Investigating Climate Change through Argumentation:

Purposeful Questioning Supports Argumentation and Knowledge Acquisition

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Abstract

Over several weeks, 125 young adolescents engaged deeply with the topic of climate change in a discourse-based program designed to build argumentation skills. We put to a test the hypothesis that information on this complex and critical topic is best acquired and made use of in argument if acquiring it is experienced as having purpose and able to fulfill a role in argument. Activities in an experimental condition followed the program's practice of making available topic-related information in the form of brief Q&As on an as-requested basis. Offered to them as a potential resource in peer dialogs on the topic, throughout the activity participants selected questions they wished answers to, and these were provided. Students in a comparison condition followed the traditional classroom practice of being assigned to read an introductory text as background information on the topic. It contained information identical to that in the Q&A cards experimental group participants chose to access. In both conditions, all information remained available once accessed. Both groups benefited in knowledge gain, as well as skill development in coordinating evidence with claims in final essays. But the experimental group showed greater knowledge as well as skill gain, a difference we suggest is attributable to the knowledge gained having an anticipated purpose making them more likely to make use of it.

Key words: learning; knowledge acquisition; climate change; discourse, argument, writing

Public significance statement

These findings suggest that information is best acquired and made use of in reasoned argument if acquiring it is sought and experienced as having purpose, compared to passive receipt of the same information in the form of traditional required "prior reading" text.

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Suppose your objective is to make young adolescents aware and informed about an issue of broad, global impact, one serious enough to warrant concerted attention by experts and laypeople alike – an issue, say, such as global food supply, nuclear threat, or climate change. Yet thinking deeply about the issue demands some basic technical knowledge. How would you undertake to provide a new generation with a minimum knowledge base that can lead the way to lifetime awareness of and commitment to the issue? Assume you have the time and funds to undertake this goal and the issue is climate change, a topic that requires some amount of factual knowledge if discussion of the topic is to be productive. To secure its attainment, what instructional method should you employ with an available group of average young adolescents – those of the generation who will inherit the climate change problem and its consequences? You are skeptical about the effectiveness of traditional methods of conveying factual information such as lecture or assigned reading. In the case of climate change, you might instead develop an engaging multi-media narrative with vivid graphics and voice over, perhaps employing a fear tactic emphasizing likely consequences of inaction. Would you be confident in predicting a lasting effect?

Here, we put to rigorous test a different hypothesis as to what will make factual knowledge stick. A powerful factor, we propose, in acquiring, retaining, and making use of knowledge is whether learners anticipate how they will use this knowledge, which we claim they will do because they have requested it and as a consequence see its potential value. To test this hypothesis, we engaged fifth and sixth graders in a student-to-student argumentation skill

development program (Crowell & Kuhn, 2014; Iordanou & Kuhn, 2019; Kuhn et al., 2008; Kuhn & Crowell, 2022; Kuhn et al., 2017; Kuhn, 2018) for a summary description and review of the program see Rapanta & Felton, 2022, or Iordanou, K., & Rapanta, 2021). In the present study, students' debate addressed a complex topic, climate change.

Especially for a topic as complex as the present one, it was essential that students have access to basic information related to the topic to inform their discourse. Previous research has established that students can gain both topic knowledge and argumentation skill in the context of a single well-designed intervention (Asterhan & Schwarz, 2016; Iordanou et al., 2019; Larrain et al., 2021). Yet we have not previously put to experimental test our program's practice, followed here, of making available topic-related information in the form of answers to questions that participants themselves request during their discourse. Because they have requested it, we have proposed, they see its potential value, anticipating how they might use it in pursuit of specific argumentation goals.

In a comparison condition, in contrast, participants were assigned to read a text containing information identical to that experimental group participants could choose to access. Across conditions, once accessed, the information remained equally and readily at hand and available for use.

The rationale underlying the study design thus has roots that go back as far as Piaget's (1929) constructivist model, and, in more contemporary form, active learning theory (Chi, 2021), which stipulates that active learning goes beyond simply paying attention and requires the learner's active participation if learning is to occur. The present study also connects to recent work recognizing the important role of questioning in cognitive development (Kuhn et al., 2020; Butler & Ronfard, 2020).

In sum, the research question, and hypothesis to be tested in the present study, is whether purposeful questioning, compared to prescribed reading of the same information, will enhance acquisition of needed knowledge and its subsequent use in argumentation.

