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Research report

The level of scientific competence among Year 6 pupils in Bilingual Education Programme schools

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Summary

1. Introduction

1.1 Study characteristics

This report presents the findings of the study commissioned by the British Council in Spain to assess the scientific knowledge and skills acquired by Year 6 Primary pupils at Bilingual Education Programme (BEP) schools.

To that end, the research team designed a tool (Instrument B, comprising two questionnaires) to gather data on pupils' attitudes towards and knowledge of science. Instrument B was administered via Microsoft 365 Forms (under licence to the University of Valladolid), thus ensuring respondents' data privacy. Participating primary school teachers were given the link providing access to the questionnaire and administered it during class time.

Instrument B, which does not require pupils to enter their name, begins by asking respondents to fill in their school code, classroom number, form number, gender and whether any of their family members work in science or technology. The rest of the form consists of two questionnaires: a first 10-item one on attitudes towards science (Vega-Agapito, et al., 2024) and a second 29-item questionnaire on scientific knowledge and competence.

Consistent with the preliminary report published in June 2024, and following the chronological order in which the research was conducted, the findings of the first questionnaire (on attitudes towards science) are presented in aggregate form. These data are followed by analysis considering variables such as school setting, gender and family members working in science. The data from the second questionnaire (Science content) are then presented by dimension or field and analysed in relation to the variables and content areas.

1.2 Curricular foundation

Scientific competence spans four dimensions (Cañal, 2012): conceptual, methodological, attitudinal and integrative. According to Cañal, the conceptual dimension involves understanding and applying scientific concepts and models to the world around us. The methodological or instrumental dimension entails identifying and designing strategies to explore problems then gathering and processing information from which to draw conclusions. The attitudinal dimension requires an interest in and understanding of scientific and socio-environmental inquiry and the ability to make autonomous decisions in personal and social contexts. Finally, the integrative dimension assesses pupils' capacity to combine and use all the above dimensions in personal contexts.

To measure Year 6 Primary pupils' acquisition of scientific competence, all four dimensions must therefore be analysed. Of the two questionnaires administered, the first focuses on the attitudinal dimension, specifically attitudes towards science, while the second measures the conceptual, methodological/instrumental and attitudinal dimensions in relation to specific science topics. The data collected thus allow comprehensive assessment of pupils' scientific competence.

The study was conducted during the 2022/23 school year when Spain's LOMCE law on improvement of education quality was still in force. Consequently, in addition to the aforementioned dimensions, the study content is organised around the following five disciplinary areas belonging to natural science, as set out by the law:

- Content area 1- Introduction to science
- Content area 2- Introduction to science
- Content area 3- Living beings
- Content area 4- Matter and energy
- Content area 5- Technology, objects and machines

The content area geology is also included, coming under the umbrella of social science.

2. Methodology

2.1 Sample

The sample was selected using a non-probabilistic convenience criterion and consisted of Year 6 Primary pupils at BEP schools. It is representative of the study population as it draws from 53 of the 90 possible schools, covers 11 of Spain's 12 autonomous communities and cities where these schools are located and includes 60% of Year 6 pupils at these schools.

The first questionnaire on attitudes towards science (Appendix 2) received 2,430 responses, while the second questionnaire on Science content was completed by 2,253 pupils. The discrepancy in response numbers arises because the questionnaires were administered on two separate days to avoid pupil fatigue, and not all pupils who completed the first questionnaire were able to complete the second.

The responses to the two questionnaires were screened, removing those with illegible school codes, incorrect form numbers or identifiers and those submitted at night or outside school hours and which could not therefore be confidently attributed to pupils. This reduced the number of responses analysed to 2,396 for the first questionnaire (Attitudes Towards Science) and to 1,919 for the second questionnaire on conceptual and methodological dimensions and attitudes towards specific science topics.

Table 1 presents the breakdown of the samples analysed for the 2,396 pupils who completed the attitudes towards science questionnaire and the 1,919 who completed the content questionnaire across the different independent variables considered (gender, family background, school setting and school size). The information on these variables was obtained from pupils' responses to the general data section (Appendix 1).

TABLE 1
Breakdown by variable (excluding autonomous community) of the pupil sample that completed the two questionnaires

Independent variable	Category	Attitudes questionnaire frequency	Content questionnaire frequency
Gender	Female	1.128	935
	Male	1.199	933
	Prefer not to say (PNS)	69	51
Family background	Family member in science	1.187	934
	No family member in science	1.209	985
School setting	Rural	248	220
	Urban	2.148	1.699
School size	Small • 1 group	167	135
	Medium• 2-3 groups	1.688	1.369
	Large • 4 or more groups	541	415

The dependent variables analysed were attitudes towards science (ATS), gathered via the first questionnaire, and skills related to attitudinal, conceptual and instrumental content (organised by dimension and curricular content area), gathered in the second questionnaire.

2.2 Tools

First questionnaire: Attitudes towards Science (ATS)

To assess ATS, the research team used the 10-item questionnaire developed by Toma et al. (2019). One modification was made, replacing the item "When I grow up, I want to work with people who make scientific discoveries" with an item from Fraser (1981): "When I grow up, I want to be a scientist", as this represents a clearer stance on considering a career in Science.

Small adjustments were also made to the original Spanish questions to make the wording more inclusive, replacing the generic masculine "científico (scientist)" with "científico y científica" to include both genders and replacing "profesor" (teacher) with "profesora o profesor" for the same reason. This particular questionnaire was selected on three key grounds: it is age-appropriate for the sample, it is a validated and reliable tool for measuring ATS among primary school pupils, and its brevity minimises fatigue among Year 6 pupils (Toma et al., 2019).

Preliminary principal component factor analysis was conducted using the Factor Analysis software (Lorenzo-Seva & Ferrando, 2023), identifying three factors grouping the questions:

- Factor 1 - Adoption of scientific attitudes
- Factor 2 - Attitudes towards scientists
- Factor 3 - Inclination towards science

The questionnaire adopts a four-point Likert scale, broken down as follows:

- "Strongly disagree"
- "Disagree"
- "Agree"
- "Strongly agree"

On this basis, individual pupil scores between 1 and 1.9 were considered unsatisfactory, as they indicate the pupil answered "Strongly disagree" or "Disagree" to statements expressing positive attitudes towards Science, thus suggesting negative ATS; scores between 2 and 2.9 were deemed satisfactory, since they reflect pupil agreement with items expressing positive ATS; and scores between 3 and 4 were classified as excellent, indicating the "Agree" or "Strongly agree" response to items expressing highly positive ATS.

