

EMPOWERING SUSTAINABLE EDUCATION: REFLECTIONS FROM THE MIRACLE PILOT INITIATIVES

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Abstract

The MIRACLE (coMics and IllustRations Augmented to tackle Climate change in primary Education) project, funded by Erasmus+, aims to integrate climate change education into primary schools through innovative teaching methods, including augmented reality (AR) and comic creation. This paper presents the findings from the first pilot implementation, which focused on enhancing teacher and pupil digital skills, promoting a green teaching culture, and addressing eco-anxiety. The pilot testing of the project's learning scenarios involved 365 students and 40 teachers from partner schools in Greece, Spain, Malta, Croatia, and Portugal. The project also highlights the importance of a Whole-School Approach, emphasizing active involvement from parents and the broader community. Results of pre- and post-tests are summarized, highlighting the impact of learning about climate change on knowledge, attitudes, and behaviour.

Introduction

Climate change (CC) is an urgent global issue with dangerous consequences. It requires innovative experiential approaches to teach its effects and modify attitudes in support of pro environmental actions. The MIRACLE (coMics and IllustRations Augmented to tackle Climate change in primary Education) project develops inclusive strategies for teachers and students to learn about and engage with CC, a topic that at Primary Education level is perceived as abstract, distant, and complex, and may contribute to growing feelings of sadness, hopelessness, and anxiety.

MIRACLE draws on augmented reality as a medium to educate about climate issues, directly expose users to novel stimuli, and create comics about sustainability, offering the pupils' learning experiences that are engaging, available, and impactful. Comics in education support scientific literacy (Tatalovic, 2009) and creativity, helping learners develop imagination and read between the lines. Comics with AR can also boost digital skills development (Nidhom et al, 2019).

MIRACLE also promotes the STEAM approach in primary education through interdisciplinary teaching in environmental contexts, focusing on the basic science behind CC and comics art through a partnership among six entities: 1) three primary schools located in Ireland, Croatia, and Malta; 2) two technology SMEs, CleverBooks (Ireland) and Jaitek (Spain); 3) a non-profit civil company (Greece); 4) two higher education institutions (The University of Malta and The Autonomous University of Madrid); 5) a Foundation (Fundación Siglo22, Spain); and 6) wider society. The project facilitates participation in and outside the partnership, fostering equity and equality at all levels.

Background and Rationale

Europeans rank climate change among the most serious problems facing the world today (European Commission, 2021). Protecting the environment is important to 84% of EU citizens personally; 78% consider that environmental issues impact directly on their daily lives and health and almost all feel that urgent action is needed to tackle biodiversity loss (European Commission, 2024). Putting environmental sustainability at the heart of education and training means responding to the realities of the 21st century and equipping learners with the competencies they need to contribute positively to a sustainable society and economy. Teachers and trainers across Europe are already actively teaching for sustainability, often driven by their sense of responsibility to prepare future generations. At the same time, many educators say they lack training and support in sustainability education and training, in particular, regarding interdisciplinary approaches, active pedagogies, and the challenging subject matter (Goller & Rieckmann, 2022).

Teachers need time, resources, and free professional development opportunities to provide quality climate education. They need time as part of their working day to plan, train and innovate in climate education. They need quality teaching and learning materials, which can be provided by open educational resources, and they need to develop their confidence to teach climate change science. The hope is that they will educate their students to be actively involved in local, regional, national, and European actions on environmental sustainability, and build lifelong habits that are environmentally conscious and sustainable.

The MIRACLE project develops an inclusive Digital Learning Environment (DLE) to upskill teachers' digital and sustainability competencies, empowering them to support school community members as agents of change in the spirit of the European Commission's Digital Education Action Plan (2020). Using immersive technologies, MIRACLE creates an integrated and inclusive DLE, "The MIRACLE Augmented Classroom", which raises pupils' awareness of environment and climate change and guides behavioural changes in individual preferences,

consumption habits, and lifestyles in line with: a) the New European Bauhaus initiative (Rosado-García et al, 2021); b) the European Council Recommendation on learning for environmental sustainability (European Council, 2022); and c) the “GreenComp: The European sustainability competence framework” (Bianchi et al, 2022). Teachers, mentors, school principals, school staff, parents, and the wider community (Whole School Approach) (Bryan & Henry, 2012) develop digital and sustainability competencies through innovative pedagogical practices and activity implementation.

The project is an innovative approach to ESD carried out by a multidisciplinary group of experts from five European countries, aiming to facilitate collaborative and transformative learning in order to affect change for sustainability. The project will demonstrate how education and learning coupled with multi-stakeholder engagement can effectively drive community action to tackle sustainable development challenges at the local level and help achieve European and global goals. The MIRACLE project relies upon people from all parts of the school community to achieve success.

Methodology

The MIRACLE project responds to the need for a systemic green component of education and responds to the existing challenges by:

- adopting an interdisciplinary approach to learning about environmental sustainability, putting the learner at the centre of the co-creation processes;
- providing pupils with an interactive and immersive experience with Augmented Reality of co-created digital comics, creating lasting knowledge and understanding of the topic and sparking their interest in science;
- adopting a “Whole School Approach” where sustainability is embedded in all processes and operations;
- providing schools with the basic science behind Climate Change, including data and tools on how to monitor the effectiveness of sustainability initiatives and efforts;
- mapping the national curricula for sustainability at all grades of primary education so that schools can easily integrate the project's learning activities;
- offering teachers training and support in sustainability education and training, in particular regarding interdisciplinary approaches, active pedagogies, and the challenging subject matter.

The main concrete results developed in the five Work Packages (WPs) of the project are

1. WP1: All administration, monitoring, assessment reports and tools
2. WP2: The MIRACLE Sustainability Mindset in European Schools
3. WP3: The MIRACLE MOOC
4. WP4: The MIRACLE Augmented Classroom and
5. WP5: The visual branding of the project, publications, creation of networks, info days, and multiplier events.

As part of WP3, the project will develop the "Miracle Augmented Classroom" (MAC), a flexible and innovative learning space that can enable teachers to guide pupils' discovery, facilitate their learning and the development of new skills and competencies, and promote curiosity, innovation and autonomy. The MAC will support pupils to level up their digital comic co-creations with AR, manipulate 3D models of selected topics, supported by informative videos, and participate in learning activities that culminate in community action. This method helps to create a lasting impression of the topics, and sparks learner interest in science and particularly CC.

The concrete materials of the MIRACLE project are in English with selected parts translated and adapted for Croatian, Greek, Maltese, and Spanish audiences to facilitate MIRACLE uptake and promote a shared understanding of project results in the schools.

A pilot has been administered as an exemplar for designing an effective implementation plan to gain insight into the main challenges and opportunities for the effective integration of MIRACLE in the school curriculum. This paper reviews the results of the pilot, which is intended to pave the way for further strategic actions before wide scale implementation. The opportunities afforded by international cooperation on the project include the ability to compare results internationally and determine what strategies benefit a broad number of cultural backgrounds and why. The project also provides robust opportunities for teachers rarely included in such international projects to develop leadership in CCE and STEAM teaching in an international context. Furthermore, it allows each of the partners to develop and increase their capabilities in line with the selected priorities.

Pilot Survey Design

Pilot Surveys were designed as two blind treatments (pre- and post-test) for three groups: students; teachers; and community members. Each school was assigned a unique id, and each respondent in each school received a unique personal id that was recorded for purposes of paired statistical analysis but not shared with the researchers. This paper will summarize in the aggregate the results of the pre- and

post-tests for student and teacher groups from Croatia, Greece, Malta, Portugal, and Spain.