Learning to Argue and Learning Through Arguing

Also central to the present work is commitment to the value of discourse-based learning (Asterhan & Schwarz, 2016; Kuhn, 2019). Argumentation skills are increasingly recognized as critical intellectual tools in state and national standards, across the curriculum in both science and humanities and as preparation for informed participatory citizenship. Yet argumentation skills are weak across age levels, whether assessed verbally or in writing (Kuhn, 1991; Gilbert & Graham, 2010) and serious public discourse is at a record low level, largely confined to echo chambers dominated by sound bites and slogans (Barbera et al., 2015).

The present study is situated in a line of work aiming to develop skills of argument, both dialogic and individual, primarily among young adolescents (for review, see Iordanou & Rapanta, 2021). Students of all levels from early elementary through post-secondary are known to perform poorly on assessments of expository writing in which they are asked to make an argument in support of a claim (Graham & Rijlaarsdam, 2016). The most basic skill in this respect is to advance a claim that is coordinated with evidence that can function to support (or weaken) it.

In an extended line of research, we, along with others (De La Paz, Butler, Levin, & Felton, 2024; Larrain et al. 2021, Matos, 2021; Rapanta, 2021; Resnick et al., 2018; Shi, 2019; Weinstock, 2005) have shown that dense engagement in argumentation is a facilitative condition for development of evidence-based argumentation skills (Kuhn & Moore, 2015). Our approach

has roots not only in Piaget's constructivism but equally in the sociocultural theory of Vygotsky (1978, 1987), and other contemporary socioculturalists (Resnick et al., 2010; Reznitskaya et al., 2001; Scribner & Cole, 1981). The everyday social practice of argumentation serves as a starting point and pathway in the development of individual argumentation skills. In Vygotsky's terminology, the intermental with practice is internalized and transformed into the intramental. The philosophical foundations of our work draw foremost on the dialogic approach of Walton (1989).

Central to our particular dialogic approach to developing argument skill is to engage students repeatedly in rich and extended peer dialogs on significant and cognitively demanding issues that they likely have existing opinions about but not necessarily deep knowledge. Our view of dialog is thus as communication with (actual or envisioned) others, instead of simply as talk. This communication is purposeful, interactive, and allows meta-communication, that is, reflective communication about the dialog in addition to engagement in the dialog itself. With extended practice, more advanced argumentation strategies of counterargument, rebuttal, integration, and weakening as well as supportive use of evidence are mastered and come to be used more consistently. These stronger strategies gradually come to dominate weaker ones, a process demonstrated in much microgenetic research (Kuhn, 1995; Siegler, 2006). The general idea behind microgenetic studies of cognitive skill development is that dense engagement and practice over an extended period will accelerate the development of an otherwise naturally occurring process, thereby allowing the researcher to gain better understanding of the process. In argumentation, microgenetic research demonstrates that with consistent practice, advanced argumentive skills such as counterargument develop gradually, along with meta-strategic understanding — of when and why to use strategies — and epistemic understanding – of

disposition to engage in argumentation and one's epistemic standards of what constitutes persuasive evidence for belief adoption and revision (Iordanou, 2022; Kuhn et al., 2008). The co-development of meta-level understanding along with argumentation skills at the procedural level highlight the central role of metacognition in the development of argumentation skills (Iordanou, 2022).

The approach centers around electronic student-to-student dialogic argumentation, which serves as a path to the development of skill in individual written argument. Students choose sides on a topic and then engage in electronic dialogs regarding the issue with a rotating series of peers from an opposing team who favor the contrasting position. The written format provides a record that externalizes thought into tangible, retrievable form and supports reflection on what has been said. The written record of the dialog thus has the potential to become the object of various reflective activities. The rounds of dialog culminate in preparation for and implementation of a final live debate between the two teams, followed by debrief review and evaluation of each team's performance, and finally a culminating individual essay on the topic that each student writes.