For overall attitudes (all three factors), the sum of the scores across the 10 items ranged from a minimum of 10 to a maximum of 40. In this case, scores between 10 and 19 were considered unsatisfactory, those between 20 and 29 were deemed satisfactory and scores between 30 and 40 were considered excellent.

Three sociodemographic questions were added to the 10-item questionnaire – school (code, classroom and form number), gender and whether pupils have family members working in science (Appendix 1) – bringing the question total to 13.

Second questionnaire: Content

To measure pupil performance on the conceptual, instrumental and attitudinal dimensions, a second questionnaire was designed ad hoc. Prior to distribution, the draft underwent expert review by seven university lecturers (specialising in experimental science teaching, environmental education, experimental sciences and teacher training) and six primary school teachers.

This second questionnaire consisted of 29 closed questions on natural science designed to assess participating pupils' knowledge and skills. The questionnaire was heterogeneous, comprising a diverse selection of questions linked to the five natural sciences content areas in the LOMCE curriculum, alongside additional questions on the geology content area (belonging to social science). The 29 questions thus covered all six content content areas (Table 2).

TABLE 2
Content questionnaire: question types by dimension and content

Question number	Dimension[a]			LOMCE content area[b]					
	Cognitive	Instrumental	Attitudinal	1	2	3	4	5	Geology
1	X	X		X			X		
2	X					X			
3	X				X				
4	X			X				X	
5			X						X
6			X			X		X	X
7	X	X	X	X		X	X		
8	X						X		
9	X								X
10	X	X		X			X	X	
11		X		X	X				
12		X		X	X				
13		X		X		X		X	
14		X		X		X		X	
15		X				X			
16		X		X	X				
17		X		X	X				
18		X		X	X				
19	X	X	X						X

20	X	X					X		
21	X	X	X		X				
22	X	X			X				
23	X	X		X		X	X		X
24	X	X		X		X	X		X
25	X			X		X	X		X
26	X					X			
27		X					X		
28	X						X	X	
29		X		X			X		

Note: [a] The dimension addressed in each question was assessed by a panel of 13 experts. [b] Allocation to each content area was based on the assessment criteria and learning standards set out in the LOMCE.

Allocation to each content area followed the LOMCE assessment criteria and learning standards. The questions were also designed to relate to the conceptual, procedural/instrumental or attitudinal domains, or to various domains simultaneously. The number of response options ranged from three to six, though exceptionally included eight in one question and two in another (this question was later excluded from analysis as it sought personal opinion on the topic).

Some questions had a single answer, while others allowed multiple responses, meaning correct choices required subsequent weighting during statistical analysis.

To ensure greater objectivity when determining what was considered a correct answer, multiple choice questions containing contradictory or mutually exclusive responses were invalidated when pupils selected both options. For instance, in the question on whether the arm is a machine, if a pupil answered that it is a simple machine and also that it is not a machine, it was clear that they had not fully understood the machine concept.

Multiple responses were also invalidated when pupils selected all the options and thus made it impossible to determine whether they actually knew the correct answers.

In multiple-choice questions, meanwhile, contradictory options were disregarded to leave solely the correct options.

For example, the first question offered four options, two of which were correct:

a. The cutlery has a mass of 125 g
b. The cutlery has a mass of 125 ml
c. The cutlery occupies a volume of 200 g
d. The cutlery occupies a volume of 200 ml

If all four options were selected, the answer scored zero; if just the two correct options were selected, the answer scored two; if two options – one correct and one incorrect – were selected, the answer scored zero; and if three options were selected, of which two were correct but likewise meaning two were mutually exclusive, the answer scored one.

Exceptions were made for some attitudinal questions, where responses deemed less aligned with sustainability principles, for example, were not penalised.

The average time taken to complete the questionnaires was 5.55 ± 4.49 minutes for the 10 Attitudes towards Science questions and 27.24 ± 9.95 minutes for the 29 questions on conceptual, instrumental and attitudinal content relating to specific science topics.

3. Analysis of level of scientific competence among year 6 Primary pupils at Bilingual Education Programme schools

3.1 Analysis of scientific competence on the attitudinal dimension (first questionnaire: Attitudes towards Science)

3.1.1. Introduction

The attitudinal dimension comprises both attitudes towards science and attitudes towards specific science topics such as the environment or health. The findings on pupils' attitudes towards science are presented first without considering the influence of the different variables studied. These findings are then followed by analysis of each variable's individual influence.

3.1.2. Attitudes towards science

Analysis of all responses received reveals that pupils at BEP schools performed adequately in items 1, 2, 4, 5, 6 and 7 and excellent scores on items 3, 8 and 9. However, they performed unsatisfactorily on item 10 ("When I grow up, I want to be a scientist"), scoring below 2.

The mean scores for each of the three factors relating to attitudes reveal an excellent result for Factor 1 (Adoption of scientific attitudes) and satisfactory results for Factor 2 (Attitudes towards scientists) and Factor 3 (interest in science). For an overall ATS score, where all responses are considered, the results confirm pupils at BEP schools demonstrate an adequate level of ATS, which is close to excellent.

3.1.3. Attitudes towards Science by variable

3.1.3.1. Influence of gender

One of this report's most significant findings, based on the statistical tests applied, is that girls achieved higher scores and exhibited more favourable attitudes across the ATS factors and the overall ATS construct than boys. Girls thus possess more favourable attitudes towards science. This finding raises an interesting question: why do these attitudes decline as girls progress through the education system and why, when compared with their male peers, do they opt out of the science subjects they find challenging?

3.1.3.2. Influence of family background in science

Pupils at BEP schools with family members working in science exhibited more favourable attitudes towards scientific research and scientists and a greater interest in science, resulting in more positive attitudes surfacing in the overall ATS construct.

3.1.3.3. Influence of school setting

The school setting was classified as either rural or urban, with rural defined as having a local population of fewer than 10,000 inhabitants. The results show no significant differences in attitudes between rural and urban schools across any of the factors.

3.1.3.4. Influence of school size

Schools were classified by size according to the number of Primary year groups: schools with only one year group were categorised as small; those with two or three were considered medium-sized; and schools with four or more year groups were classified as large. Pupils at small and medium-sized schools exhibited better attitudes in Factor 3 (Inclination towards science). School size thus influences only some of the latent dimensions of ATS.

3.1.3.5. Influence of ATS questionnaire response time on scores

The average time taken to complete the ATS questionnaire was 5.55 ± 4.49 minutes. Analysis revealed no correlation between response time and the score achieved.