Results – Student Survey

A series of demographic questions collected information on the students' age, gender, grade level, and country. The student survey includes seven Knowledge questions, eight Attitude questions, and seven Behaviour questions, all created with a 5-point Likert Scale (1 = “Strongly Disagree”; 2 = “Disagree”; 3 = “Neither Agree nor Disagree”; 4 = “Agree”; and 5 = “Strongly Agree”). There were also five open-ended questions that are not analysed here.

In order to determine the effect of training in CC, the pre-test was administered before the CC lesson, and the post-test after. The number of subjects completing the pre-test and post-test from each country are summarized in Table 1.

Table 1

Students Completing the Pre-test and Post-test in Five Countries

Country	Pre-test n	Post-test n
Croatia	50	41
Greece	110	70
Malta	74	27
Portugal	74	49
Spain	57	57
<i>Total</i>	<i>365</i>	<i>244</i>

Cronbach's Alpha Values were calculated for CC latent items for all five countries together, with 365 students completing the pre-test and 244 completing the post-test. Cronbach's Alpha varied from .803 to .890, with a qualitative interpretation of “Good”, meaning the results are reliable.

In Croatia, Greece, Malta, and Portugal, the total of students completing the pre-test was not equal to the total of students completing the post-test. As a result, inferential statistical analysis could not be used in the combined analysis of all five countries together. However, in Spain, the same students completed both pre-test and post-test (n = 57). Therefore, student data is analyzed in two ways:

1. The first analysis combines the data from students in all five countries with all the Knowledge questions, all the Attitude questions, and all the Behaviour questions considered individually and in sets.
2. The second analysis focuses on student data from Spain and includes inferential statistics. As the same students completed both pre-test and post-

test, it was possible to implement a Non-parametric Paired-Samples Wilcoxon-Test on those results and report on levels of significance for each question within each set.

An analysis of the open-ended questions is not included here, but this information is incorporated informally in the pilot teacher reports.

Students Combined Results: Croatia, Greece, Malta, Portugal, and Spain

The combined survey results are analysed in three groups: Knowledge, Attitudes, and Behaviour.

Students Combined: Knowledge Questions

For the pre-test, the students indicated they knew least about: utilizing augmented reality to learn more about CC ($X=2.523$); the enhanced greenhouse effect ($X=2.751$); and how to create comic books about climate change ($X=2.896$). Each of these scored below the midpoint of the 5-point Likert scale. The highest score was for Knowledge Question (KQ) 7, “I know how to collaborate or work with other pupils to learn more about climate change” ($X=3.718$); this might reflect their overall experience in working with others rather than specific experience in working with others to learn about climate change. The results are summarized in Table 2.

For each Knowledge question, the post-test mean was greater than the pre-test mean, indicating that the students had benefitted from the CC lesson.

The Mean Percent Variation (M%V) provides the percentage by which the post-test mean differed from the pre-test mean (see Table 2). The greatest differences between the pre- and post-test were for KQ1, “I know the meaning of the enhanced greenhouse effect” (M%V =26.48%), and KQ4, “I know how to create comics about climate change” (M%V=25.380%). The smallest difference was for KQ7, “I know how to collaborate or work with other pupils to learn more about climate change” (M%V=6.583%), likely because this question scored the highest in the pre-test.

Table 2

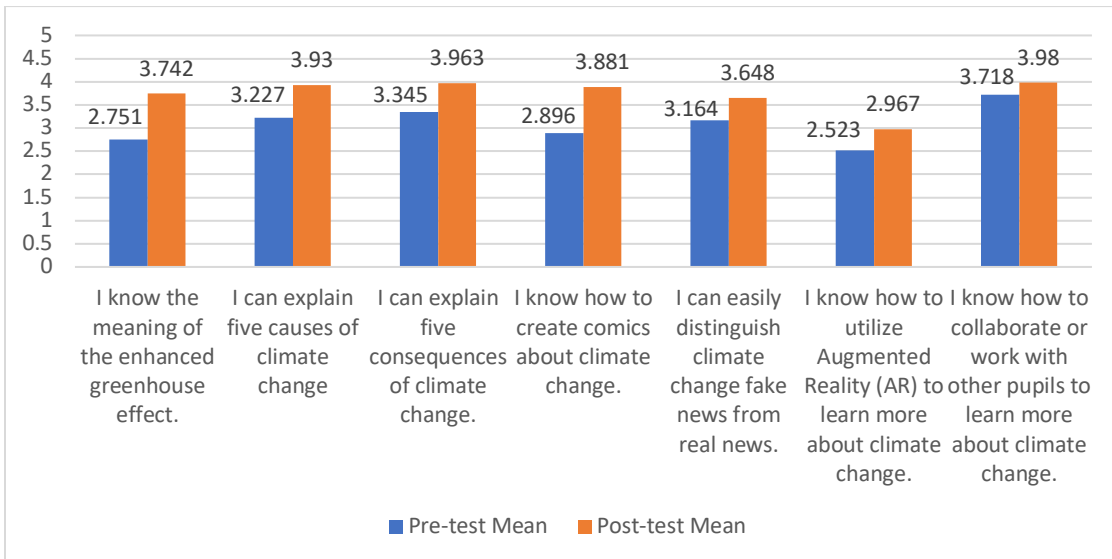
Students Combined: Pre-test and Post-test Results for Knowledge Questions (5-pt Likert Scale with 1=Strongly Disagree”

Survey Question	Survey Question Text	Pre-test Mean (1-5)	Post-test Mean (1-5)	Mean % Variation (M%V) (%)
Student Knowledge Q1	I know the meaning of the enhanced greenhouse effect.	2.751	3.742	26.483%
Student Knowledge Q2	I can explain five causes of climate change	3.227	3.930	17.888%
Student Knowledge Q3	I can explain five consequences of climate change.	3.345	3.963	15.594%
Student Knowledge Q4	I know how to create comics about climate change.	2.896	3.881	25.380%
Student Knowledge Q5	I can easily distinguish climate change fake news from real news.	3.164	3.648	13.268%
Student Knowledge Q6	I know how to utilize Augmented Reality (AR) to learn more about climate change.	2.523	2.967	14.965%
Student Knowledge Q7	I know how to collaborate or work with other pupils to learn more about climate change.	3.718	3.980	6.583%

Figure 1 demonstrates these results visually.

Figure 1

Students Combined: Pre-test and Post-test Results for Knowledge Questions



Students Combined: Attitude Questions

All the Attitude Questions (AQ) scored above the midpoint in the pre-test, with the highest score being for AQ1, “I believe climate change is real and dangerous” (X=3.934) (Table 3). The lowest mean was for AQ6, “I believe I am at great risk of being manipulated by climate change fake news” (X=3.030).

As with the Knowledge questions, **the mean response to the Attitude questions rose in every case between the pre-test and the post-test**, though some of the increases were small. The highest post-test score was for AQ1, “I believe climate change is real and dangerous” (X=4.270). The greatest difference between the pre- and post-test was for AQ2, “I believe I can have an impact on slowing climate change”, with an M%V of 13.099%.