A strength of the program is that it engages young adolescents in direct debate with one another, one-on-one or at most two-on-two, decentering the teacher as the channel through which discourse flows. Students quickly come to recognize that they are responsible for addressing one another's claims, drawing on evidence and arguments to support and challenge them. Equally important, students are "on duty" 100 % of the time. They cannot relax into the passive listener role frequent in whole-class discussion. The teacher meanwhile relinquishes a role of authority as the source of knowledge and replaces it with shared construction of meaning and another basis for authority – that of evidence and argument. Another feature is that students engage deeply

with the topic, over successive occasions. Because these dialogs take place electronically, they provide a record that promotes subsequent reflection (Iordanou, 2022). Through sustained engagement and practice, students gain an increasing sense of responsibility to one another. They come to embrace and uphold norms of discourse (Zillmer, 2016; Iordanou, 2022) beginning with close listening and relevant responding – that this responsibility entails. Claims are expected to have reasons and these must stand to the challenge of strong argument and evidence that may weaken them. In time, students come to feel the empowerment of entering into a community of discourse, coming to recognize and value the purpose and power of authentic discourse as worth the investment and energy it entails.

Methods

Participants

A total of 125 fifth and sixth grade primary school students (61 female) from two urban schools having similar characteristics participated in the study. The sample comprised three classes of fifth graders from one school and three classes of sixth graders from the other school. Ages ranged from 11-12 yrs. Students were largely from middle-class families and within an average range of ability and academic achievement typical for these schools. Ethics approval from the Cyprus National Bioethics Committee and Ministry of Education has been secured, as well as written parental consent.

Participants were assigned at the class level randomly to experimental and comparison conditions. Four of the six participating classes, two 5^{th} grade and two 6^{th} grade classes (n=78), were assigned to the experimental condition and two to the comparison condition.

Design

The study was designed to address the previously stated research question: Does purposeful questioning, compared to prescribed reading of the same information, enhance acquisition of needed knowledge and its subsequent use in argumentation?

Students were able to choose their own initial positions on the specific topic involving climate change: that educating people about the issue versus charging a high tax on purchase of fuels that contribute to the problem is the better way to address the problem of climate change. The core activity of the intervention was a series of electronic dialogs conducted in same-side pairs with classmates who held the opposing position. Direct student-to-student interaction in these dialogs promoted students connecting directly to opponents' statements; additional activities provided opportunities to review and reflect on the dialogs and the respective positions. Purposefulness of the activity was promoted in both conditions by means of framing it as preparation for a final live "Showdown" debate.

Experimental and comparison groups differed only with respect to how that information was made available. In the comparison condition, students were first asked to read a short, printed text (see Appendix). They were told the information would be important in the activities to follow, but were not told how. They were given as much time as they wished to read the text, which then remained readily accessible.

In the experimental group, periodically during their dialogs same-side student pairs were invited to choose, from a list of possible questions, one the answer to which they thought could prove useful to them in their argumentation. A set of 34 cards were available. Each had a question visible on one side of the card and a brief answer to it on the reverse side. Cards were balanced as to which option (education vs. tax) the question primarily concerned (see Appendix). Collaborating same-side pairs were able to choose up to six new cards at a time and reveal their

answers. Once chosen, the cards accumulated and remained readily accessible. By the end of the intervention, students in the experimental condition had available the same information as did students in the comparison condition in the form of a printed text.

A primary outcome variable assessed at the conclusion of the intervention was the extent of participants' knowledge regarding climate change and its remedies. In addition, but of critical interest, in order to assess the extent to which participants in the two conditions may have gained differentially in argumentation skill, in particular the key skill of coordinating claims and evidence, they were asked to write an individual essay at the conclusion of the intervention. In addition to the climate change topic, a new topic was added to this assessment – Whether adolescents who commit serious crimes should be dealt with in a juvenile court system or the adult court system. In assessing argument skill, the new topic remedies a potential confound with differential knowledge gain across conditions in the climate change topic.

Procedure

The intervention took place during 12 ninety-minute sessions occurring twice per week over a period of six weeks.

The initial scenario presented, in both conditions, was the following:

> Scientists have observed Earth's surface is warming. Many of the warmest years on record have happened in the past 20 years. This is called Climate Change. Carbon dioxide, which is released in the atmosphere when burning some fuels, is the largest contributor to global warming. As a result of climate change ice is melting, sea levels are rising, and plants and animals are in danger. European Union is considering different

ways to deal with climate change. Some policy makers suggest to educate people about the dangers of climate change. They suggest that when individuals learn about the issue, they will care more about it and want to do something. Some other policy makers suggest charging a high tax on purchase of fuels that contribute to the problem. They believe that individuals will consume less of those fuels; therefore, this would be an efficient way to deal with the problem. What should happen? Is climate change best reduced by educating people about its dangers or by charging a high tax on purchase of fuels that contribute to the problem?

