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Impact of implementing a long-term STEM-based active learning course on students' motivation

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Abstract This paper aims at analysing the effect of implementing a long-term STEM-based active learning course on students' motivation. First of all, a course that introduces science, technology and engineering concepts to students was designed. The key point was to provide the students with authentic learning activities based on real-world problems. The students had to solve those problems working in 3-members group. The teacher's role was as a learning guide. The course was implemented in a 6th grade class (primary education) and in a 7th grade class (secondary education) throughout a whole academic year. The Instructional Materials Motivation Survey (IMMS) was used to measure the students' motivation in two different moments: at the end of the first term and at the end of the third term. The IMMS is based on the ARCS Model and measures four motivational factors: attention, relevance, confidence and satisfaction. The high scores obtained in the IMMS manifest that most students were motivated with the STEM course. Indeed, the highest scores were obtained in the questions corresponding to the satisfaction factor. Furthermore, results evidence that the level of motivation varied only slightly from the first to the third term test. Hence, we can affirm that the hands-on learning activities proposed during the STEM course allow to create a learning experience that interests and engages students. Finally, obtained results allow to know how the students feel about the new STEM course and to redesign it, if necessary, in order to improve the studied motivational factors.

Keywords Students' motivation · STEM · Authentic activities · Active learning · ARCS Model

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1 Introduction

Nowadays, there is a clear interest in promoting science, technology, engineering and mathematics (STEM) at school. Politicians and educators are aware of the importance of understanding those disciplines in order to prepare citizens for the high-technological present and future. Indeed, the supply of highly qualified scientists, technologists, engineers and mathematicians is perceived by governments globally as being vital in securing economic prosperity [2]. It is noteworthy the fact that the identification and development of STEM talent has become a national priority in most developed countries (e.g, [5], [34]).

Notwithstanding the contemporary push for developing STEM, there is a general lack of interest in those disciplines among young people.Several reports have pointed out current failures of educational systems in helping students to understand how to solve real-world problems using knowledge gained through the study of science, technology, engineering, and mathematics studies([8], [1]). It appears many students are losing their potential competitiveness for the high-tech knowledge-based economies, because of their low performances in and dislikes of these subjects. As a result, STEM educational reform has become a topic of discussion in political, economic, and educational circles around the world.

However, recently studies manifest some of the problems found when trying to include STEM subjects at school. Ritz and Fan [30] report the perceptions of 20 international technology education scholars on their country's involvement in science, technology, engineering, and mathematics (STEM) education. As Ritz and Fan pointed out, the definition and focus of STEM education varies within countries, probably as it should, based on individual educational and economic needs of the people in these nations. Due to that fact, the STEM (and also the individual subjects it involve) are not taught equally in every country. Ritz and Fan [30] comment that the implementation of STEM has resulted in varied approaches with each having potential difficulties for long-term success. Specifically, many discussions of STEM have focused on the improved teaching of separate subjects, especially those of science and mathematics, as pointed out by Bybee [8]. In some cases, STEM has incorporate technology and engineering into its framework as a means to show how scientific applications can be incorporated within science and mathematics lessons. In other cases, STEM is thought as a multidisciplinary approach to learning that can be used to integrate knowledge from the separate STEM subjects into existing science, technology, engineering design-based studies, or problem-based learning strategies. Some see it taught as a new integrative subject labeled as STEM ([28], [31]). In this interpretation, educational practices would use multiple STEM subjects and integrate these into single courses. Ritz and Fan conclude that work remains for educational communities to refine the meaning of STEM, develop materials to guide student learning and instruction, and train teachers in methods of how best to deliver this knowledge. Sanders [33] points out that STEM education should be a project-based, integrated technology education program, which could help students learn how to solve real-world technology and engineering problems using knowledge of science and mathematics.

Further, Williams [38] point out that the STEM movement has been initiated and developed by the social and economic rationales. Spurred on by the global financial crisis, it is hoped that coordination and integration of STEM activities will better equip a workforce for dealing with the contemporary nature of business and industry. As stated by Williams, the problem for educators here is that the consequent absence of a sound educational rationale for this combination of subjects inhibits its development.

Another factor that should be considered according to Bell [2] is the teacher. Bell affirms that teacher's perception of STEM, their personal knowledge, and understanding of that knowledge, is intrinsically linked to the effectiveness of STEM delivery in their own classroom practice. The author comments that where a teacher's own knowledge and understanding is deficient, findings indicate the potential for pupil learning is limited. Bell [2] points out that STEM subjects are vibrant, engaging and exciting, but somewhere along the line pupils disengage with study beyond compulsory schooling.

1.1 Related work

There exist several proposals that aim at introducing technology or engineering, which are not always studied at school.As mentioned above, the definition of technology may differ from one country to another. Consequently, the learning proposals can be different from one to another.

Rogers and Portsmore [32] developed an effective platform to teach engineering in schools. Their goals are to excite students about engineering, math, and science, teach them these disciplines in a hands-on and practical way, and improve the engineering confidence of the next generation. They use the LEGO/ROBOLAB toolset to provide hands-on opportunities to young students thus helping to build and develop their confidence and interest in math, science, and engineering.

In [36], Stevens et al. report on the development, delivery, and outcomes of a culturally driven science, technology, engineering, mathematics (STEM) program, iSTEM, aimed at increasing engagement in STEM learning among 3rd-8th grade students. They selected this age/grade range based on STEM literature that suggests that engaging elementary and middle school students has the greatest impact on closing the STEM educational gap [5]. Furthermore, engaging these young students is critical in preparing them for relevant high school courses that then allows them to pursue a STEM career in post-secondary education. Results indicate that the program has been successful in engaging students in iSTEM as well as increasing their interest in STEM and their science beliefs.

Peterman et al. [29] describe two technology-enhanced STEM projects that aim at improving students' attitudes about scientific careers. The work they present documents the extent to which the Career Interest Questionnaire (CIQ) effectively measures the impact of technology-enhanced STEM educational experiences on students' career attitudes. Overall CIQ scores did not change as the result of participating in either project.

The work presented in [24] shows that the use of robotics and game design influence self-efficacy in technology and computational thinking. However, the authors conclude that there are no significant differences between pre and post scores on STEM attitude or interest in STEM careers for the overall group. The works presented in [22] and [23], on the contrary, show that robotics helps students to learn STEM subjects and it promotes students' interest toward STEM.