Table 3

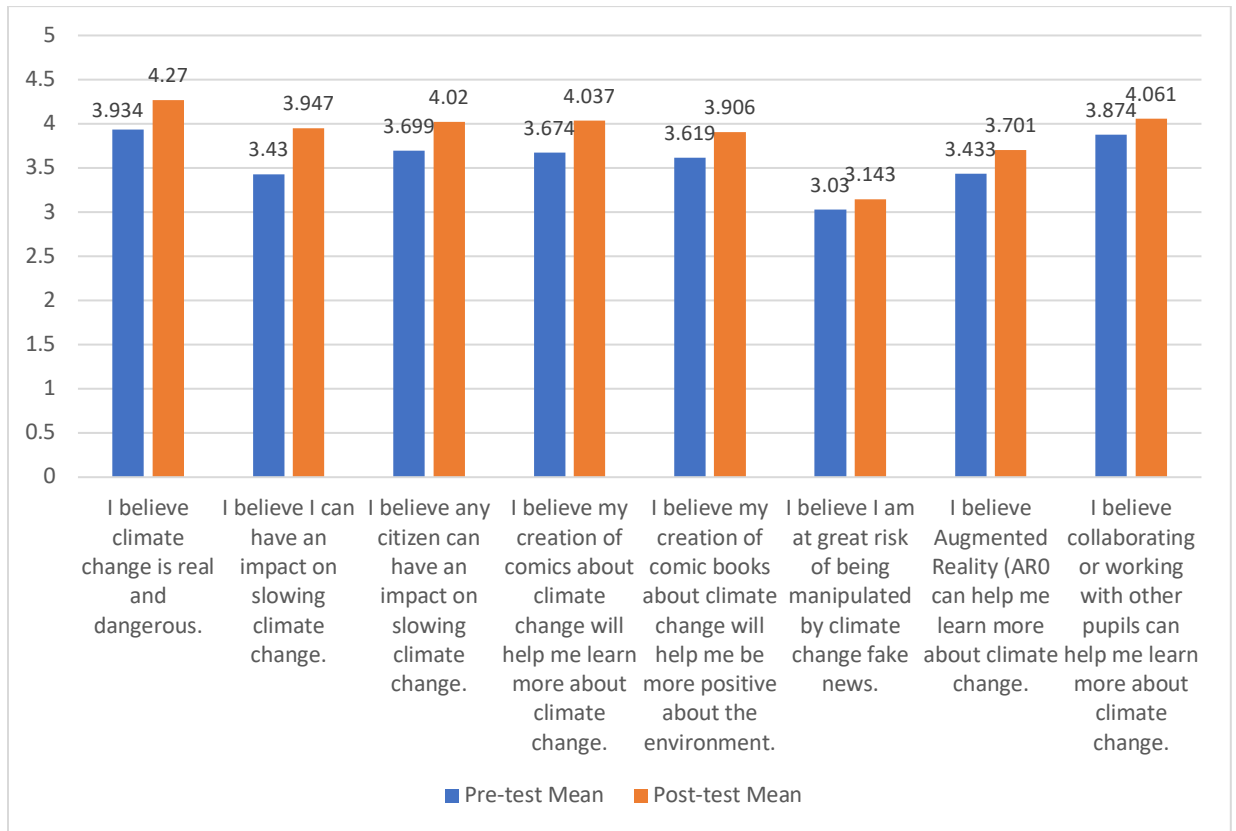
Students Combined: Pre-test and Post-test Results for Attitude Questions (5-pt Likert Scale with 1=Strongly Disagree”

Survey Question	Survey Question Text	Pre-test Mean (1-5)	Post-test Mean (1-5)	Mean % Variation (M%V)
Student Attitude Q1	I believe climate change is real and dangerous.	3.934	4.270	7.869%
Student Attitude Q2	I believe I can have an impact on slowing climate change.	3.430	3.947	13.099%
Student Attitude Q3	I believe any citizen can have an impact on slowing climate change.	3.699	4.020	7.985%
Student Attitude Q4	I believe my creation of comics about climate change will help me learn more about climate change.	3.674	4.037	8.992%
Student Attitude Q5	I believe my creation of comic books about climate change will help me be more positive about the environment.	3.619	3.906	7.348%
Student Attitude Q6	I believe I am at great risk of being manipulated by climate change fake news.	3.030	3.143	3.595%
Student Attitude Q7	I believe Augmented Reality (AR) can help me learn more about climate change.	3.433	3.701	7.241%
Student Attitude Q8	I believe collaborating or working with other pupils can help me learn more about climate change.	3.874	4.061	4.605%

Results are also presented in Figure 2.

Figure 2

Students Combined: Pre-test and Post-test Results for Attitude Questions (5-pt Likert Scale with 1=Strongly Disagree”



Students Combined: Behaviour Questions

The last set of multiple choice questions focused on participant behaviours in order to examine whether the CC lessons translated into behavioral changes that might have a positive effect on the environment.

In general, the pre-test average for Behaviour Questions (BQ) was lower than that of the other categories. On the pre-test, the average of five of the eight Behaviour questions was below “3”, the midpoint of the 1-5 Likert scale. The lowest initial score was for Behaviour Question 6 (BQ6), “I am actively using Augmented Reality (AR) to learn more about climate change”, with a pre-test mean of 2.493 on a scale of 5. Still, this score is high considering it is unlikely any of the students were actually using AR in any context let alone to learn about CC. The highest pre-test average was for BQ1(X=3.156), “I am actively engaging in ways to combat climate change by reducing my carbon footprint”. Still, this is only slightly above the Likert scale midpoint. The results are summarized in Table 4.

Table 4

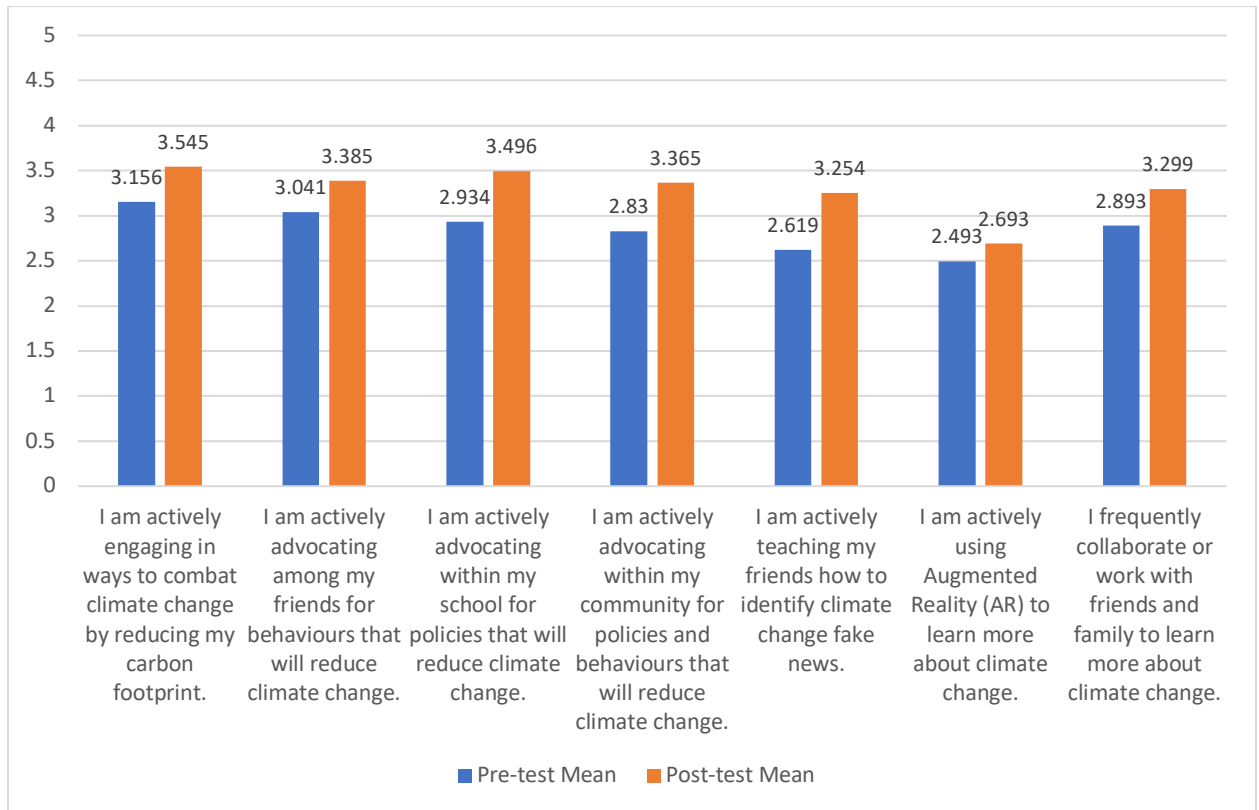
Students Combined: Pre-test and Post-test Results for Behaviour Questions (5-pt Likert Scale with 1=Strongly Disagree”