3.2 Analysis of scientific competence in the attitudinal, cognitive and methodological dimensions (second questionnaire)

3.2.1. Introduction

The results of the 29 questions were analysed by dimension: attitudinal (towards specific topics such as health or the environment), conceptual and instrumental. The influence of the different variables within each dimension was then considered.

3.2.2. Attitudes towards specific science topics

Content questionnaire items 5, 6, 7, 19 and 21 (see Table 2) assess attitudes towards specific science topics. The responses to questions 5, 6, 7 and 19 indicate that pupils exhibit care for the environment, while question 21 reveals positive attitudes towards health. Figure 1 presents the results without considering the variables' influence.

Statistical analysis of the influence of the different variables reveals significant differences between girls and boys in the attitudinal content relating to specific topics, with girls achieving higher scores. This finding aligns with the observation in Section 3.1.3.1 that girls exhibit more favourable ATS.

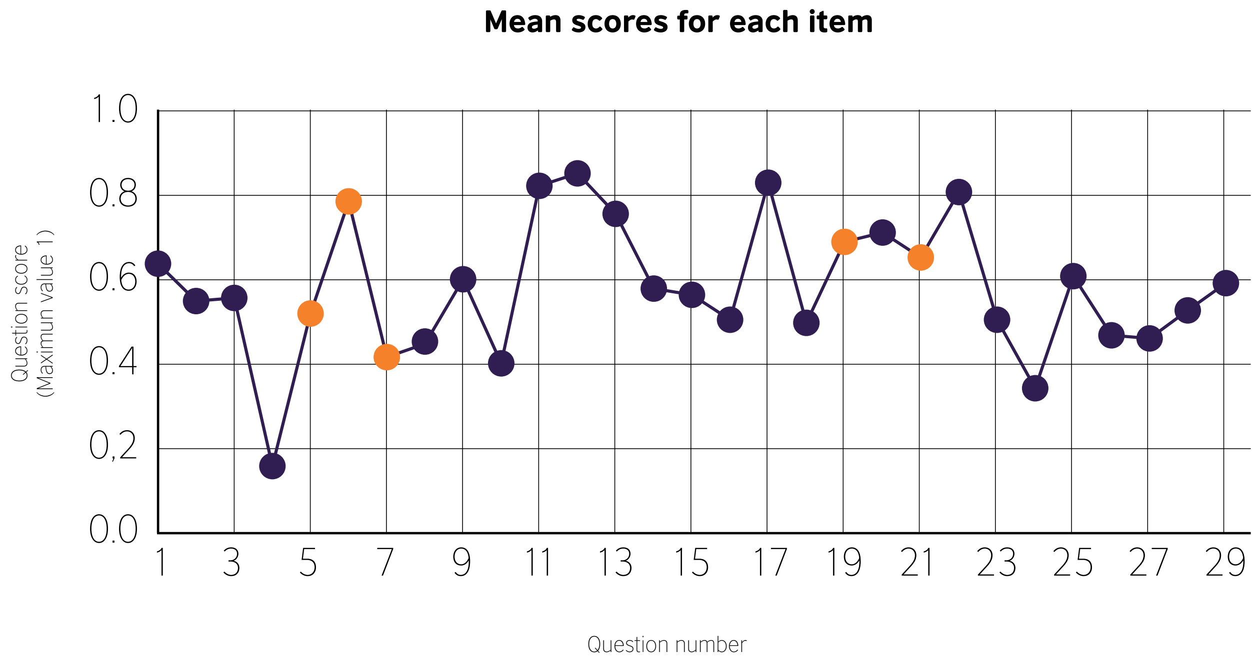
As regards the influence of having family members working in science, pupils that met this criterion scored higher.

No significant differences were found in attitudinal content scores between small and large schools.

Regarding school setting (rural or urban), significant differences were evident between pupils at urban schools and those at rural ones, with those at urban schools achieving higher scores.

Finally, a comparison was made between the responses to the questions on health and on care and respect for the environment and the responses to the first questionnaire on ATS. These were recoded into ranges. Statistical analysis of the processed data confirms that pupils who exhibited excellent ATS achieved the highest scores in the attitudinal content.

FIGURE 1
Mean content questionnaire score

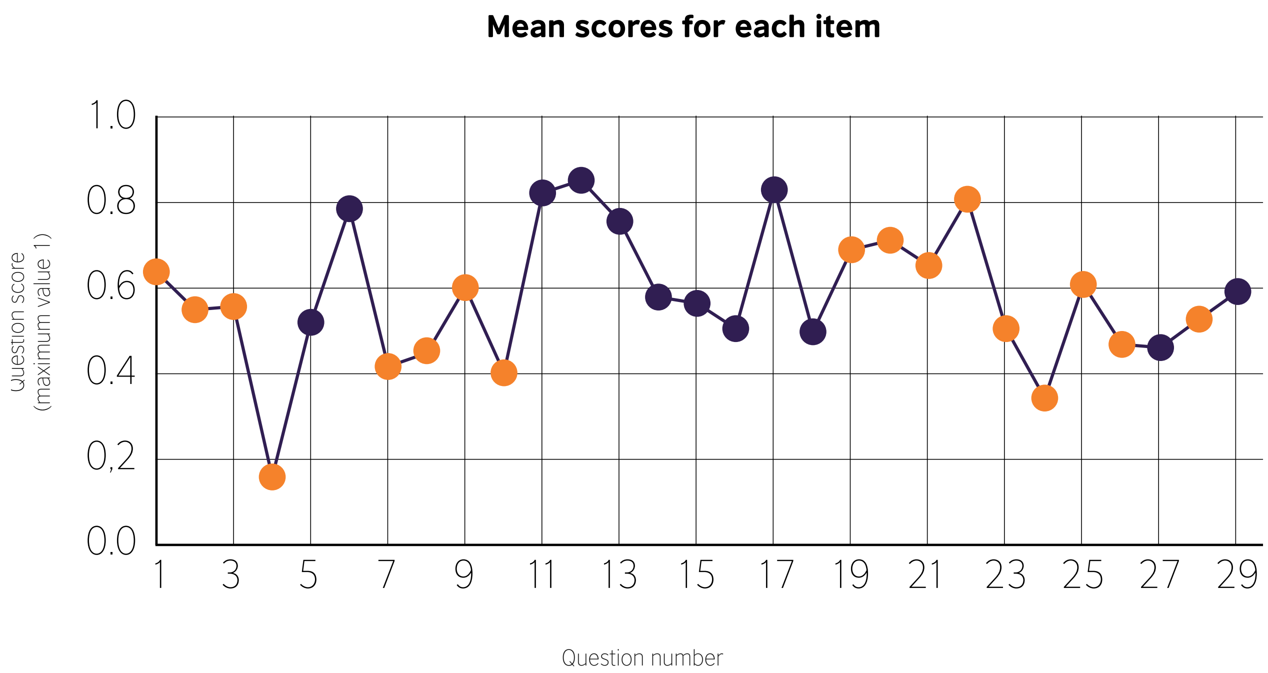


Note: the mean scores of the items measuring attitudinal science content are shown in orange

3.2.3. Conceptual/cognitive dimension

As Table 2 shows, the content questionnaire items assessing understanding of conceptual content are numbers 1, 2, 3, 4, 7, 8, 9, 10, 19, 20, 21, 22, 23, 24, 25, 26 and 28.