Hands-on learning proposals that promote mechanical reasoning or analogical reasoning also enable to foster STEM disciplines. For instance, McKenna and Agogino [26] present the Simple Machines Learning Environment (SIMALE) to support mechanical reasoning and understanding of simple machines for middle school and high school students and show its effectiveness in student learning. Their primary goals were to foster development of simple machines concepts, and to encourage students to make connections between abstract and more concrete forms of reasoning in order to effectively apply their knowledge to a range of problems.

Liu and Schunn [25] show that higher levels of mechanistic knowledge are associated with more frequent and complex mathematical strategy use. Hence, the authors suggest that mechanistic knowledge may be on pathway through which adaptive mathematical strategy use can be improved. The participants are asked to program a robot to navigate a maze and to create a navigation strategy that would work for differently sized robots.

Similarly, Cuperman and Verner[12] propose to foster analogical reasoning and design skills through creating bio-inspired robotic models. The authors found, among others, that the students acquire technological content knowledge essential or using the construction kit and constructing simple robotic systems. Furthermore, they are highly motivated to learn scientific and technological concepts and perform hands on activities.

1.2 Objective

The above research studies are in accord regarding the importance of introducing STEM at school in order to enhance students' abilities and interest in those subjects. However, motivation is often viewed as highly unpredictable and changeable, subject to many influences over which the teacher or designer has no control, as pointed out in [16]. Consequently, both teachers and designers often view their responsibility as providing good quality instruction, and assume it is the student's responsibility to decide whether or not to take advantage of the opportunity to learn as noted by Keller in [16].

This paper proposes a STEM-based active learning course to overcome the aforementioned lack of interest in STEM subjects and to engage primary and secondary school students in their learning. The idea of the STEM course is to support students in enhancing their learning motivation while solving problems based on real-world objects. In addition, the students learn concepts and processes related to STEM subjects, which are presented as an integrative subject.

In a parallel work recently published [3], we showed that the spatial ability and mechanical reasoning of the students that assisted to the STEM course presented in this paper were improved. The current research is focused on analysing the impact of implementing the STEM course on students' motivation. To carry out this analysis, this research was designed to answer the following questions:

- Are the students motivated?
- Is the students' motivation maintained during the STEM course?
- Does the motivation depend on the gender of the participants?
- Does the motivation depend on the grade of the participants?

The Instructional Materials Motivation Survey (IMMS), which is based on the ARCS Model, is used to quantify the students' motivation. Other research works used the IMMS to measure the impact of using a new material or learning system (e.g., [10], [9], [13], [11]). The ARCS Model measures four motivational factors: attention, relevance, confidence and satisfaction.

This work studies each of the four categories of motivation in order to redesign the STEM course in future editions of it, in case it was necessary. Since this is the first year of implementation of the STEM course at the school, the information provided by the IMMS with respect to each of the motivation factors will be very useful to know how the students feel about the course and how we could improve their learning experience.

The remainder of the paper is organized as follows. The design of the STEM-based active learning course is presented in detail in section 2. Section 3 exposes the methodology adopted to carry out the current research. Experimental results and discussion are provided in section 4. Finally, conclusions and future work are given in Section 5.

2 STEM-based active learning course

In a pilot project published in [4], we analysed the use of educational robotics to develop spatial abilities in 12 year old students. To carry out that project, a course to introduce robotics to 6th grade primary school students was designed. With only an 8 sessions-course, obtained results showed that the students that joined the course improved significantly their spatial abilities compared to the students that did not join the course. Additionally, the teacher who implemented that project noticed the high levels of motivation and interest of the students for the robotics course. He also noticed (although he did not demonstrate it) that the students did not only learn concepts related to mathematics, but also related to science, engineering and technology.

Based on the good results obtained in the pilot project [4], the school decided to design a more general course. Particularly, an integrative subject labeled as STEM course was designed. As Bybee [8], we believe that technology education can be the integrator of science, mathematics, and engineering concepts and principles for developing solutions to real-world problems.On the other hand, technology education practices apply many engineering principles [7].

The idea of the STEM course was to introduce technology and engineering while enhancing the motivation and interest for learning of the students. The course was compulsory for all the students and was taught during a whole academic year. In this first year of implementation, the STEM course was included in the annual planning of two different grades: 6th grade (primary education) and 7th grade (secondary education). As mentioned in [5], engaging elementary and middle school students has the greatest impact on closing the STEM educational gap.

2.1 Material

The material used in the STEM course consisted of 7 different Fischertechnik[1] sets. This material is suitable to learn STEM subjects. Concretely, it allows to present technology and to make it understandable through playing. Table 1 summarizes the distribution of the sets used in each of the grades (see Fig. 1 for illustrations of sample sets). Each kit, which allows to construct several realistic models, aims at fostering different skills. An example of a realistic model corresponding to each of the kits is shown in Fig. 2. These models allow to propose authentic educational activities connected to the everyday life.

Table 1 Sets used in the STEM course

6th		7th	
ROBOTICS LT Beginner Set	4	ROBOTICS TXT Discovery Set	4
Oeco Energy	2	Oeco Energy	2
Mechanic + Static	2	Pneumatic 3	2
Optics	2	Dynamic XL	2

The ROBOTICS sets include the ROBO pro Light software, which explains the basic principles of programming to students. A snapshot of the software is shown in Fig. 3. Students can use sensors and actuators to build and then control models like hand dryers, a carousel, barriers, a conveyor belt with die-cutting machine, or mobile tracked vehicles.

The Oeco Energy set aims at showing how the electricity can be produced, storages and used from natural energy sources such as water, wind and sun

[1] http://www.fischertechnik.de/en/home.aspx

Fig. 1 Material used in the 6th grade (top row): ROBOTICS LT Beginner Set, Oeco Energy, Mechanic + Static, Optics; and in the 7th grade (bottom row): ROBOTICS TXT Discovery Set, Oeco Energy, Pneumatic 3, Dynamic XL

Fig. 2 Examples of the realistic models constructed with the material used in the 6th grade (top row) and in the 7th grade (bottom row)

using different models and a wide variety of experiments. This set includes a solar motor (2V) and 2 solar modules (1V; 400 mA).

The Mechanic and Static set is suitable for all future engineers and technicians. The provided models show how a shaft drive or manual transmission works or how a stable bridge can be constructed, etc. This set offers topics relevant to STEM subject area curricula such as technology and the natural sciences, and helps students gain a basic knowledge of mechanical and technical principles.