Survey Question	Survey Question Text	Pre-test Mean (1-5)	Post-test Mean (1-5)	Mean % Variation (M%V) (%)
Student Behaviour Q1	I am actively engaging in ways to combat climate change by reducing my carbon footprint.	3.156	3.545	10.973%
Student Behaviour Q2	I am actively advocating among my friends for behaviours that will reduce climate change.	3.041	3.385	10.162%
Student Behaviour Q3	I am actively advocating within my school for policies that will reduce climate change.	2.934	3.496	16.076%
Student Behaviour Q4	I am actively advocating within my community for policies and behaviours that will reduce climate change.	2.830	3.365	15.899%
Student Behaviour Q5	I am actively teaching my friends how to identify climate change fake news.	2.619	3.254	19.514%
Student Behaviour Q6	I am actively using Augmented Reality (AR) to learn more about climate change.	2.493	2.693	7.427%
Student Behaviour Q7	I frequently collaborate or work with friends and family to learn more about climate change.	2.893	3.299	12.307%

As with the Knowledge and Attitude questions, **in each case participants’ scores on the Behaviour questions increased in the post-test.** In the post-test, the mean for BQ6, the lowest initial score, increased to 2.693, though this is still below the midpoint of the scale. The average for BQ1, “I am actively engaging in ways to combat climate change by reducing my carbon footprint” which had the highest mean of 3.156 on the pre-test, increased to 3.545 on the post-test. Overall, the biggest changes as measured by M%V were in response to BQ5, “I am actively teaching my friends how to identify climate change fake news” (19.514% increase) and BQ3, “I am actively advocating within my school for policies that will reduce climate change.” (16.076% increase). The results are graphed in Figure 3.

Figure 3

Students Combined: Pre-test and Post-test Results for Behaviour Questions (5-pt Likert Scale with 1=Strongly Disagree”



Students Combined: Comparison of Survey Results by Category

Results of the Knowledge, Attitude, and Behaviour Questions can be compared by utilizing a Weighted Average (WAvg). This is calculated by summing up the mean value for each question in a specific category, and then dividing this sum by the number of questions in the category. This allows consideration of students’ average response to each group of questions. The results are summarized in Table 5.

Table 5

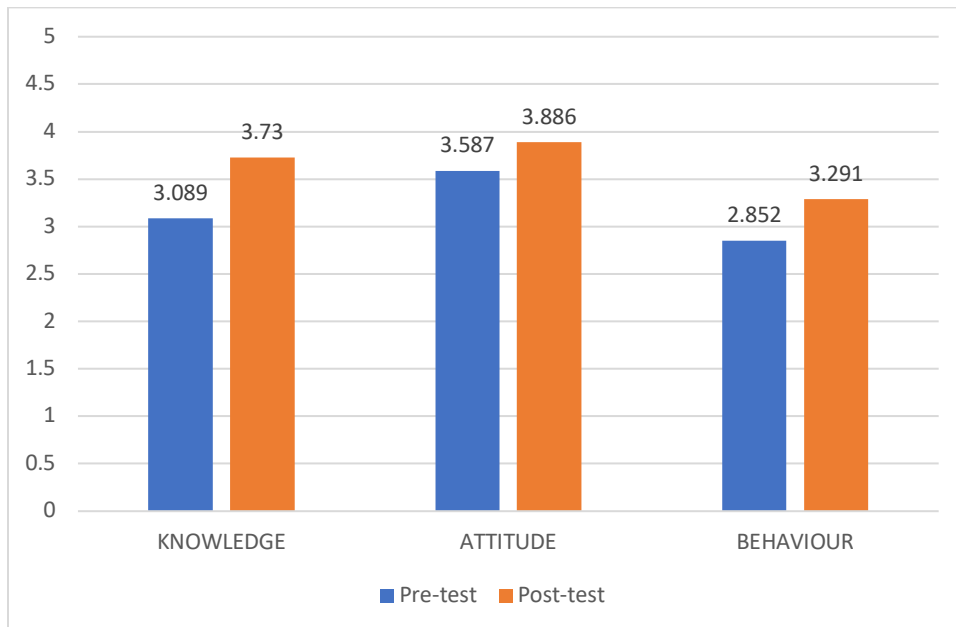
Students Combined: Weighted Averages of Pre- and Post-test Knowledge, Attitude, and Behaviour Question Sets

CC Latent Variable	Pre-Test WAvg	Post-Test WAvg	WAvg Variation (%)
KNOWLEDGE	3.089	3.730	17.185
ATTITUDE	3.587	3.886	7.694
BEHAVIOUR	2.852	3.291	13.339

For each category, the students’ average increased between pre- and post-test. Overall, the greatest gain occurred in the Knowledge question set, with an increase of 17.185%. The smallest gain occurred in the Attitude question set, with an increase of 7.694%; note that this set had the highest initial average, which could explain a lower gain in the post-test. The results are graphed in Figure 4.

Figure 4

Weighted Averages of Student Pre- and Post-test Knowledge, Attitude, and Behaviour Question Sets



Student Results from Spain Analysed Separately

As exactly the same 57 students responded to the pre-test and post-test in Spain, the Spanish data is analysed on its own to perform tests of significance. As with the combined data, the analysis includes three sets of questions: Knowledge, Attitude, and Behaviour. As the Likert scale data is ordinal, the Wilcoxon signed rank test is used to test the difference between the pre-test and post-test means.

Students from Spain: Knowledge Questions

Table 6 presents data from the Spanish student pre- and post-test on the Knowledge questions, including tests of significance. **For each question, averages increased between pre- and post-test.** Three of the questions were highly significant ($p < .001$): KQ1, “I know the meaning of the greenhouse effect”, KQ2, “I can explain five causes of climate change”, and KQ4, “I know how to create comics about climate change”. The remaining questions demonstrated an increase in knowledge in the post-test but were not statistically significant.