FIGURE 2
Puntuación media de las preguntas del cuestionario de contenidos



Note: the mean scores of the items measuring conceptual science content are shown in orange

Figure 2, which presents all results, shows that questions 4, 7, 8, 10, 24 and 26 produced particularly low scores. Performance on question 4, which concerns the conceptualisation of the nature of machines, and question 24, which asks pupils to explain their answer to question 23 – "Do you think groundwater is always safer to drink than water in rivers above ground?" – was especially poor. Nevertheless, for most of the questions (11) pupils scored above the mean value (0.5), which is considered highly satisfactory.

Analysis of the different variables' influence on the conceptual content reveals no significant differences between girls, boys and pupils who preferred not to disclose their gender. Pupils with family members working in science, however, achieved higher scores than those without.

Significant differences were evident between small and large schools in terms of conceptual content scores, with small schools performing better. When comparing the influence of setting on conceptual content scores, meanwhile, pupils at urban schools outperformed those at rural ones.

Pupils who exhibited excellent attitudes towards science also achieved the highest scores on the conceptual content.

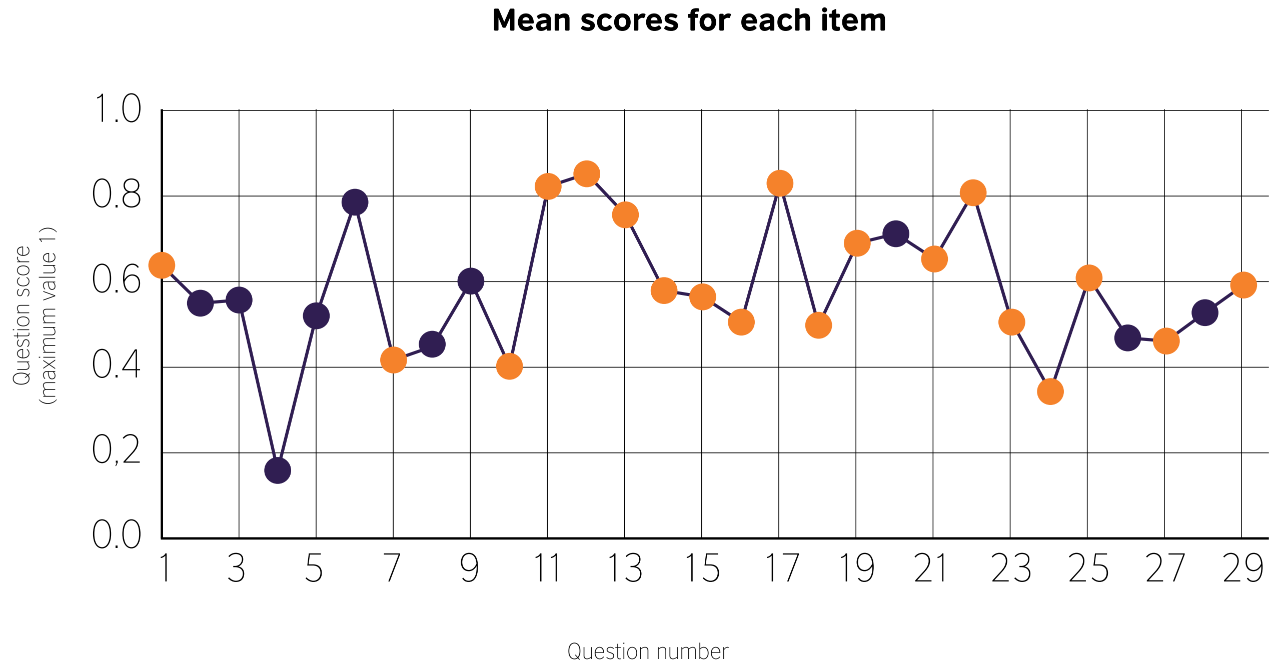
3.2.4. Methodological/instrumental dimension

The content questionnaire items assessing acquisition of instrumental knowledge are numbers 1, 7, 10, 11, 12, 13, 14, 15, 16, 17, 18, 21, 22, 23, 24, 25, 27 and 29 (see Table 2). Only four questions (numbers 7, 10, 24 and 27) scored below the mean value of 0.5, indicating a highly satisfactory level of instrumental content knowledge (see Figure 3, which presents the results without considering the variables' influence).

Analysis of the influence of the variables reveals that girls, pupils with family members working in science and those attending urban schools achieved higher scores on the instrumental content. No significant differences were found, however, between small, medium-sized and large schools.

Finally, pupils who exhibited excellent ATS also achieved the highest scores for instrumental content, further confirming girls' greater predisposition towards science at this stage of education.

