., Hasselman, F., & Louws, M. (2015). The Relationship between Primary School Teacher and Student Attitudes towards Science and Technology. *Education Research International*, 2015, 1-7. <https://doi.org/10.1155/2015/534690>
- DeWitt, J., & Archer, L. (2015). Who Aspires to a Science Career? A comparison of survey responses from primary and secondary school students. *International Journal of Science Education*, 37(13), 2170-2192. <https://doi.org/10.1080/09500693.2015.1071899>
- EC (European Commission). (2016). *Horizon 2020. Monitoring Report 2014*. Luxembourg. Retrieved on 21 August 2017 from http://ec.europa.eu/research/evaluations/pdf/archive/h2020_monitoring_reports/second_h2020_annual_monitoring_report.pdf
- EC (European Commission). (2015). *Science education for Responsible Citizenship*. Luxembourg: Publication Office of the European Union.
- El-Hani, C. N., & Greca, I. M. (2013). ComPratica: A Virtual Community of Practice for Promoting Biology Teachers Professional Development in Brazil. *Research in Science Education*, 43, 1327-1359.
- Fraser, B. J. (1981). *TOSRA: Test of science-related attitudes handbook*. Hawthorn: Australian Council for Educational Research.
- Hacieminoglu, E. (2016). Elementary school students' attitude toward science and related variables. *International Journal of Environmental and Science Education*, 11(2), 35-52. <https://doi.org/10.12973/ijese.2016.288a>
- Hamed, S., Rivero, A., & del Pozo, R. M. (2016). El cambio en las concepciones de los futuros maestros sobre la metodología de enseñanza en un programa formativo. *Revista Eureka sobre Enseñanza y Divulgación de las Ciencias*, 13(2), 476-492.
- Haworth, C. M., Dale, P., & Plomin, R. (2008). A Twin Study in the Genetic and Environmental Influences on Academic Performance in Science in nine-year-old boys and girls. *International Journal of Science Education*, 30(8), 1003-1025. <https://doi.org/10.1080/09500690701324190>
- Heil, D. R., Pearson, G., & Burger, S. E. (2013). Understanding Integrated STEM Education: Report on a National Study. Paper presented at 2013 ASEE Annual Conference & Exposition, Atlanta, Georgia.
- Hsieh, H-F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research*, 15(9), 1277-1288. <https://doi.org/10.1177/1049732305276687>
- Ireland, J. E., Waters, J. J., Brownless, J., & Lupton, M. (2012). Elementary teacher's conceptions of inquiry teaching: messages for teacher development. *Journal of Science Teacher Education*, 23, 159-175. <https://doi.org/10.1007/s10972-011-9251-2>
- Jarvis, T., & Pell, A. (2005). Factors influencing elementary school children's attitudes toward science before, during, and after a visit to the UK National Space Centre. *Journal of Research in Science Teaching*, 42(1), 53-83. <https://doi.org/10.1002/tea.20045>
- Jones, G., Howe, A., & Rua, M. (2000). Gender differences in students' experiences, interests, and attitudes towards science and scientist. *Science Education*, 84, 180-192. [https://doi.org/10.1002/\(SICI\)1098-237X\(200003\)84:2<180::AID-SCE3>3.0.CO;2-X](https://doi.org/10.1002/(SICI)1098-237X(200003)84:2<180::AID-SCE3>3.0.CO;2-X)
- Keeley, P. (2009). *Elementary Science Education in the K-12 system*. Retrieved from <http://www.nsta.org/publications/news/story.aspx?id=55954>
- Lindahl, B. (2007). A longitudinal Study of Students' Attitudes towards Science and Choice of Career. *80th NARST International Conference*, New Orleans.
- LOMCE (Ley orgánica para la mejora de la calidad educativa). (2013, 10 December). *Ley Orgánica 8/2013, 9 de diciembre*. Boletín Oficial del Estado, nº 295.