Table 6

Students from Spain: Pre-test and Post-test Results for Knowledge Questions (5-pt Likert Scale with 1=Strongly Disagree)

Survey Question	Survey Question Text	Pre-test Mean (1-5)	Post-test Mean (1-5)	Mean % Variation (M%V) (%)	W	P-Value
Student Knowledge Q1	I know the meaning of the enhanced greenhouse effect.	3.088	3.947	21.763	169.000	< 0.001
Student Knowledge Q2	I can explain five causes of climate change	2.982	3.842	22.384	161.500	< 0.001
Student Knowledge Q3	I can explain five consequences of climate change.	3.544	3.877	8.589	212.000	n.s. (0.079)
Student Knowledge Q4	I know how to create comics about climate change.	3.018	4.035	25.204	104.500	< 0.001
Student Knowledge Q5	I can easily distinguish climate change fake news from real news.	3.632	3.789	4.144	391.500	n.s. (0.607)
Student Knowledge Q6	I know how to utilize Augmented Reality (AR) to learn more about climate change.	2.807	3.175	11.591	265.500	n.s. (0.193)
Student Knowledge Q7	I know how to collaborate or work with other pupils to learn more about climate change.	3.526	3.825	7.817	297.000	n.s. (0.182)

Students from Spain: Attitude Questions

Among the attitude questions, **in each case the results of the post-test demonstrated students were more engaged with climate change issues after the lesson** (Table 7). However, only one question was statistically significant, AQ2, “I believe I can have an impact on slowing climate change” ($p=.037$). It is interesting to note that in the pre-test, AQ2 “I believe I can have an impact...” scored 3.579 on the Likert scale, below AQ3, “I believe any citizen can have an impact...”, which scored 3.842. However, in the post-test, AQ2 “I believe I can have an impact...” scored 4.000, above AQ3, “I believe any citizen can have an impact...” which

scored 3.860. It appears that after the lesson the students felt more empowered and able to make an impact than they believed others were likely to.

Table 7

Students from Spain: Pre-test and Post-test Results for Attitude Questions (5-pt Likert Scale with 1=Strongly Disagree”

Survey Question	Survey Question Text	Pre-test Mean (1-5)	Post-test Mean (1-5)	Mean % Variation (M%V) (%)	W	P-Value
Student Attitude Q1	I believe climate change is real and dangerous.	4.018	4.228	4.967	183.00	n.s. 0.189
Student Attitude Q2	I believe I can have an impact on slowing climate change.	3.579	4.000	10.525	133.00	0.037
Student Attitude Q3	I believe any citizen can have an impact on slowing climate change.	3.842	3.860	0.466	228.50	n.s. 0.941
Student Attitude Q4	I believe my creation of comics about climate change will help me learn more about climate change.	3.719	3.860	3.653	259.00	n.s. 0.497
Student Attitude Q5	I believe my creation of comic books about climate change will help me be more positive about the environment.	3.544	3.842	7.756	299.00	n.s. 0.196
Student Attitude Q6	I believe I am at great risk of being manipulated by climate change fake news.	3.053	3.368	9.353	315.50	n.s. 0.199
Student Attitude Q7	I believe Augmented Reality (AR) can help me learn more about climate change.	3.368	3.456	2.546	352.00	n.s. 0.789
Student Attitude Q8	I believe collaborating or working with other pupils can help me learn more about climate change.	3.754	3.895	3.620	181.50	n.s. 0.432

Students from Spain: Behaviour Questions

Table 8 summarizes results of the pre- and post-test behaviour questions administered to students in Spain. **In every case, self-report of behaviour related to managing climate change increased after the lesson.** Results were statistically significant for every question but BQ3, “I am actively advocating within my school for policies that will reduce climate change”. This suggests students felt more empowered within their personal community than within their school.

Table 8

Students from Spain: Pre-test and Post-test Results for Behaviour Questions (5-pt Likert Scale with 1=Strongly Disagree”

Survey Question	Survey Question Text	Pre-test Mean (1-5)	Post-test Mean (1-5)	Mean % Variation (M%V) (%)	W	P-Value
Student Behaviour Q1	I am actively engaging in ways to combat climate change by reducing my carbon footprint.	3.018	3.614	16.491	185.50	0.003
Student Behaviour Q2	I am actively advocating among my friends for behaviours that will reduce climate change.	2.965	3.509	15.503	214.50	0.012
Student Behaviour Q3	I am actively advocating within my school for policies that will reduce climate change.	3.404	3.579	4.890	219.00	n.s. 0.397
Student Behaviour Q4	I am actively advocating within my community for policies and behaviours that will reduce climate change.	3.018	3.421	11.780	149.50	0.029
Student Behaviour Q5	I am actively teaching my friends how to identify climate change fake news.	2.333	3.263	28.501	98.00	<.001
Student Behaviour Q6	I am actively using Augmented Reality (AR) to learn more about climate change.	2.579	3.123	17.419	219.00	0.044
Student Behaviour Q7	I frequently collaborate or work with friends and family to learn more about climate change.	2.737	3.474	21.215	201.00	0.003

Students from Spain: Comparison of Survey Results by Category

As with the five countries combined, the results of Spain's Knowledge, Attitude, and Behaviour Questions can be compared. The results are summarized in Table 9, including Wilcoxon score and probability level.

Table 9

Students from Spain: Weighted Averages of Pre- and Post-test Knowledge, Attitude, and Behaviour Question Sets

CC Latent Variable	Pre-Test WAvg	Post-Test WAvg	WAvg Variation (%)	W	p
KNOWLEDGE	3.228	3.784	14.693	275.00	<.001
ATTITUDE	3.610	3.814	5.349	550.00	n.s. (0.291)
BEHAVIOUR	2.865	3.426	16.375	323.00	<.001

All categories demonstrate an increase between pre- and post-test. As the data from Spain includes perfectly matched pairs for pre- and post-test, it was also possible to utilize inferential statistics utilizing a paired samples test to calculate significance. The categories of Knowledge and Behaviour demonstrate significantly higher averages between pre- and post-test, while the difference in the Attitude category, the highest overall, is not significant.

Results – Teacher Survey

A pre-test and post-test survey were administered to the teachers from all five countries that were involved in the project. The survey questions in many cases were identical to those asked of the students, but some demographic and content questions directed to the teacher role. Forty teachers from five countries completed the pre-test survey. Twenty-two teachers completed the post-test survey (Table 10).

Table 10

Teachers completing the Pre-test and Post-test in Five Countries

Country	Pre-test n	Post-test n
Croatia	6	3
Greece	13	9
Malta	14	4
Portugal	4	3
Spain	3	3
<i>Total</i>	<i>40</i>	<i>22</i>

As with the combined students, the numbers completing the pre-test were not identical to those completing the post-test, and therefore inferential statistical analysis could not be used. Instead, the data from all teachers is combined, with all the Knowledge questions, all the Attitude questions, and all the Behaviour questions considered individually and in sets. An analysis of the Teacher open-ended questions is not included here, but this information is incorporated informally in the pilot teacher reports.

Teachers Combined: Knowledge Questions

In the pre-test the average of each question except for one was above the midpoint of the 5-point Likert scale. The average response to KQ6, “I can utilize Augmented Reality (AR) to facilitate climate change pupil learning” was 2.925, very slightly below the midpoint of 3. The highest score on the pre-test was KQ3, “I can explain five consequences of climate change” (X=4.275), followed closely by KQ2, “I can explain five causes of climate change” (X=4.200) (Table 11).