FIGURE 3
Mean content questionnaire score

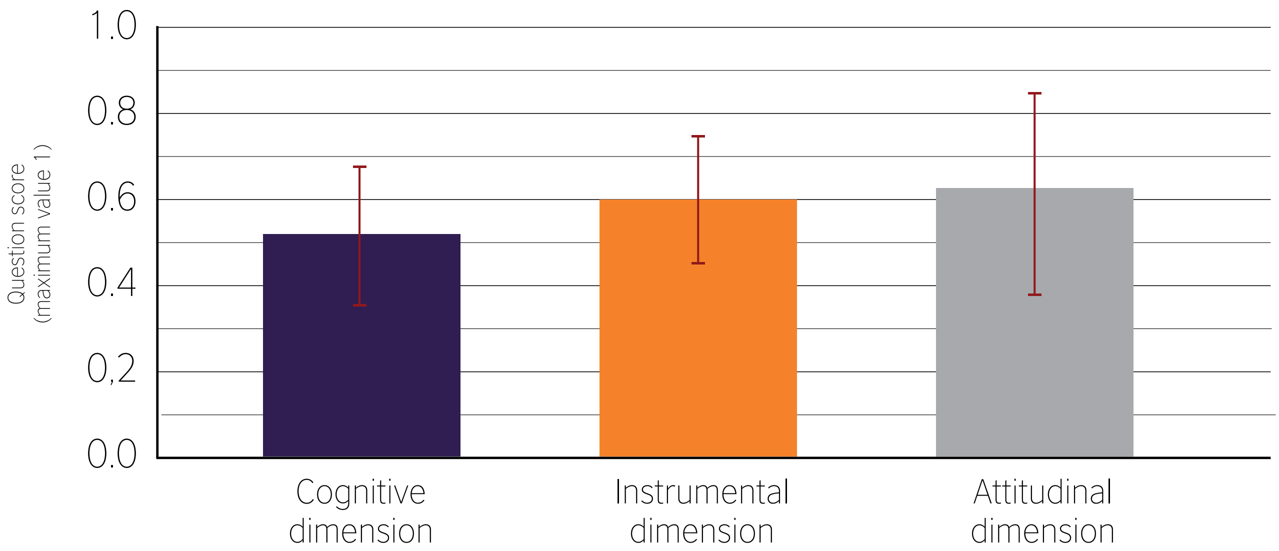


Note: the mean scores of the items measuring instrumental science content are shown in orange

3.2.5. Comparative summary of the dimensions in the content questionnaire

The scores across the three dimensions measured in the content questionnaire are remarkably similar: on the cognitive dimension pupils scored 0.531 ± 0.154, on the instrumental dimension they scored 0.603 ± 0.155 and on the attitudinal dimension they scored 0.610 ± 0.229. All three dimensions thus exceed the minimum required score of 0.5 (equivalent to a pass mark of 5). The cognitive/conceptual dimension, however, was the one that produced the lowest score (see Figure 4).

FIGURE 4
Comparison of the scientific competence dimensions in the content questionnaire

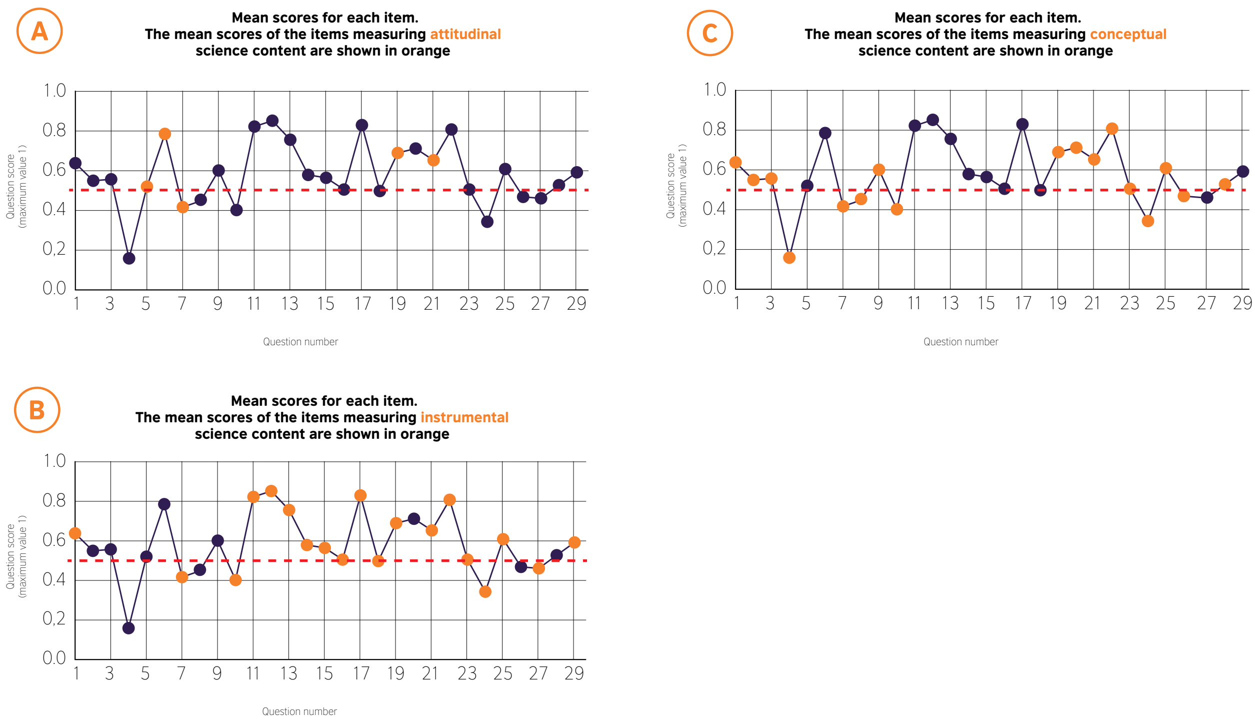


Closer analysis of each dimension reveals that in the attitudinal dimension (Figure 5A) – which concerns specific topics such as the environment and health – only one of the five questions scored below 0.5 (20%), namely the one on whether invasive species affect the environment. In the instrumental dimension (**Figure 5B**), four of the 19 questions (21%) – relating to how to study the effects of invasive species, how to design a circuit, how to design procedures to explain the characteristics of groundwater and how to apply the filtration process – fell below the desired level. In the conceptual dimension (Figure 5C), meanwhile, six of the 17 questions (35%) – those covering the machine, invasive species, dilation, circuits, groundwater and living beings concepts – failed to reach a satisfactory level.

Analysis of the integrative dimension, comprising questions that simultaneously address the attitudinal, conceptual and instrumental dimensions – namely questions 7, 19 and 21 (see Table 2) – reveals that only one of the three items (33%) scored below 0.5: the question on invasive species.

Of the seven questions that scored below 0.5, three were exclusively conceptual, one exclusively instrumental, one integrative and two combined the conceptual and instrumental dimensions. The cognitive and instrumental dimensions are thus those most prevalent among the questions that failed to reach a satisfactory level, indicating that these are the areas with the greatest knowledge gaps.

FIGURE 5
Mean content questionnaire score



3.3 Analysis of scientific competence by content area

The findings are presented below by curricular content area. The division follows the content organisation model laid down in the LOMCE for the Spanish national curriculum in force at the time of the study. Table 3 also presents the alignment between the Spanish and BEP curricula.