- Marginson, S., Tytler, R., Freeman, B., & Roberts, K. (2013). *STEM: Country comparisons* (Final Report). Melbourne: Australian Council of Learned Academies.
- Martin-Hansen, L. (2002). Defining inquiry. *The Science Teacher*, 69(2), 34-37.
- NRC (National Research Council) (2011). *Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics*. Washington, DC: The National Academies Press.
- NRC (National Research Council) (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academy Press.
- NRC. (2011). *Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics*. Washington, DC: The National Academies Press.
- NRC. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academy Press.
- OECD (Organisation for Economic Co-operation and Development). (2005). *Conference on Declining Student Enrolment in Science and Technology*. Amsterdam: OECD Global Science Forum.
- OECD (Organisation for Economic Co-operation and Development). (2006). *Evolution of Student Interest in Science and Technology Studies*. OECD Global Science Forum.
- Oh, P. S., & Yager, R. E. (2004). Development of Constructivist Science Classrooms and Changes in Student Attitudes toward Science Learning. *Science Education International*, 15(2), 105-113.
- Osborne, J. F., Simon, S., & Collins, S. (2003). Attitudes towards Science: a review of the literature and its implications. *International Journal of Science Education*, 25, 1049-1079. <https://doi.org/10.1080/0950069032000032199>
- Osborne, J., & Dillon, J. (2008). *Science Education in Europe: Critical Reflections*. London: The Nuffield Foundation.
- Pitt, J. (2009). Blurring the Boundaries - STEM Education and Education for Sustainable Development. *Design and Technology Education: an International Journal*, 14(1), 37-47.
- Puacharearn, P., & Fisher, D. (2004). *The effectiveness of cooperative learning integrated with constructivist teaching on improving learning environments in Thai secondary school science classrooms*. Australia: Curtin University of Technology.
- Ritz, J. M., & Fan, S. C. (2014). International View of STEM education. *Proceedings PATT-28 conference*, Florida.
- Rocard, M., Csermely, P., Jorde, D., Lenzen, D., Walberg-Henriksson, H., & Hemmo, V. (2007). *Science Education Now: A renewed Pedagogy for the Future of Europe*. Brussels: Directorate General for Research, Science, Economy and Society. Retrieved from https://ec.europa.eu/research/science-society/document_library/pdf_06/report-rocard-on-science-education_en.pdf
- Said, Z., Summers, R., Abd-El-Khalick, F., & Wang, S. (2016). Attitudes toward science among grades 3 through 12 Arab students in Qatar: findings from a cross-sectional national study. *International Journal of Science Education*, 38(4), 621-643. <https://doi.org/10.1080/09500693.2016.1156184>
- Sanders, M. (2009). STEM, STEM education, STEM mania. *Technology Teacher*, 68(4), 20-26.
- Science and Engineering Education Advisory group. (2012). *Supporting Scotland's STEM education and culture*. Retrieved from <http://www.gov.scot/resource/0038/00388616.pdf>
- Tai, R. H., Qi Liu, C., Maltese, A. V., & Fan, X. (2006). Planning early for careers in science. *Science*, 312, 1143-1145.
- UNESCO (United Nations Educational, Scientific and Cultural Organization). (2015). *Education for all 2000-2015. Achievements and challenges*, France. <https://doi.org/10.1126/science.1128690>
- Yoon, H-G., Kim, M., Kim, B. S., Joung, Y. J., & Park, Y. S. (2013). Pre-service teachers' views of inquiry teaching and their responses to teacher educators' feedback on teaching practice. *Eurasia Journal of Mathematics, Science & Technology Education*, 9(4), 347-359. <https://doi.org/10.12973/eurasia.2013.944a>

APPENDIX 1

Adapted TOSRA. Spanish version

1. Merece la pena gastar dinero en la ciencia
2. Un científico se parece mucho a las demás personas
3. Prefiero resolver un problema haciendo un experimento en lugar de recibir una respuesta
4. Tengo curiosidad por las cosas que me rodean y por el mundo en el que vivo
5. Conocimiento del Medio es la asignatura más interesante
6. Me gustaría recibir materiales científicos para poder hacer experimentos en casa
7. Cuando sea mayor, me gustaría trabajar con personas que realizan descubrimientos científicos
8. La ciencia puede ayudar a que el mundo sea un lugar mejor
9. Los científicos son igual de simpáticos que las demás personas
10. Es mejor descubrir la respuesta mediante un experimento antes que preguntar al profesor
11. Me gusta escuchar a las personas que tienen una opinión diferente a la mía
12. Me gustaría tener más horas de Conocimiento del Medio a la semana.
13. Me gusta hablar sobre la ciencia fuera de clase.
14. Cuando sea mayor, quiero estudiar algo que tenga que ver con la ciencia.

APPENDIX 2

Achievement test. Sample questions*Theoretical questions:*

Define what you think is a simple machine. Give an example.

Define what you think is a compound machine. Give an example.

Multiple choice questions:

- Two balls (one black, one white) are the same size. The black ball weighs 10 kg and the white ball weighs 5 kg. Both balls are thrown from a building at the same moment and from the same height. Which of the two balls reach the ground first? Select the correct option and explain your answer.

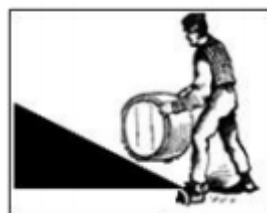
- a) Both balls hit the ground at the same time.
- b) The black ball arrives first.
- c) The white ball arrives first.

- Consider the following pictures. Sandro must load a truck with a heavy barrel. For this, he can use ramp A or ramp B. Indicate whether the following statements are true (T) or false (F). Explain the answers you think are false.

Ramp A



Ramp B



- a) In both the ramp A and the ramp B, Sandro must apply the same force to transport the barrel.
- b) If Sandro chose ramp B, he will apply less force to transport the barrel in comparison to using ramp A.
- c) Sandro must not use any ramp. He'd better pick up the barrel and transport it without any ramp.

<http://www.ejmste.com>