Table 11

Teachers Combined: Pre-test and Post-test Results for Knowledge Questions (5-pt Likert Scale with 1=Strongly Disagree”

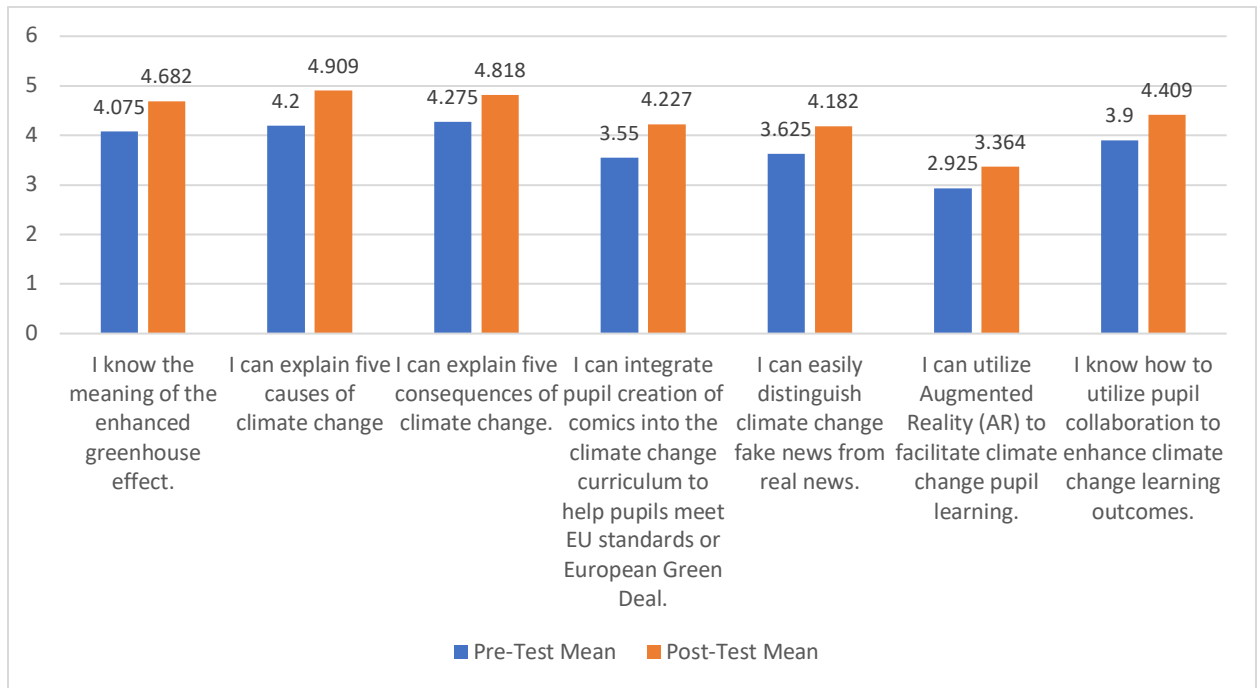
Survey Question	Survey Question Text	Pre-test Mean (1-5)	Post-test Mean (1-5)	Mean % Variation (M%V) (%)
Teachers Knowledge Q1	I know the meaning of the enhanced greenhouse effect.	4.075	4.682	12.965%
Teachers Knowledge Q2	I can explain five causes of climate change	4.200	4.909	14.433%
Teachers Knowledge Q3	I can explain five consequences of climate change.	4.275	4.818	11.270%
Teachers Knowledge Q4	I can integrate pupil creation of comics into the climate change curriculum to help pupils meet EU standards or European Green Deal.	3.550	4.227	16.016%
Teachers Knowledge Q5	I can easily distinguish climate change fake news from real news.	3.625	4.182	13.319%
Teachers Knowledge Q6	I can utilize Augmented Reality (AR) to facilitate climate change pupil learning.	2.925	3.364	13.050%
Teachers Knowledge Q7	I know how to utilize pupil collaboration to enhance climate change learning outcomes.	3.900	4.409	11.545%

As with the students, **each knowledge question for the teachers demonstrated a gain between the pre- and post-test.** The largest gain was for KQ4, “I can integrate pupil creation of comics into the climate change curriculum to help pupils meet EU standards or European Green Deal” (16.016%), demonstrating the impact of training on implementation on this critical program (European Commission, 2019). The smallest gain was for KQ3, “I can explain five consequences of climate change” (X=4.818, M%V = 11.270%); recall that this was the highest scoring question in the pre-test and therefore there was not much room for improvement.

These results are depicted in graph form in Figure 5 below.

Figure 5

Teachers Combined: Pre-test and Post-test Results for Knowledge Questions



Teachers Combined: Attitude Questions

Every one of the Attitude questions that teachers responded to averaged above 4 on the Likert scale on both the pre-test and post-test. This is the only set of questions for which this occurred. The lowest score was AQ7, “I believe Augmented Reality (AR) can help me learn more about climate change” (X=4.000), while the highest score was AQ1, “I believe climate change is real and dangerous” (X=4.775). Results are summarized in Table 12.

Table 12

Teachers Combined: Pre-test and Post-test Results for Attitude Questions (5-pt Likert Scale with 1=Strongly Disagree”

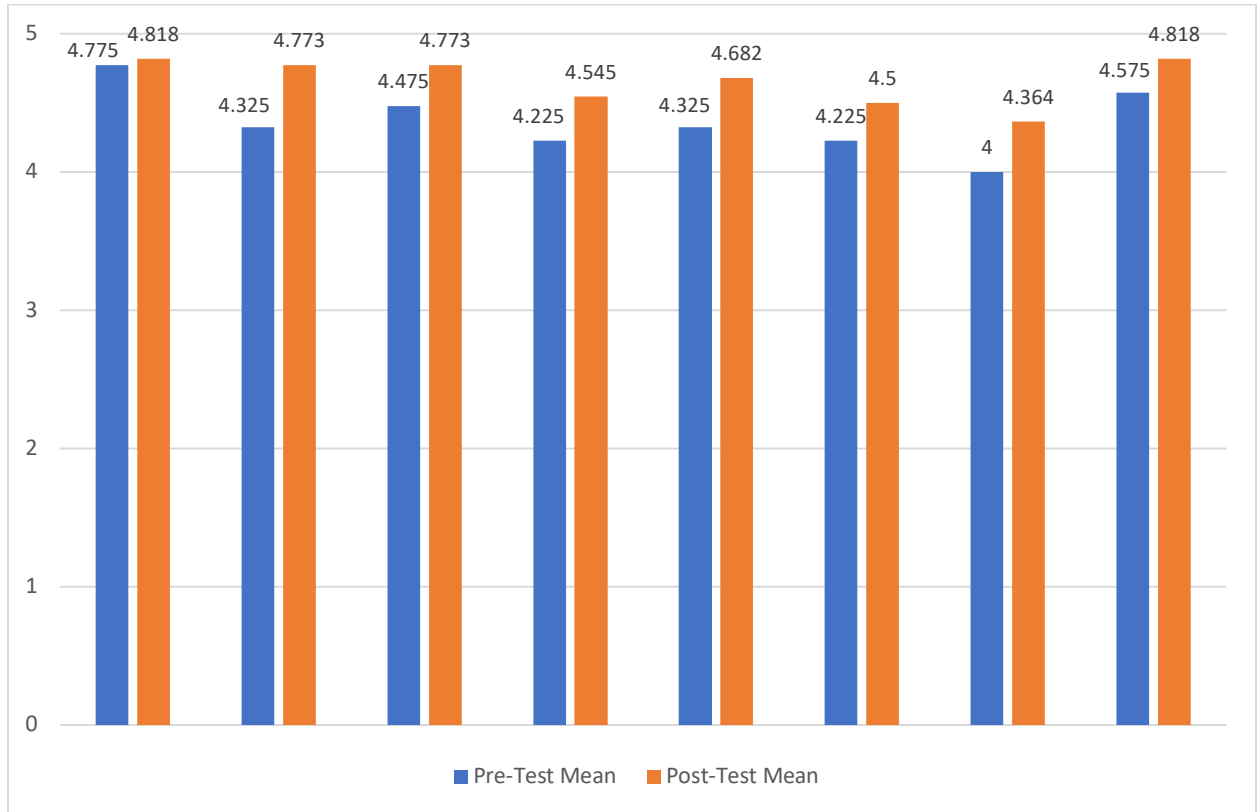
Survey Question	Survey Question Text	Pre-test Mean (1-5)	Post-test Mean (1-5)	Mean % Variation (M%V)
Teacher Attitude Q1	I believe climate change is real and dangerous.	4.775	4.818	0.892%
Teacher Attitude Q2	I believe I can have an impact on slowing climate change.	4.325	4.773	9.386%
Teacher Attitude Q3	I believe any citizen can have an impact on slowing climate change.	4.475	4.773	6.243%
Teacher Attitude Q4	I believe my creation of comics about climate change will help me learn more about climate change.	4.225	4.545	7.041%
Teacher Attitude Q5	I believe my creation of comic books about climate change will help me be more positive about the environment.	4.325	4.682	7.625%
Teacher Attitude Q6	I believe I am at great risk of being manipulated by climate change fake news.	4.225	4.500	6.111%
Teacher Attitude Q7	I believe Augmented Reality (AR) can help me learn more about climate change.	4.000	4.364	8.341%
Teacher Attitude Q8	I believe collaborating or working with other pupils can help me learn more about climate change.	4.575	4.818	5.044%