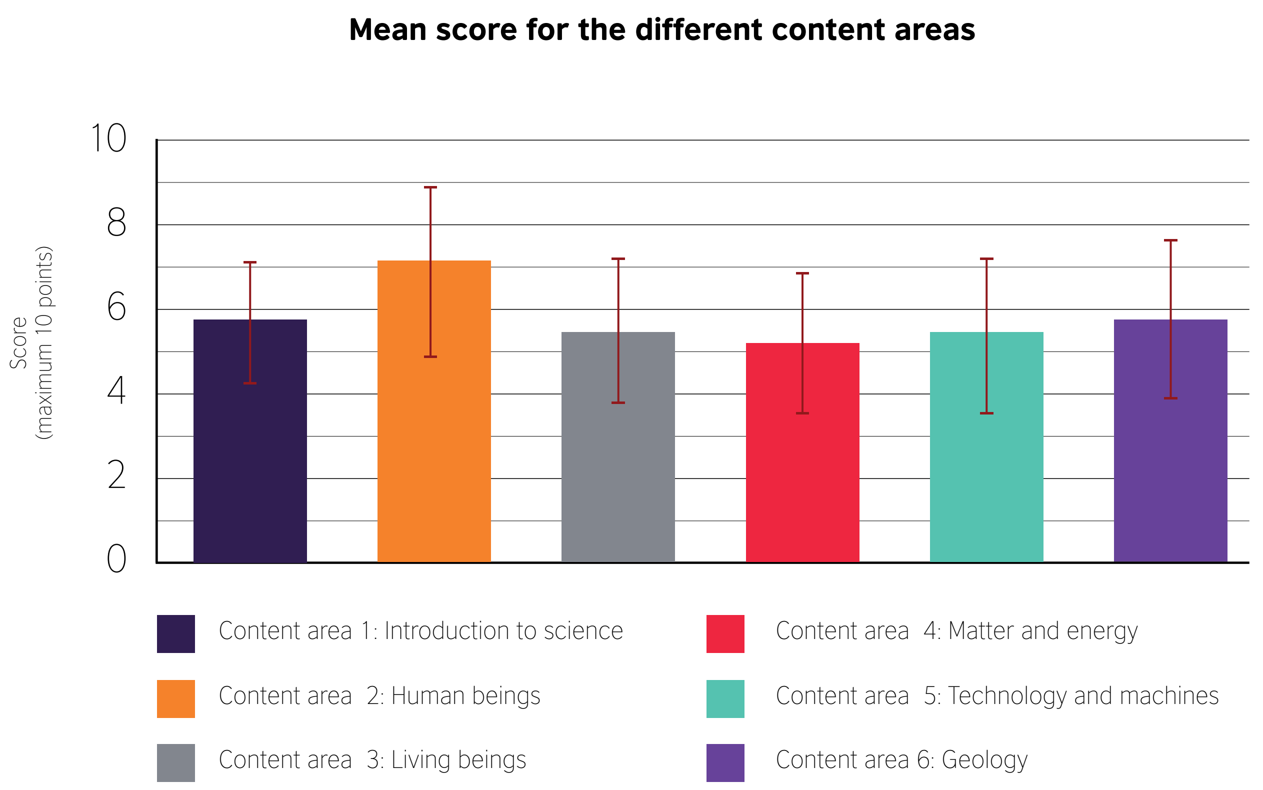
TABLE 3
Alignment between the Spanish and integrated BEP curricula

Spanish curriculum	BEP curriculum
Content area 1 – Introduction to science	Scientific work
Content area 2 – Human beings and health	Human beings
Content area 3 – Living beings	Living beings: plants, animals, etc.
Content area 4 – Matter and energy; materials, mass and volume; separation of components; reactions; forces; energy and sources; magnetism; light, sound and heat.	Everyday materials; states and properties of matter; sound; light; forces and magnetism
Content area 5 – Technology, objects and machines; machines, electricity and circuits; science past and present	Electricity and machines
Content area 6 – The world we live in (geology, environment)	Rocks; earth and space; habitat

3.3.1. Content area scores: overall analysis

As **Figure 6** shows, pupil scores on all six content areas surpassed the minimum required (5). Content area 2 – Human beings and health registered the highest score (5.645 ± 1.462), while content area 4 – Matter and energy recorded the lowest (5.215 ± 1.675), followed by content area 5 – Technology, objects and machines (5.321 ± 1.820). These findings reveal that respondents possess an adequate level of knowledge and, in fact, exceed the minimum threshold. Overall, considering all the content areas, pupils' science knowledge can be considered highly satisfactory and displays encyclopaedic breadth.

FIGURE 6
Mean content questionnaire score



3.3.2. Content area scores by variable

3.3.2.1. Influence of gender

Statistical analysis reveals significant differences between girls and boys, with girls achieving higher scores in content areas 1, 2, 3 and geology. Scores were similar between genders for content area 4 – Matter and energy, and content area 5 – Technology, objects and machines. This finding raises an important question: why do these attitudes decline as girls progress through the education system and why, when compared with their male peers, do they opt out of the science subjects they find challenging?

3.3.2.2. Influence of family background in science

Pupils with family members working in science achieved higher scores across all content areas, confirming that respondents with relatives in science demonstrate greater knowledge of the field.

3.3.2.3. Influence of school setting

Urban schools consistently reported higher scores across all content areas.

3.3.2.4. Influence of school size

Analysis of school size reveals significant differences between small and large schools in content area 1 – Introduction to science, content area 4 – Matter and energy and content area 5 – Technology, objects and machines, with small schools achieving higher mean scores in all three areas.

3.3.2.5. Influence of ATS

A significant relationship is evident between pupils' ATS and their scores across all six content areas: pupils who exhibited excellent ATS also achieved the highest scores in all the areas analysed. This is another of the report's key findings and underscores the importance of ATS and of developing positive attitudes since the latter are found to influence knowledge acquisition. Later sections examine whether this correlation is statistically significant.

3.3.3. Influence of content questionnaire response time on scores

The average time taken to complete the content questionnaire was 27.74 ± 9.95 minutes. Applying Spearman's rank correlation coefficient (rs = 0.324) to the value indicates a weak-to-moderate positive correlation between response time and scores, suggesting that longer response times are associated with higher scores.

Analysis of the variables influencing questionnaire response time reveals that gender, family members working in science, school size and ATS alignment all affect scores. School setting, however, did not exert any effect.

In terms of gender, girls took longer to complete the questionnaire, while pupils with family members working in science spent more time on it than those without that family background. This may reflect the importance these two groups place on taking time to reflect on their answers, suggesting that their capacity for reflection is more developed.

School size also influenced content questionnaire response time: large schools averaged 28.065 ± 9.284 minutes, medium-sized schools 27.332 ± 9.973 minutes and small schools averaged 30.882 ± 11.091 minutes. Pupils at small schools thus took the longest to complete the content questionnaire.