Initial assessment

Participants' topic knowledge and argumentation skills were assessed at both initial and final assessments, prior to and subsequent to the intervention. Initial topic knowledge was assessed to establish there were no significant differences between the two conditions (see Results section for details). Also, participants and school classes were added as random effects in glmm models in analyses.

Knowledge. At the initial assessment, participants were presented an open-ended question asking them to write what they knew about climate change, in particular if there are any risks and what those risks are. Responses were coded based on the number of relevant pieces of information provided. Participants received a score of 0 if they did not report any relevant piece of information or if they said that they didn't know about the issue and one point for each new piece of knowledge they reported. Random selection of 25% of students' responses were rescored by an independent rater, resulting in a 93% agreement. Disagreements were resolved through discussion.

Argumentation skill. In addition to assessing knowledge, students' argument skill was assessed, to investigate the possibility that deeper knowledge acquisition would enhance argumentation skill, specifically with regard to coordination of evidence with claims.

Participants were also asked to write an essay to support the position they had chosen as the better one on the climate change topic– education vs. tax. They were instructed to "Write the argument you would make to someone who didn't agree that your position is the better one."

Final assessment

Knowledge. To assess participants' knowledge following the intervention, an instrument was used that paralleled the 34-item body of information students were exposed to during the intervention. Half of the items were in multiple-choice format and the other half short-answer questions. Each test item corresponded to a Q&A provided to the experimental group during the intervention or a parallel text sentence in the passage read by the comparison group (see Appendix). Cronbach's alpha was .824, which indicates a high level of internal consistency. A participant received one point for every correct answer, receiving a score ranging from zero to 34. For the short open-ended questions, participants received half credit if the answer was correct but incomplete.

Argumentation skill. At the final assessment, participants were again asked to write an essay to support the position they had chosen as the better one on the climate change topic– education vs. tax.

Included at the final assessment was an assessment of argumentation skill not only on the climate topic but also on a new topic. If the experimental group had accumulated a greater amount of represented knowledge on the climate topic, this could advantage argumentation skill.

The new topic on which participants were asked to write was whether teenagers who commit serious crime should be served by a court just for juveniles or by a regular adult court. Participants were instructed to try to give as full an idea of the issue as they could for someone who has not thought about the topic. Information, in the form of 10 pieces in Q&A format relevant to the topic were made available (for example, Q: "How does a juvenile court system differ from a regular one?"; A: "The judges and staff in a juvenile system are specially trained to deal with young people in trouble. Punishments tend to be less severe and sentences shorter in juvenile court."), with the instruction that participants could make use of this information if they wished but were not required to do so.

Essay coding

One of the authors and another coder, blind to condition and time (by covering students' names and date from the essays), segmented into idea units and coded the essays participants wrote on intervention and transfer topics. Inter-rater reliability on segmenting and coding was achieved on a subset of 25% of units with 92% agreement for segmenting and Cohen's kappa .90 (p<.001), for coding. Differences were resolved by discussion and one of the authors proceeded with segmenting and coding the remaining essays, again blind to condition and time. To assess use of knowledge claims as evidence, we sought statements that offered an explicit or implicit answer to the question "How do you know?" and were at least potentially empirically verified or verifiable, in which case they were coded as evidence. For further analyses, we included only segments that included a claim and evidence. If a participant cited a piece of information, either from the Q&A items or other evidence known to them, without connecting it to any claim, these were coded as nonfunctional units and were not included in the data analysis. Units that

contained a claim and accompanying evidence used to support (or weaken) it, were classified as functional units. These were further classified as serving one of four functions, using a previously reported coding scheme (Kuhn et al., 2016) based on the rationale that skilled argument requires attention to all four potential argument functions (support-own, weaken-other, support-other, weaken-own).

Transparency and Openness

The data are available upon request from the authors.