Scores for teachers increased on every attitude question in the post-test. Mean % Variation for the Attitude Questions is lower than for the other sets of questions since the averages are so high to begin with. The lowest gain was for AQ1, “I believe climate change is real and dangerous” (X=4.818, M%V = 0.892%). The biggest gain was for AQ2, “I believe I can have an impact on slowing climate change” (X=4.773, M%V = 9.386%).

Results are graphed in Figure 6.

Figure 6

Teachers Combined: Pre-test and Post-test Results for Attitude Questions



Teachers Combined: Behaviour Questions

In the pre-test Behaviour question set, teacher responses ranged from an average of 2.675 for BQ6 (“I am actively using Augmented Reality (AR) to facilitate climate change pupil learning”) to 4.150 for BQ2 (“I am actively advocating among my friends for behaviours that will reduce climate change”). Results are summarized in Table 13.

Average responses to each Behaviour question increased between pre- and post-test for the teachers. The highest score on the post-test was for BQ1, “I am actively engaging in ways to combat climate change by reducing my carbon footprint” ($X=4.500$). The next highest mean was 4.364, shared by BQ2 “I am actively advocating among my friends for behaviours that will reduce climate change” and BQ3 “I am actively advocating within my school for policies that will reduce climate change”. The questions with the greatest gain were BQ5 “I am actively teaching my pupils how to identify climate change fake news” ($M\%V = 18.699\%$) and BQ7 “I frequently implement pupil collaboration to enhance climate change learning” ($M\%V = 18.675\%$).

Table 13

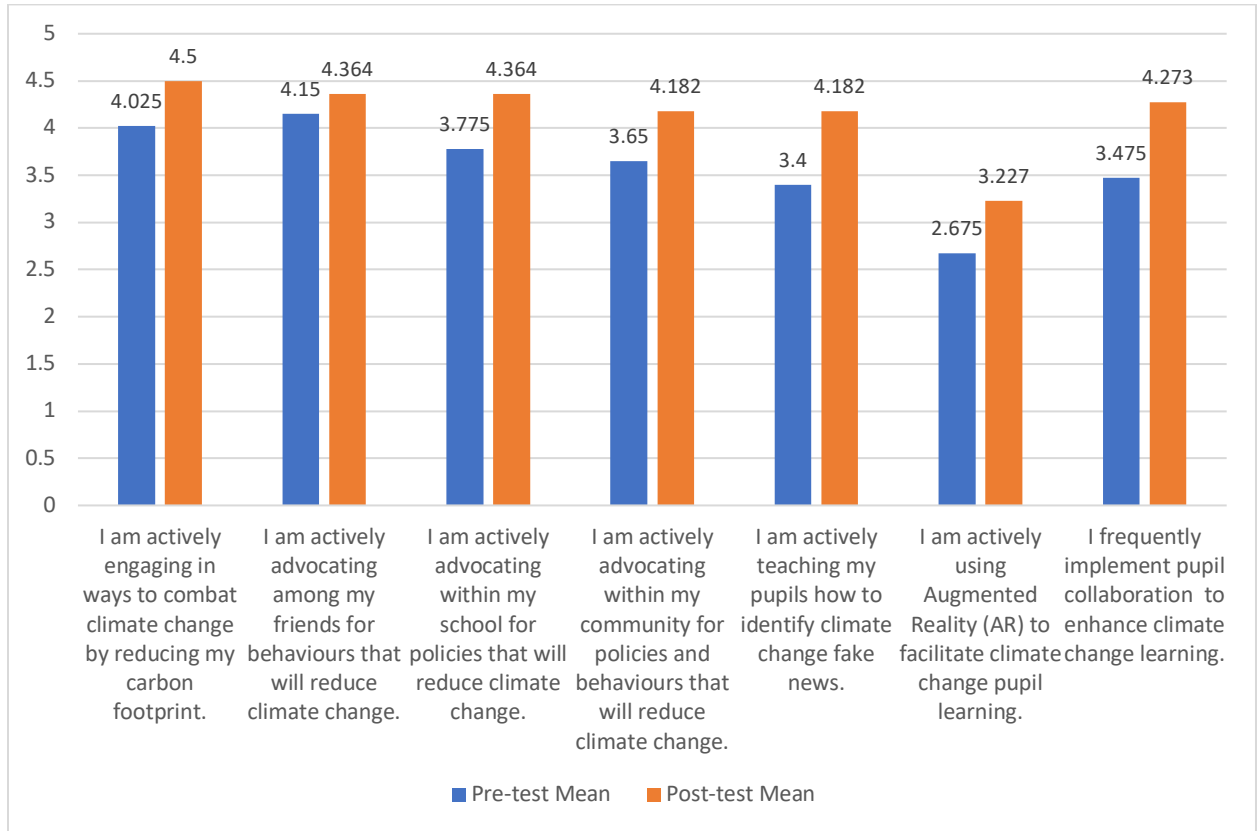
Teachers Combined: Pre-test and Post-test Results for Behaviour Questions (5-pt Likert Scale with 1=Strongly Disagree”

Survey Question	Survey Question Text	Pre-test Mean (1-5)	Post-test Mean (1-5)	Mean % Variation (M%V)
Teacher Behaviour Q1	I am actively engaging in ways to combat climate change by reducing my carbon footprint.	4.025	4.500	10.556%
Teacher Behaviour Q2	I am actively advocating among my friends for behaviours that will reduce climate change.	4.150	4.364	4.904%
Teacher Behaviour Q3	I am actively advocating within my school for policies that will reduce climate change.	3.775	4.364	13.497%
Teacher Behaviour Q4	I am actively advocating within my community for policies and behaviours that will reduce climate change.	3.650	4.182	12.721%
Teacher Behaviour Q5	I am actively teaching my pupils how to identify climate change fake news.	3.400	4.182	18.699%
Teacher Behaviour Q6	I am actively using Augmented Reality (AR) to facilitate climate change pupil learning.	2.675	3.227	17.106%
Teacher Behaviour Q7	I frequently implement pupil collaboration to enhance climate change learning.	3.475	4.273	18.675%

The results are graphed in Figure 7.