The Optics set is provided with optical lenses with various focal lengths, mirrors, lens tip lamps and a variety of other parts that allow construction of a microscope, magnifier, telescope and periscope.

The Pneumatic set takes a learning-by-playing approach to the principles of pneumatics, with realistic models to show how pneumatic valves and cylin-

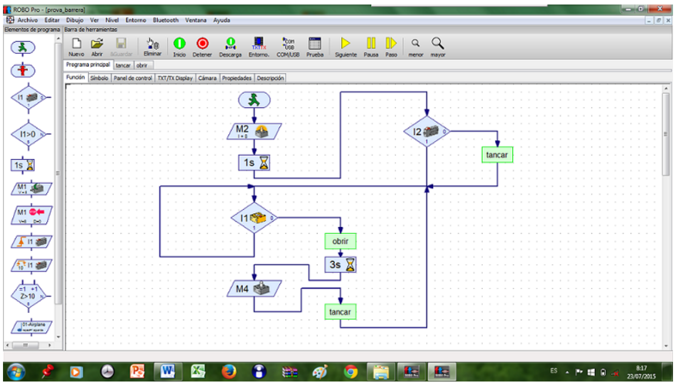

Fig. 3 Snapshot of the ROBO Pro Light 4.0 software

ders work. This set also offers topics relevant to STEM subject area curricula such as technology and the natural sciences, and helps students gain a basic knowledge of technical principles.

Finally, the Dynamic XL allows to play with a ball that races through tight curves and chutes and shoot through different tracks.

It should be highlighted that the students have had not worked with a material like this before. They find it very attractive, since they can manipulate it to construct realistic models. This fact enhances students' motivation, who want to learn how real objects work.

2.2 Team working

The students worked in 3-members group, promoting thus the team and collaborative working. Each team had a computer to work with, in case the particular kit requires it. As in [12], a team of three learners was found preferable to enable self-expression and active participation, while still allowing the benefits of team collaboration. The sessions were planned in order to allow the rotation of the sets among the working teams. That is, at the end of the STEM course, all the teams will have worked with every kit.

Fig. 4 shows students working in groups. Each group was assigned a particular kit together with the Fischertechnik's original manual. Furthermore, the teacher provided documentation to each of the teams containing the information about the main characteristics of the assigned kit, its components and some useful instructions to understand how they work. It is noteworthy that the groups were responsible of the material. The documentation also included a problem the team had to solve during the session. In general, they had to perform a real-world object model and to answer some questions related to it. Each of the team had a different problem to solve during the session. This fact often generated discussions among the teams, which used to be interested in the models their classmates were preparing.

Fig. 4 Students working in 3-members groups

Fig. 5 Classroom where the STEM course was implemented

An important consideration of the STEM course was that the classroom environment should be a large space. Therefore, the science laboratory was used (see Fig. 5). There were big rectangular tables that were suitable for working in groups. Furthermore, the space was very well illuminated, which is crucial when working with such a large amount of different components. Additionally, the stools allow a better position to work.

2.3 Hands-on learning

One of the goals of the STEM course was to promote an active learning in which the students are the most active agent in their learning process. In other words, the idea is to propose authentic learning activities to the students. Furthermore, in order to motivate the students to learn, problems based on real-life objects were given to them. That is, they had to construct a model of a real-life object and, sometimes, they had to program it in order to simulate how it really works. Some of the objects they had to construct were: different bridge structures, different car models, etc. Additionally, they had to program

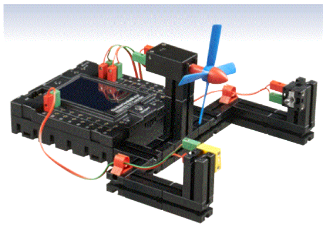

Fig. 6 Hand dryer model, ROBOTICS TXT Discovery set

some of them such as: human and non-human robots, a washing machine, a traffic light, an automatic sliding door, etc. Fig. 2 shows examples of the models constructed in the sessions of the STEM course. These realistic models engaged the students to learn, since they see these objects in their everyday life and want to know how they work.

The teacher's role was as a guide and the students had to face their activities working in group and through a hands-on learning. At the end of the sessions, the teacher had evidences of the work of each of the teams via the documentation they completed, the files they created, pictures of the constructed models and annotations from personal observations.

In order to illustrate the authenticity of the educational activities proposed during the STEM course, two examples of activities are provided at this section. A first example of a problem given to a group that worked with the ROBOTICS TXT Discovery set is shown in the box below.

Task III: *Build the hand dryer model shown in Fig. 6 according to the instructions of the Fischertechnik's manual (page 10).*

- *The hand dryer should be programmed in a way that when the light barrier is interrupted, the fan must be connected. Then, after 10 seconds, it must be automatically disconnected (File name: Task3a.rpp).*
- *Modify the program of the previous section. In this new version, during the first 5 seconds the fan should rotate at his maximum velocity and during the last 5 seconds it should rotate at a moderate velocity (File name: Task3b.rpp).*
- *Since the goal is to save energy, create a new program in which the fan turns on when hands approach the dryer and it turns off when hands go away from it (File name: Task3c.rpp).*

A second example of a problem given to a team that works with the Mechanic and Static kit is also provided.

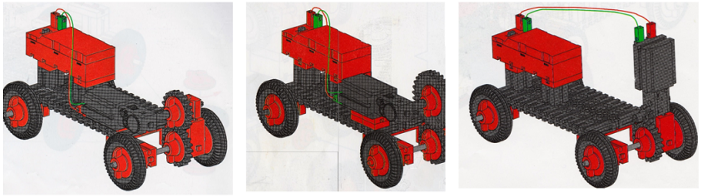

Fig. 7 Different vehicle models, Mechanic and Static set: (left) model 1; (middle) model 2; (right) model 3

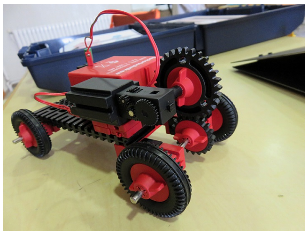

Fig. 8 Vehicle model 2 built by the students

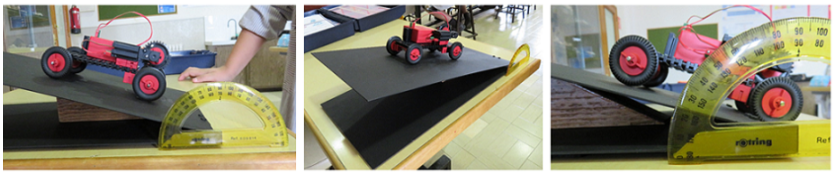

Fig. 9 Vehicle model 2 going up the ramp

Task V:

- *Build the vehicle model 1 shown in Fig. 7 (left) according to the instructions of the Fischertechnik's manual (page 14).*
- *Build the vehicle model 2 shown in Fig. 7 (middle) according to the instructions of the Fischertechnik's manual (page 17).*
- *Build the vehicle model 3 shown in Fig. 7 (right) according to the instructions of the Fischertechnik's manual (page 19).*
- *For each of the vehicle models, detail:*
  Q1: *its transmission relation,*
  Q2: *the time it spends travelling 5 meters,*
  Q3: *if it is able to go up a ramp.*

Fig. 8 shows the model 2 built by the corresponding team. This model was able to go up a ramp of 21°, as it is shown in Fig. 9. Table 2 summarizes the solution provided by the corresponding team. They deduced that the vehicle model 2 is the fastest one. They also concluded that they needed to adapt the ramp to the characteristics of each model.

Table 2 Solution given by the team working with the task V

question	model 1	model 2	model 3
Q1	1	1.5	0.5
Q2	6.19 sec	4.28 sec	11.44 sec
Q3	yes, 24°	yes, 21°	yes, 28°

It is important to remark that the students arrived to a solution working as a team. It is also significant to notice that in order to be able to solve the assigned tasks or problems, they must understand concepts and procedures related to engineering and technology (e.g., when using the ROBO Pro Light software, or when calculating the transmission relation of each of the models).

3 Methodology

The main purpose of this study was analyse the impact of implementing the STEM course on students' motivation. This evaluation is performed by means of the aforementioned IMMS, which measures the impact of using a new learning material. Details on the IMMS are provided in section 3.2. It should be noticed that this is the first time the STEM course is implemented and it is important the information that the IMMS can provide.

In addition, one of the goals of the research was to measure the evolution of the students' motivation. In order to avoid the initial positive reaction and motivation with respect to a new material, the students' motivation was measured the first time at the end of the first term (December 2015), after 12 sessions of the course. Then, at the end of the third term (June 2016), the students completed the same motivation test again to detect if their motivation was maintained.

This research also analysed if the motivation depends on the gender of the participants. Finally, the relation between motivation and the grade (6th or 7th) was also studied.

3.1 Context

The study described in this paper was conducted in a school in a small city. Concretely, the study was carried out with a 6th grade class and a 7th grade class. There were 26 students in the 6th grade class (14 boys and 12 girls) and 22 students in the 7th grade class (11 boys and 11 girls).

It should be highlighted that the co-author of this paper was the designer of the sessions and the teacher in the STEM course presented in this project. Besides, the co-author of this paper is a primary school teacher and also an industrial engineer. His multidisciplinary educational background gives him tools to teach technology and engineering at primary school. In addition, he had experience in teaching the robotics course implemented in the pilot project [4].

The STEM course was taught in a 1-h/week setting throughout all the 2015-16 academic year (Monday, 4:00-5:00pm for 7th grade and Thursday, 4:00-5:00pm for 6th grade). A total of 26 and 28 sessions were developed in the 7th and 6th grades, respectively.

3.2 Instruments

The Instructional Materials Motivation Survey (IMMS) is used in this research. This survey was designed by Keller [20] to find out how motivated students are, were, or expect to be, by a particular course. The IMMS is based on the ARCS Model, which was developed also by Keller (e.g., [15], [16], [17], [19]) and which considers four different motivation factors: attention, relevance, confidence and satisfaction.

The ARCS Model was developed by Keller (e.g., [15], [16], [17], [19]) and it is a problem solving approach to designing the motivational aspects of learning environments to stimulate and sustain students motivation to learn. This model, which has been validated in several research studies (e.g., [37], [35], [27]), provides a systematic approach to designing motivational tactics into instruction [18]. The analysis of motivational needs and corresponding selection of tactics are based on four dimensions of motivation, namely attention (A), relevance (R), confidence (C) and satisfaction (S). These four categories represent sets of conditions that are necessary for a person to be fully motivated.

The first factor, attention, refers to learners' cognitive responses to instructional stimuli, which should lead to learners' further effort to explore the learning task [14]. The second factor, relevance, is related to how well the instruction meets a learner's needs and goals [6]. Learners need to perceive content as compatible with their learning preferences, consistent with personal learning goals, and connected to their prior experiences [21]. The confidence factor is based in learners' perceived possibility to be able to successfully accomplish the learning task. If the learners are attentive, interested in the content, and moderately challenged, then they will be motivated to learn. But to sustain this motivation, the fourth condition of motivation is required: satisfaction. It refers to positive feeling about one's accomplishments and learning experiences. It means that students receive recognition and evidence of success that support their intrinsic feelings of satisfaction and they believe they have been treated fairly [18].

The IMMS comprises 36 5-point Likert-scale items and contains 12 questions corresponding to attention (A), 9 to relevance (R), 9 to confidence (C) and 6 to satisfaction (S). These questions are provided in section 4. Therefore, responses are measured on a scale from 1 (not true) up to 5 (very true). Thus, the total range scores ranging from 36 to 180. However, as Keller proposed in [20], the average score for each subscale or factor and the total score is shown instead of using sums. This converts the totals into a score ranging from 1 to 5 and makes it easier to compare the performance on each of the subscales. The IMMS has a documented reliability coefficient of 0.96 [20].

Keller pointed out in [20] that the survey can be used with undergraduate and graduate students, adults in non-collegiate settings, and with secondary students. They can also be used with younger students who have appropriate reading levels. With younger students or ones who are not sufficiently literate in English, some of the items may have to be read aloud and paraphrased to relate them to the classroom experiences of the audience. The original survey was translated to Spanish and, as suggested by Keller, some questions were adapted to the concrete reality.

4 Experimental results

This section reports the obtained results in order to answer the research questions formulated above. Recall that the students' motivation was measured in two different moments: at the end of the first term and at the end of the third term. Besides, the study was carried out with a 6th grade class (primary school) and a 7th grade class (secondary school).