Pupils with excellent ATS scores also took longer to finish the questionnaire (28.462 ± 9.798 minutes) than those with satisfactory (27.845 ± 9.694 minutes) or unsatisfactory (25.029 ± 11.672 minutes) ATS scores.

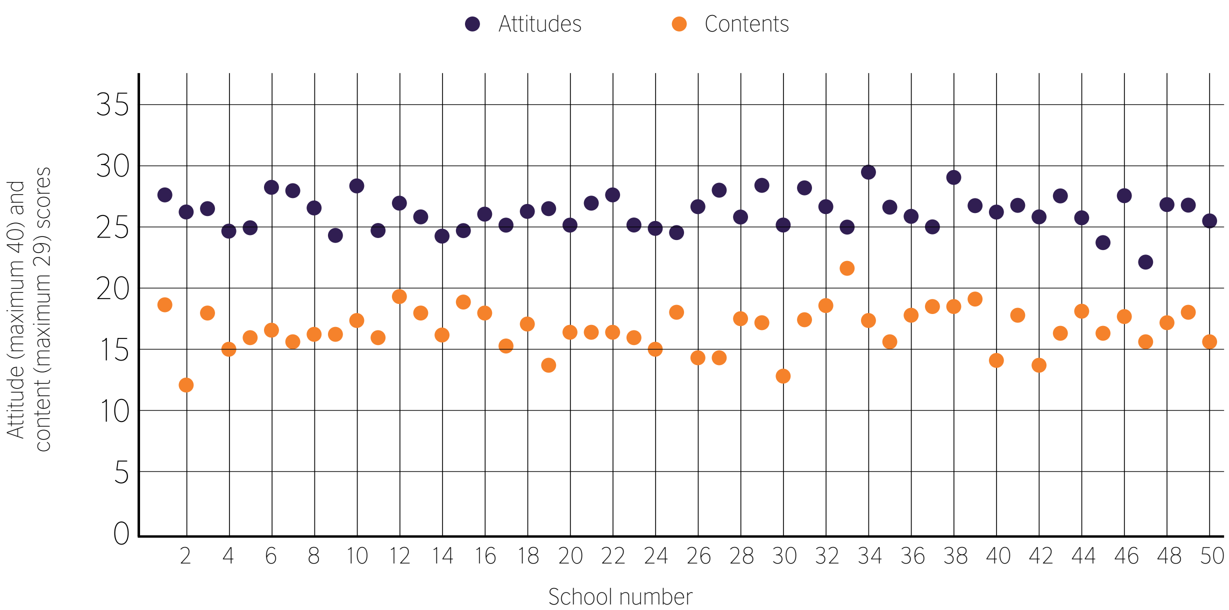
3.4. Combined analysis of attitudes and content scores

Earlier findings suggest a relationship between higher ATS scores and better acquisition of science knowledge. Pupils with excellent ATS scores achieved higher scores in the conceptual and instrumental content, in all six content areas analysed and in the attitudinal content relating to the environment and health.

Figure 7 compares mean ATS scores with content (attitudinal, cognitive and instrumental) scores across all participating schools. It should be noted that the maximum possible attitudes score was 40, while the maximum for the conceptual content was 29. The range of scores across schools is narrow in both cases, meaning that the scores are very similar, particularly as regards attitudes. The paths of the two sets of scores also run parallel to one another: as ATS scores decline, so do content scores.

Testing whether a demonstrable relationship between attitudes and content exists using Spearman's rank correlation coefficient (rs = 0.211) confirms there is a statistically significant (rs > 0.1) positive correlation between attitudes and content, indicating that higher ATS scores are indeed associated with higher content scores.

FIGURE 7
Comparison of mean content questionnaire and attitude scores



4. Conclusions and recommendations

Pupils at BEP schools tend to exhibit highly positive attitudes towards science across most of the items and factors that comprise them. This results in these pupils achieving a satisfactory overall ATS score.

However, item 10 ("When I grow up, I want to be a scientist") scored below the minimum threshold. This finding highlights the need to address this specific aspect: the way scientists are portrayed to pupils must be reconsidered to make a career in science appear appealing and attainable. To this end, schools are recommended to draw on young contemporary Spanish role models such as Nuria Galiana, Sara García Alonso, Arkaitz Carracedo or Daniel López Serrano to show that science is an attractive career choice, that it is also practised by young Spaniards, and that it is therefore within pupils' reach. Schools should also showcase a broad spectrum of scientist roles beyond the stereotypical laboratory setting.

In addition to this, the scientific method should be taught both theoretically (by explaining the steps involved) and practically (by applying it). This dual approach will help pupils understand how the method works and familiarise them with the process scientists follow, thereby making the profession more appealing and accessible as they learn what scientists do and how they solve problems.

Pupils at BEP schools do not present any issues with regard to gender, confirming that the current teaching approach is effective. Girls and boys exhibit similar ATS, and in many cases girls achieve better ATS scores, demonstrating both greater knowledge of attitudinal and instrumental content and greater knowledge of the content of areas 1, 2, 3 and geology. The fact that girls took longer to complete the content questionnaire – which is associated with higher scores and thus greater knowledge and mastery of the content – suggests that they are more reflective than boys.

Another key factor in this study is having family members working in science. Pupils with relatives in science exhibited more favourable ATS and achieved higher scores in the content questionnaire across all the dimensions (attitudinal, conceptual and instrumental) and in all the content areas analysed. It is likely that these pupils receive science-related toys, engage in science-related activities in their free time (such as museum visits, science clubs, watching science programmes), regularly discuss science topics at home and receive help from family members working in science.

Schools could therefore consider purchasing science-related toys for pupils to play with at break times or in after-school clubs. Reading science-themed books such as Big Bad Wolf Investigates Fairy Tales: Fact-checking your favourite stories with SCIENCE! by Catherine

Cawthorne and Sara Ogilvie (2024) or other science books could also be beneficial. These materials can be introduced from Early Years onwards to foster an interest in science. Schools could also organise educational visits to science-related settings, offer science-focused extracurricular activities (see above), watch science programmes or invite professionals from different scientific fields to chat about what they do. This could serve as a starting point for children to begin discussing science. Participation in citizen science projects, external workshops and science fairs would also help pupils engage with the world of science.

The study also found that the school setting influences outcomes, with pupils at urban schools achieving higher content questionnaire scores across all dimensions and content areas. Schools should therefore analyse the profiles of both pupils and teachers at urban and rural schools to identify any differences that may affect the results and to ensure that teaching approaches are consistent across both settings.