Results

Prior knowledge

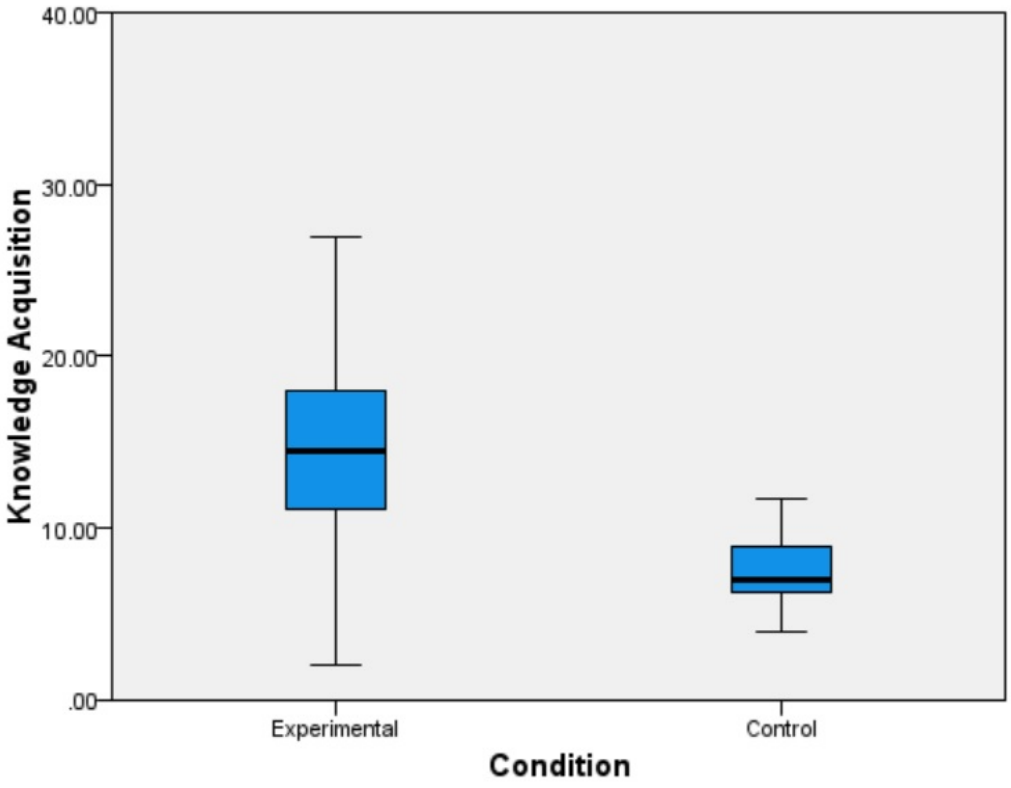
Participants' responses to the initial open-ended knowledge assessment showed them able to report little knowledge on the topic. Number of items generated ranged from 0 to 6 in the comparison condition and 0 to 7 in the experimental condition. Scores were normally distributed and no outliers identified. There was a nonsignificant difference between the prior knowledge scores of the experimental (M=2.60, SD=1.71) and the comparison condition (M=2.43, SD=1.70), $t(98)$=.45, p=66. The most popular pieces of knowledge provided were that "exhaust fumes cause climate change" and "glaciers are melting as a result of climate change". Very few students noted the greenhouse effect (n=3) and some of them refer to recycling as a possible solution. None of the students mentioned education or tax on carbon as measures to deal with climate change.

Knowledge acquisition

Final knowledge scores were normally distributed, with one outlier identified. Analyses were conducted with and without the outlier and the results were equivalent. Below the results are reported with the whole dataset (with 'outlier'). At the final assessment, there was a significant difference in knowledge achievement scores between the two conditions, $t(103)=7.04$, $p<.001$. As seen in Figure 1, the experimental condition outperformed the comparison condition, receiving a score twice as high ($M=15.38$, $SD=5.96$) as the comparison condition ($M=7.77$, $SD=3.40$). The majority of the comparison condition students (71.4%) received scores in the lowest quartile, with only a small percentage of experimental condition (7.8%) scores falling in that low range.

Figure 1

Final Knowledge Scores by Experimental and Control Condition



Climate change essays

To assess the extent to which essays differed across conditions, in particular with respect to the use of acquired knowledge as evidence in the essays, we performed generalised linear mixed effects models (GLMM) with the Poisson family using the glmer function from the 'lme4 package (Bates et al., 2015) in R (v4.2.1.; R Core Team 2020). We examined main and interactive effects of Condition and Time on number of idea units contained in students' essays, number of evidence-based idea units, and number of functional evidence-based idea units, including different types of these, using a separate model for each outcome. Condition (experimental vs. comparison) and Time (initial v final assessment) were added as fixed effects and participants and school classes with varied intercepts were added as random effects in each model. Pairwise comparisons were performed between the levels of predictors, controlling for multiple testing using the Bonferroni method, using the pairs function from the emmeans package (Lenth, 2020). Assumptions for the GLMM were examined using simulated residuals analysis indicating no significant influential outliers in the model nor evidence of overdispersion.