4.1 Students' motivation

This section studies the students' motivation by analyzing the mean and standard deviation of the scores obtained for each of the grades in each of the IMMS questions. Specifically, questions are grouped and studied according to the four factors that conform the ARCS Model. Any of the test could be shown, since results from one test to the other did not differ significantly, as presented in next section. However, in order to avoid repetition, only results corresponding to the first term test are detailed.

Table 3 shows the mean and standard deviation of the scores given for the participants to the questions corresponding to the attention factor. Notice that the lowest scores were obtained in the reverse questions. This fact makes one think that it was difficult for the students to interpret that type of questions (recall that the SD is in general higher in those questions). The maximum score in the 6th grade was obtained in question 20 (*This course has things that stimulated my curiosity*), with a mean score of 4.85 (3.86 in 7th grade). In the case of the 7th grade, the maximum score was obtained in question 8 (*These materials are eye-catching*), with a mean score of 4.27 (4.62 in 6th grade). The average score obtained taking all the questions of this category was 4.29 and 3.79 in the 6th and 7th grade, respectively.

Analogously, Table 4 shows the mean and the standard deviation corresponding to the relevance factor. Again, the lowest score was obtained in the unique reverse question contained in this category. The maximum score was obtained in question 23 (*The content and style of writing in this course convey the impression that its content is worth knowing*), for both 6*th* and 7*th* levels, with a mean score of 4.77 and 3.68, respectively. The average score obtained taking all the questions of this category was 4.10 and 3.41 in the 6th and 7th grade, respectively.

Table 3 Mean and standard deviation of the scores given for the participants to the questions corresponding to the attention factor, first term test

No	Question	6th		7th	
		M	SD	M	SD
2	There was something interesting at the beginning of this course that got my attention.	3.46	1.24	3.46	1.22
8	These materials are eye-catching.	4.62	0.70	4.27	1.07
11	The quality of the writing helped to hold my attention.	4.08	1.02	3.32	1.17
12 (R)	This course is so abstract that it was hard to keep my attention on it.	3.00	1.33	2.55	1.53
15 (R)	The text and activities of this course look dry and unappealing.	3.21	1.41	2.86	0.89
17	The way the information is arranged on the pages helped keep my attention.	4.52	0.77	3.68	1.17
20	This course has things that stimulated my curiosity.	4.85	0.37	3.86	1.08
22 (R)	The amount of repetition in this course caused me to get bored sometimes.	2.96	1.31	2.82	1.18
24	I learned some things that were surprising or unexpected.	4.81	0.49	3.95	1.09
28	The variety of reading passages, exercises, illustrations, etc., helped keep my attention on the course.	4.31	0.97	3.82	0.85
29 (R)	The style of writing is boring.	3.23	1.34	2.73	0.94
31 (R)	There are so many words on each page that it is irritating.	2.73	1.61	2.70	1.22

Table 4 Mean and standard deviation of the scores given for the participants to the questions corresponding to the relevance factor, first term test

No	Question	6th		7th	
		M	SD	M	SD
6	It is clear to me how the content of this material is related to things I already know.	2.35	1.41	2.18	1.30
9	There were activities that I was able to relate to real life examples.	3.96	1.43	3.14	1.13
10	Completing this first term course successfully was important to me.	4.69	0.88	3.68	1.13
16	The content of this material is relevant to my interests.	4.12	1.21	3.64	1.00
18	There are explanations or examples of how people use the knowledge in this course to real life applications.	4.35	0.98	3.59	1.10
23	The content and style of writing in this course convey the impression that its content is worth knowing.	4.77	0.82	3.68	1.21
26 (R)	This course was not relevant to my needs because I already knew most of it.	3.00	1.44	3.09	1.23
30	I could relate the content of this course to things I have seen, done, or thought about in my own life.	4.31	1.09	3.45	1.37
33	The content of this course will be useful to me.	4.38	1.20	3.32	0.99

Table 5 Mean and standard deviation of the scores given for the participants to the questions corresponding to the confidence factor, first term test

No	Question	6th		7th	
		M	SD	M	SD
1	After the first session of the course, I had the impression that it would be easy for me.	3.46	1.24	3.45	1.22
3 (R)	This material was more difficult to understand than I would like for it to be.	2.46	1.45	2.50	1.26
4	After the introductory session, I felt confident that I knew what I was supposed to learn from this course.	3.46	1.50	2.82	1.30
7 (R)	Many of the tasks had so much information that it was hard to pick out and remember the important points.	1.88	1.53	2.19	1.40
13	As I worked on this course, I was confident that I could learn the content.	4.81	0.63	3.91	1.23
19 (R)	The exercises in this course were too difficult.	2.73	1.27	2.45	1.37
25	After working on this course for awhile, I was confident that I would be able to pass a test on it.	4.12	0.82	3.14	0.99
34 (R)	I could not really understand quite a bit of the material in this course.	2.35	1.47	2.36	1.40
35	The good organization of the content helped me be confident that I would learn this material.	4.42	1.06	4.14	0.94

The results obtained in the case of confidence factor are summarized in Table 5. Definitely, it was difficult to interpret the reverse questions. Notice that the scores corresponding to those questions were clearly lower than the others. The maximum score in the 6th grade was obtained in question 13 (*As I worked on this course, I was confident that I could learn the content*), with a score of 4.81 (3.91 in 7th grade). In the 7th grade case, the maximum score was obtained in question 35 (*The good organization of the content helped me be confident that I would learn this material*), with a score of 4.14 (4.42 in 6th grade). The average score obtained taking all the questions of this category was 3.78 and 3.47 in the 6th and 7th grade, respectively.

Finally, results corresponding to satisfaction factor are shown in Table 6. In this case, there was no reverse question. Remark that the obtained scores were in general higher than the ones corresponding to the previously studied factors. The maximum value in 6th grade was obtained for question 32 (*It felt good to successfully complete this course*), with a mean value score of 4.88 (3.77 in the 7th grade). In the 7th grade, the maximum was obtained in question 36 (*It was a pleasure to work on such a well-designed course*), with a mean value score of 4.36 (4.81 in the 6th grade). The average score obtained taking all the questions of this category was 4.68 and 3.92 in the 6th and 7th grade, respectively.