Figure 7

Teachers Combined: Pre-test and Post-test Results for Behaviour Questions



Teachers Combined: Comparison of Survey Results by Category

As with the Student data, the results of the Knowledge, Attitude, and Behaviour Questions are compared by utilizing a Weighted Average (WAvg), calculated by summing up the mean value for each question in a specific category, and then dividing this sum by the number of questions in the category. This allows consideration of teachers’ average response to each group of questions. The results are summarized in Table 14.

Table 14

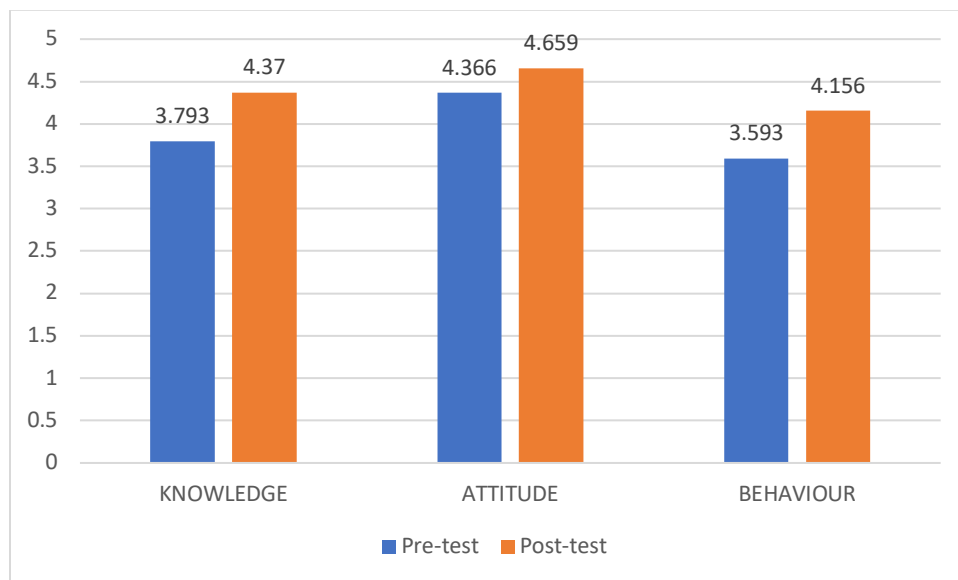
Teachers Combined: Weighted Averages of Pre- and Post-test Knowledge, Attitude, and Behaviour Question Sets

CC Latent Variable	Pre-Test WAvg	Post-Test WAvg	WAvg Variation (%)
KNOWLEDGE	3.793	4.370	13.204%
ATTITUDE	4.366	4.659	6.289%
BEHAVIOUR	3.593	4.156	13.547%

For each category, the teachers' average increased between pre- and post-test. Overall, the greatest gain occurred in the Behaviour question set, with an increase of 13.547%, followed closely by the Knowledge question set, with an increase of 13.204%. The smallest gain occurred in the Attitude question set, with an increase of 6.289%. Note however that, as with the student data, the Attitude set had the highest initial average, which could explain why the gain was lowest for this set in the post-test. The results are graphed in Figure 8.

Figure 8

Weighted Averages of Teacher Pre- and Post-test Knowledge, Attitude, and Behaviour Question Sets



Result Comparison – Student and Teacher Question Sets

In most cases, questions in the Student and Teacher question sets were identical, but in several cases, they differed as to perspective. For example, students were asked about their own use of tools to learn about CC while teachers were asked about utilizing tools to teach CC to students. As a result, rather than directly comparing each question, this analysis will directly compare the questions sets: Knowledge, Attitude, and Behaviour.

Table 15

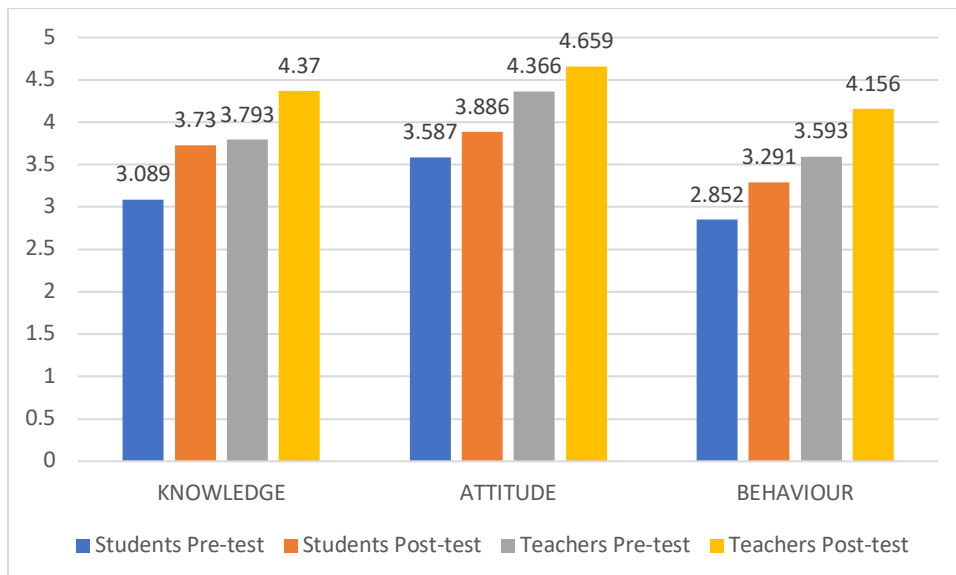
Comparison of Students and Teachers: Weighted Averages of Pre- and Post-test Knowledge, Attitude, and Behaviour Question Sets

Question Set	Students		Teachers	
	Pre-test	Post-test	Pre-test	Post-test
KNOWLEDGE	3.089	3.730	3.793	4.370
ATTITUDE	3.587	3.886	4.366	4.659
BEHAVIOUR	2.852	3.291	3.593	4.156

These results summarize the effectiveness of the lessons for both the Student and Teacher groups. For each group, on each question set, the average of the post-test exceeded that of the pre-test. It is also possible to see that for each question set, while the average of the Student post-test increased from that of the pre-test, it still fell below the average of the Teacher pre-test. For example, for the Knowledge question set, the Student post-test average was 3.730, while the Teacher pre-test average was 3.793, rising to 4.37 on the post-test. Results are graphed in Figure 9.

Figure 9

Comparison of Students and Teachers: Weighted Averages of Pre- and Post-test Knowledge, Attitude, and Behaviour Question Sets



Conclusions

For both Students and Teacher groups, for each Knowledge, Attitude, and Behaviour question and for each question set, there was an increase in desired response between the pre-test and post-test. This suggests that **the teacher training and student lessons were effective in increasing student knowledge, attitudes, and behaviour with respect to climate change.**

Logistical challenges during the pilot suggest simplifying some procedures for large scale implementation. It will not be necessary, for example, to require administration of a pre-test since the results of the pilot are sufficient to demonstrate the effect of the treatment.

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