School size varies considerably among BEP schools, ranging from one class per year level to four or five. While this does not appear to affect overall results and has no bearing on attitudinal or instrumental dimension scores, it does influence one of the three ATS factors (conceptual). In addition, small schools achieved higher scores in areas 1, 4 and 5. No further recommendations are made regarding school size beyond those outlined above.

The study reveals a clear relationship between ATS and performance in the content questionnaire, underscoring the importance of fostering positive ATS to enhance science learning: pupils who achieved excellent ATS scores consistently achieved higher scores across all dimensions and content areas analysed.

To strengthen science education, schools should therefore focus on making science lessons engaging, offering additional science time through extracurricular activities, creating spaces for discussion about science, providing science materials so pupils can experiment at home (or suggesting appropriate everyday materials they can use) and designing experiments that allow pupils to discover answers for themselves. As previously noted, schools should also portray scientists in ways that appeal to children, highlighting the characteristics of their work and presenting them as people no different from those practising other professions.

Another key finding of this study is the importance of allowing pupils sufficient time to complete academic assessments. While response time to the ATS questionnaire showed no correlation with scores, time spent on the content questionnaire – which assessed the attitudinal, cognitive and instrumental dimensions – proved decisive. Schools should therefore ensure that pupils take at least the minimum time deemed necessary by teachers to complete a test, since this will give them time to read the questions carefully (particularly since reading comprehension varies among pupils) and reflect, where required, before submitting their answers.

The authors would also like to highlight several findings relating to pupils' mastery of the different dimensions, areas and specific science content:

- The cognitive dimension produced the lowest scores, while the cognitive and instrumental dimensions contained the highest number of questions that failed to receive the desired response.
- Of the seven questions that scored below the desired threshold, one belonged to the integrative dimension (which combines all three dimensions) and two combined the conceptual and instrumental dimensions. This demonstrates the difficulty of integrating scientific competence's various dimensions and the need to address this by working on multiple dimensions simultaneously.
- The lowest-scoring content areas were matter and energy and technology, objects and machines. This aligns with the low scores achieved on questions covering the machine, dilation, circuits and filtration concepts, all of which belong to these areas.
- Two of the questions most frequently answered incorrectly were the ones on invasive species and groundwater, which – along with the question on machines – required pupils to learn scientific concepts in one context and then apply them to another. Schools are therefore recommended to place greater emphasis on applied learning since it plays a key role in developing the skills that will enable Primary pupils to tackle real-world challenges.
- The question relating to the conceptualisation of living beings also failed to reach the desired threshold. Schools should therefore teach this concept in greater depth, avoiding anthropomorphism and anthropocentrism and ensuring that pupils understand all the processes involved in the three vital functions rather than simply memorising them.

Future research could build on these findings in several ways. For instance, it would be valuable to supplement the findings with data on pupils' English proficiency to determine whether this correlates with higher content and attitude scores.

A longitudinal study could also be conducted to assess whether implementing the recommended improvements leads to better outcomes.

Furthermore, this research could be extended to older year groups using previously released PISA questions and attitude questionnaires already validated for those age ranges.

4.1 Final considerations

The data confirm that Year 6 Primary pupils attending BEP schools have assimilated scientific competence content covering the conceptual, procedural and attitudinal dimensions to a highly satisfactory extent.

The scientific knowledge demonstrated in pupils' responses indicates that they have acquired a satisfactory level of scientific competence that far exceeds the minimum requirements set out in the curriculum. The findings thus confirm that the BEP effectively promotes the acquisition of scientific knowledge and the development of scientific competence in line with the objectives in Primary education. This suggests that the BEP is capable of imparting satisfactory scientific competence in any context.

Nevertheless, a significant proportion of responses indicate that pupils' science education still has room for improvement, particularly in relation to scientific procedures – in the broadest sense – and in the specific topics of matter, energy, technology and machines. Addressing these areas would help consolidate and enhance pupils' scientific competence, reinforcing their learning.

As resources to address the identified gaps, the following are reccommended:

- Activities from the project "+Science with Consequence: school and teachers as sources of culture and scientific vocations" (FECYT-funded project FCT-21-16789). These activities target the areas where shortcomings were identified, namely energy, technology and machines: Year 1 Primary: "Transmitting movement"; Year 2 Primary: OPTICAL ILLUSION. Playing with colours to learn science; Year 4 Primary "Heat or termal energy". Activities that address all three dimensions and encourage Year 4 Primary pupils to acquire knowledge independently are also recommended, e.g. School of volcanologist.
- The SeLFiE project activities integrate all four scientific competence dimensions while adopting a STEAM approach https://project-selfie.eu/booklet-english/ and supported by CLIL (content and language integrated) strategies. The use of inquiry-based learning

and engineering design methodologies ensures that these activities engage pupils actively with the scientific method in real-world contexts.

- Scienced-themed stories which make topics more accesible to pupils.

5. References

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Appendix 1

General data

1. Enter your school code, year group, classroom and pupil number. It is very important to enter this information correctly. (Ask your teacher for the code, for example: 40003411-6a-4).*

Enter your answer

2. I am a... *

- Girl
- Boy
- Prefer not to say

3. Do you have any family members working in Science or Technology (e.g. doctor, engineer, researcher, electrician, vet, etc.)? *

- Yes
- No

Appendix 2

Attitudes towards Science questionnaire

4. Select the number that best represents the extent of your agreement or disagreement with the following statements*:
1. Strongly disagree
2. Disagree
3. Agree
4. Strongly agree

If you **DO NOT LIKE IT AT ALL**, select **1** (Strongly disagree)

If you **MOSTLY DO NOT LIKE** it, select **2** (Disagree)

If you **MOSTLY LIKE IT**, select **3** (Agree)

If you **LIKE IT A LOT**, select **4** (Strongly agree)

Attitudes towards Science questionnaire, Toma, Ortiz-Revilla and Greca (2019), adapted TOSRA scale.

	1	2	3	4
1. I like to talk about Science outside the classroom	◯	◯	◯	◯
2. Natural Sciences is the most interesting subject	◯	◯	◯	◯
3. I prefer solving problems by conducting experiments rather than receiving answers	◯	◯	◯	◯
4. Scientists are just like everybody else	◯	◯	◯	◯
5. When I grow up, I want to study something related to science	◯	◯	◯	◯
6. I'd like to have more hours of Natural Sciences every week	◯	◯	◯	◯
7. It's better to find answers by conducting experiments than by asking the teacher	◯	◯	◯	◯
8. Scientists are as nice as everybody else	◯	◯	◯	◯
9. I'd like to receive science-related materials so I can do experiments at home	◯	◯	◯	◯
10. When I grow up, I want to be a scientist	◯	◯	◯	◯