Additionally, the total scores of the IMMS questionnaire obtained by each student is also detailed (i.e., the score obtained without separating items according to the corresponding motivational factor). Concretely, the average

Table 6 Mean and standard deviation of the scores given for the participants to the questions corresponding to the satisfaction factor, first term test

No	Question	6th		7th	
		M	SD	M	SD
5	Completing the exercises of each session gave me a satisfying feeling of accomplishment.	4.77	0.51	3.73	1.39
14	I enjoyed this course so much that I would like to know more about this topic.	4.50	0.95	3.95	0.84
21	I really enjoyed attending this course.	4.77	0.51	4.05	1.25
27	The wording of feedback after the exercises, or of other comments in this course, helped me feel rewarded for my effort.	4.38	0.98	3.68	0.89
32	It felt good to successfully complete this course.	4.88	0.33	3.77	1.19
36	It was a pleasure to work on such a well-designed course.	4.81	0.57	4.36	0.85

scores are shown instead of the total scores (that is, the total scores averaged by the number of questions scored by the student). Fig. 10 shows the average scores corresponding to all the students in the first term test. In particular, the polygonal figures enclose data in between lower and upper quartiles (medians are represented by horizontal lines in thinner regions). This representation allows to visualize the average score given by each student, which range from 3.18 to 4.75 and from 2.77 to 4.53 in the 6th and 7th grades, respectively. These high scores manifest that most students were motivated by the proposed STEM-based active learning course.

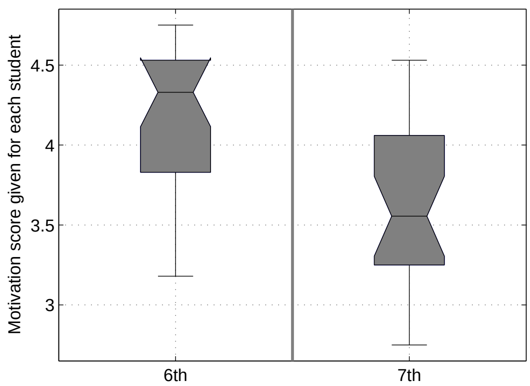

Fig. 10 Students' motivation (average score of IMMS questions), first term test

4.2 Students' motivation evolution

In this section, the goal is to study the evolution of the motivation of the students during the STEM course. Hence, results obtained in the first and third term tests are compared.

Fig. 11 shows the average scores obtained in the first term test (December 2015) and the third term test (June 2016) for the total of students in 6th and 7th grades. It can be seen that the values were, in general, very high (notice that they are always above 3). Concretely, the obtained values in the case of 6th grade ranged from 3.18 to 4.75 and from 3.03 to 4.72 in the first and third term tests, respectively. In the 7th grade case, the values ranged from 2.75 to 4.53 and 2.85 to 4.50 in the first and third term tests, respectively. These values allow to confirm that most students were motivated by the material and methodology used in the STEM course.

Furthermore, Fig. 11 manifests that the values only decreased slightly from the first to the third term in the 6th grade. Hence, the high level of motivation keep high along the STEM course. In the 7th grade, it is remarkable the positive fact that the values increased slightly from the first to the third term (see the median and the minimum values in the polygonal figures in Fig. 11). Therefore, the high level of motivation increased in general along the STEM course.

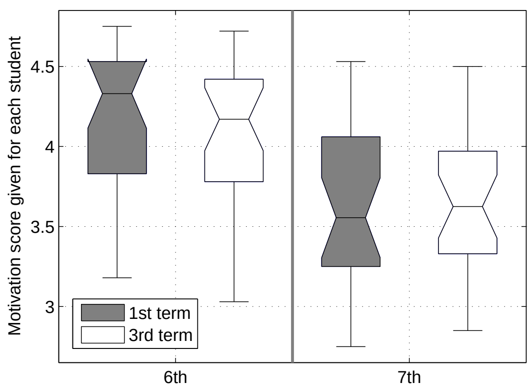

Fig. 11 Motivation evolution in both grades

Table 7 summarizes the mean (M) and standard deviation (SD) of the scores given for the participants to each of the studied factors. Specifically, the M and SD is obtained by considering all the students in 6th and 7th grades, respectively. Notice that the satisfaction factor obtained the highest mean score in both tests and in both grade levels. The confidence and the

Table 7 Mean and standard deviation of the scores given for the participants to the IMMS

	6th (N=26)				7th (N=22)			
	1st term		3rd term		1st term		3rd term	
F	M	SD	M	SD	M	SD	M	SD
A	4.29	0.58	4.23	0.67	3.79	0.47	3.80	0.47
R	4.10	0.57	3.90	0.54	3.41	0.57	3.20	0.58
C	3.78	0.56	3.64	0.56	3.47	0.56	3.56	0.61
S	4.68	0.43	4.51	0.53	3.92	0.58	3.98	0.48
Av	4.18	0.43	4.05	0.48	3.64	0.47	3.62	0.45

relevance, on the other hand, were the factors that yield the lowest mean score in 6th and 7th grade, respectively.

Additionally, a t-test was performed to compare the respective means obtained in the first and third term tests. Specifically, a two-tailed test was performed, setting $\alpha = 0.05$ as a significance level (5%). As expected, the value of p is always higher than 0.05, in both grade levels. Hence, the mean variation is not statistically significant in any of the cases.

4.3 Motivation according to participants' gender

This section aims at studying if the students' motivation depends on their gender. Fig. 12 plots the average scores of the female and male participants in the 6th grade. It is shown that the values were in general higher in the case of female participants.

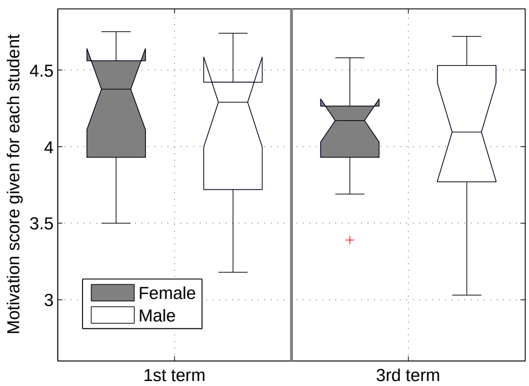

Fig. 12 Motivation according to participants' gender, 6th grade

Furthermore, the mean and the standard deviation of the scores given for the female and male participants to each of the studied factors and also the

Table 8 Mean and standard deviation of the scores given for the participants to the IMMS, 6th grade

	1st term					3rd term				
	Female(N=12)		Male (N=14)			Female(N=12)		Male (N=14)		
F	M	SD	M	SD	p	M	SD	M	SD	p
A	4.46	0.61	4.15	0.54	0.19	4.50	0.28	4.00	0.83	0.062
R	4.23	0.52	3.99	0.57	0.30	3.83	0.52	3.97	0.62	0.53
C	3.72	0.45	3.84	0.65	0.60	3.51	0.46	3.75	0.63	0.29
S	4.76	0.33	4.61	0.51	0.41	4.59	0.37	4.45	0.64	0.50
Av	4.27	0.39	4.11	0.47	0.37	4.10	0.33	4.01	0.59	0.62

average of all them are shown in Table 8. It is noteworthy that, in the first term test, the female participants gave higher scores than the male participants in the questions corresponding to attention, relevance and satisfaction. However, they gave lower scores in the questions corresponding to confidence. In the third term test, the female participants gave lower scores in the questions corresponding to relevance and confidence.

Additionally, a t-test was performed to analyse if the difference between the mean scores given by the female and male participants is statistically significant. The p-value obtained from the t-test for each of the factors in the case of 6th grade is included in Table 8 . Notice that $p > 0.05$ in all the cases. Therefore, in the 6th grade, the mean difference between male and female participants is not statistically significant in any of the factors.

Analogously, Fig. 13 shows the average scores of the female and male participants in the 7th grade. It can be seen that the male participants gave, in general, higher values than the female ones (this result is opposite to the one obtained in the 6th grade case).

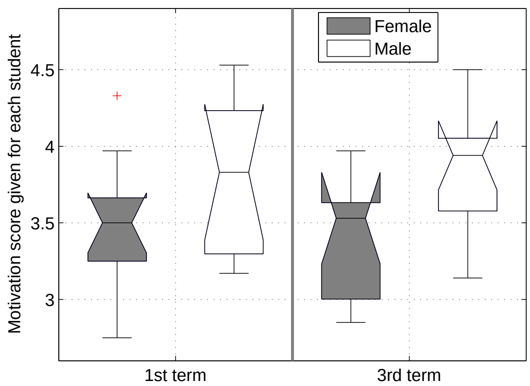

Fig. 13 Motivation according to participants' gender, 7th grade

Table 9 Mean and standard deviation of the scores given for the participants to the IMMS, 7th grade

	1st term					3rd term				
	Female(N=11)		Male (N=11)			Female(N=11)		Male (N=11)		
F	M	SD	M	SD	p	M	SD	M	SD	p
A	3.63	0.60	3.95	0.50	0.20	3.53	0.54	4.07	0.42	**0.02**
R	3.24	0.45	3.59	0.53	0.14	3.04	0.53	3.36	0.51	0.22
C	3.37	0.63	3.56	0.62	0.45	3.36	0.47	3.75	0.68	0.052
S	3.81	0.48	4.03	0.54	0.44	3.66	0.90	4.31	0.42	0.053
Av	3.50	0.42	3.78	0.49	0.20	3.39	0.37	3.85	0.40	**0.01**

Table 9 summarizes the mean and the standard deviation of the scores given for the female and male participants to each of the studied factors and also the average in the case of 7th grade. In this case, the male participants gave in general higher scores than the female participants in the questions corresponding to any of the factors. Observe that only the value corresponding to the relevance factor decreased from the first to the third term test in the case of male participants. In the case of the female participants, on the contrary, although the median of the third term questionnaire was higher than the first one, the mean of all the factors decreased.

In addition, Table 9 shows the mean and the p-value obtained from the t-test for each of the factors in the case of 7th grade. Notice that the mean difference obtained in the first term test between genders is not statistically significant in the case of 7th grade ($p > 0.05$ in all the cases). However, due to the different evolution of the motivation in each of the genders (observe that the female scores decrease, while the male ones increase), the mean difference in the third term test between genders is statistically significant in most of the cases, as it is shown in Table 9. In particular, from the results of the t-test, it can be concluded that the difference of the obtained means is statistically significant in the case of the attention factor and in the case of the average, in which cases the computed p-values are 0.020 and 0.01, respectively. The t-test gives $p = 0.052$ and $p = 0.053$ in the case of confidence and satisfaction factors, which means that the difference of the means obtained from the female and male participants is near to be statistically significant. In the relevance case, on the contrary, $p = 0.22$, which was expected since the means are similar in the female and male participants.

4.4 Motivation according to grade level

This section aims at comparing the scores obtained in the IMMS in the 6th grade (primary school) and in the 7th grade (secondary school). Fig. 14 shows the average scores obtained in the first and third term tests for the 6th and the 7th grade students. It can be seen that the scores were clearly higher in the 6th grade than in the 7th grade.

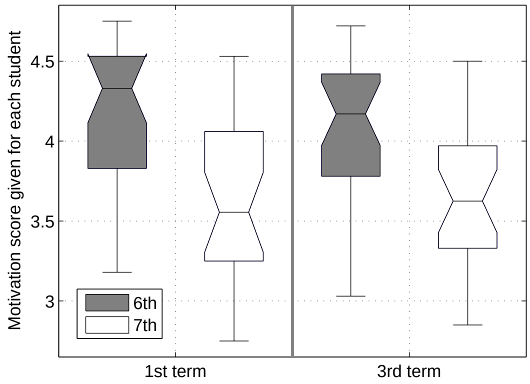

Fig. 14 Motivation according to the grade

Table 10 Mean and standard deviation of the scores given for the participants to the IMMS

	1st term					3rd term				
	6th (N=26)		7th (N=22)			6th (N=26)		7th (N=22)		
F	M	SD	M	SD	p	M	SD	M	SD	p
A	4.29	0.58	3.79	0.47	**0.0045**	4.23	0.67	3.80	0.47	**0.023**
R	4.10	0.57	3.41	0.57	**0.00015**	3.90	0.54	3.20	0.58	**0.00012**
C	3.78	0.56	3.47	0.56	0.63	3.64	0.56	3.56	0.61	0.58
S	4.68	0.43	3.92	0.58	$\mathbf{1.1 \times 10^{-5}}$	4.51	0.53	3.98	0.48	**0.0088**
Av	4.18	0.43	3.64	0.47	$\mathbf{1.36 \times 10^{-4}}$	4.05	0.48	3.62	0.45	**0.0026**

Table 10 compares the mean and the standard deviation of the scores given for the female and male participants to each of the studied factors and also the average in both grade levels and in each of the tests. Observe that the obtained means were higher in the case of 6th grade students, for any of the factors.

Finally, a t-test was performed to compare the respective means obtained in the 6th and 7th grades for each of the factors. The results shown in Table 10 evidence that the difference of the means obtained in the 6th and 7th grades is statistically significant for all the factors except for the confidence one.

4.5 Discussion

The current research studies the impact of the implementing a STEM-based active learning course on students' motivation. This section contains the discussion about the results obtained with respect to each of the research questions.

4.5.1 Students' motivation

The high scores obtained in the IMMS questions allow to confirm that most students were motivated by the STEM course. Indeed, it is important to remark that satisfaction was the factor that obtains the highest scores. Huang et al. [14] point out the importance of obtaining a large satisfaction score, which means that the learners consider the learning outcome a fair result of their invested efforts. Bolliger et al. [6], on the other hand, are concerned about the fact that the satisfaction subscale received the lowest mean in their study. The authors mention that satisfaction can have an impact on motivation. Therefore, it seems that compared to other studies that also use the ARCS Model, the results obtained in this research manifest that the learners see that the learning process is worthwhile to continue.

The lowest scores, on the contrary, were obtained in the questions corresponding to confidence and relevance factors in the 6th and 7th grades, respectively. Taking into account these results, the teacher should revise the activities proposed in the 6th level and try to maintain a challenge but, at the same time, ensure that it is not too difficult for the students. In the case of 7th level, teacher should proposed tasks that were important and useful for the students in order to increase the scores given to relevance factor.

It should be highlighted that the results were negatively influenced for the low scores obtained in the reverse questions of the IMMS. Future research should include a clarification about that concern. Finally, it is noteworthy that several students added one or two possibilities in the responses of the IMMS questions after the 5 (very true) to emphasize they really liked the STEM course or they really agreed with that particular affirmation or question. Some of them even included sentences and questions about their desire of continuing the course the following year.

The second author, who was the teacher who implemented the STEM course, saw a clear correlation between his observations during the sessions and the obtained results from the IMMS about the motivation of the students. In general, the students did not want to leave the STEM session when it finished and asked for more time to work with their project.

4.5.2 Motivation evolution

Results manifest that students' motivation varied only slightly throughout the whole academic year: sometimes it slightly decreased, other times it slightly increased, but the variation was not statistically significant. Specifically, in the 7th grade, it is remarkable the positive fact that the values increased slightly from the first to the third term. It should be remarked that the STEM course was taught throughout all the 2015-16 academic year (26 and 28 sessions were developed in the 7th and 6th grades, respectively). It is important to remark that we were not able to find any study about the students' motivation evolution with respect to a long-term course or material. A mentioned above, during the first sessions the novelty of a course or instructional material may bias the results obtained when quantifying students' motivation. However, sometimes the high levels of motivation may decreases as the number of sessions increases.

4.5.3 Students' motivation and gender

Results show that, in general, the difference between mean scores given by the female and male participants was not statistically significant, in any of the motivation factors and any of the grades. It is evidenced that female participants gave higher scores than male participants in 6th grade and, on the contrary, male participants gave higher scores in the 7th grade.

The only case when the difference between female and male participants scores was statistically significant was in the attention factor and in the average of all the factors in the third term test at 7th grade. Curiously, the scores given by the female participants decreased from the first to the third term test, while the scores given by the male participants increased from the first to the third test.

4.5.4 Students' motivation and grade level

Obtained results evidence that the students in 6th grade were, in general, more motivated that the ones in the 7th grade. Concretely, results show a statistically significant difference between the scores given by the students in the 6th and 7th grades. The confidence factor was the only one for which the difference between the mean scores obtained in each grade was not statistically significant. Indeed, the teacher who implemented the STEM course had already noticed the better pre-disposition of the 6th grade students.

5 Conclusions

This paper aimed at analysing the impact of implementing a STEM-based active learning course on students' motivation. A STEM course was designed and implemented as a new integrative subject in a 6th grade class (primary education) and a 7th grade class (secondary education) throughout a whole academic year. The objective of the STEM course was to support students in enhancing their learning motivation and interest in STEM disciplines while solving problems based on real-life objects.

To carry out the study, the IMMS, based on the ARCS Model, was used to quantify the students' motivation at the end of the first term and also at the end of the third term. From the high scores obtained in the IMMS questions, it can be concluded that most students were motivated during the STEM course. The highest scores were obtained in the case of the satisfaction factor, for both grade levels. This fact confirms that most students felt good about their accomplishments and were satisfied with the STEM course. The lowest scores were obtained in the questions corresponding to the confidence factor in the case of 6th grade and to the relevance factor in the 7th grade case. These results should be taken into account to redesign the STEM course in future editions.

Results evidence that, in general, the level of motivation was maintained along the whole academic year. The variation between the first term test and the third term test is not statistically significant. This result is crucial, since it is very difficult to maintain the interest of the learners about a material during a whole academic year. Even at the last session most of the students asked of the continuation of the STEM course the following year. Furthermore, results also revealed that there is not a statistically significant difference between scores given by the female and male participants.

Finally, the research manifested that 6th grade students gave clearly higher scores compared to the 7th grade students. Indeed, there exists a statistically significant difference between the scores given by the participants of one and other grade. The fact that the 6th grade students are still in primary education could be one of the factors explaining their higher interest for the STEM course. The 7th grade students are in secondary education and, in general, it is more difficult to catch their attention and curiosity.

To sum up, obtained results reinforce, on the one hand, the feasibility of designing and promoting STEM at school. On the other hand, this research shows that students are motivated and engaged in their learning when they actively participate in the classroom solving problems based on real-life objects. Besides, it is evident that this proposal could be adapted to any context to promote the STEM at school, while enhancing the students' motivation in their learning.

Before implementing the STEM course, it should be taken into account that the teacher should have technology and engineering knowledge in order to prepare the activities and problems properly and to answer doubts about the artifacts that surely will appear during the sessions. Another thing that should be considered is that the school must provide a timetable for the students to assist to the course. Sometimes the curricula does not allow to include a new subject.

Future lines of research include, first of all, to redesign some activities of the STEM course, taking into account the lowest scores obtained in some of the questions of the IMMS test. Further, it would be interesting to extend the STEM course to other grade levels. It would allow to study the evolution of students'motivation throughout consecutive academic years. Finally, it would be desirable to analyse if the STEM course improves the students'attitudes about scientific careers.

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