As seen in Table 2, there was a main effect of Time for all outcome variables, with students in both conditions performing better at the final assessment compared to the initial assessment (see condition means in Table 1). However, Time X Condition interaction was also significant for all outcome variables, showing that the gains exhibited by the experimental condition were greater than those of the comparison condition. Essays in the experimental condition included twice as many evidence-supported idea units as did essays in the comparison condition. This was also the case for the more advanced argumentive strategy of using evidence to weaken other's position.

Table 1

Means (and Standard Deviations) of Idea Units, Evidence, Functional Evidence, Support-own and Weaken-other Functional Types Contained in Intervention Topic Essays at Initial and Final Assessment by Condition

	Experimental condition means		**Comparison condition means**	
	Initial (SD)	**Final (SD)**	**Initial (SD)**	**Final (SD)**
Idea units	2.59 (1.33)	6.88 (3.29)	2.67 (1.09)	4.27 (2.18)
Evidence	1.04 (.98)	4.11 (2.97)	1.23 (.90)	2.20 (1.42)
Functional evidence	1.03 (.97)	3.88 (2.95)	1.23 (90)	2.10 (1.32)
Support-Own units	.77 (.86)	2.03 (1.64)	.97 (.81)	1.33 (.84)
Weaken Other units	.23 (.48)	1.45 (1.49)	.30 (.47)	.70 (.95)

Table 2

Main and Interaction effects of Condition and Time on Number of Idea Units, Evidence, Functional Evidence, Support-own and Weaken-other Units Contained in Intervention Topic Essays

	Time			**Condition**			**Time X Condition**		
	IRR	**Sig.**	**95% CI**	**IRR**	**Sig.**	**95% CI**	**IRR**	**Sig.**	**95% CI**
Idea units	2.12	< 0.001	1.82 - 2.48	1.32	0.05	1.00 - 1.76	1.56	0.005	1.15 - 2.13
Evidence units	2.85	< 0.001	2.27 - 3.58	1.32	0.34	0.75 - 2.31	2.10	0.001	1.33 - 3.31

Functional evidence units	2.74	< 0.001	2.17 - 3.44	1.27	0.45	.69 - 2.34	2.17	0.005	1.37 - 3.44
Support-Own units	2.05	< 0.001	1.56 - 2.69	1.17	0.55	.69 - 1.98	1.77	0.040	1.03 - 3.07
Weaken-Other units	3.79	< 0.001	2.41 - 5.97	1.60	0.30	.65 - 3.91	3.06	0.016	1.24 - 7.59

Transfer topic essays

To examine whether any gains in the ability to coordinate claims and evidence transferred to a new topic, an independent-samples t-test was conducted between conditions on final assessment essays on the transfer topic. The data were normally distributed and there were no outliers in the data.

Idea units. The number of idea units in the experimental condition (M=5.59, SD=2.84) was greater than the number in the comparison condition (M=3.79, SD=1.19), a statistically significant difference of 1.80, 95% CI [.889 to 2.702], $t(92)=3.94$, $p<.001$. The effect size for the difference between the conditions was calculated using Cohen's d, resulting in a value of 2.6, 95% CI% [.278 to 1.105], which is considered a large effect size.

Evidence. Results were similar when we considered only evidence-based idea units. The experimental condition produced several times more evidence-based idea units (M=4.13, SD=2.53) compared to the comparison condition (M=1.44, SD=1.44), a statistically significant difference of 2.69, 95% CI [1.937 to 3.437], $t(102)=7.11$, $p<.001$, with a large effect size of Cohen's d=2.26, 95% CI [.755 to 1.620].

Functional evidence-based units. Turning to our key outcome variable, functional evidence-based idea units, an independent-samples t-test showed the experimental condition outperformed (M=3.62, SD=2.42) the comparison condition (M=1.06, SD=1.10), a statistically

significant difference 2.56, 95% CI [.333 to 1.896], $t(110)=7.68$, $p<.001$, with a large effect size, Cohen's $d=2.12$, 95% CI [.773 to 1.639].

Support-Own units. Functional evidence-based units which function to support one's position were more prevalent among the experimental condition ($M=2.10$, $SD=1.58$) than among the comparison condition ($M=.85$, $SD=.99$), a significant difference 1.25, 95% CI [.761 to 1.738], $t(96)=5.08$, $p<.001$. The effect size for the difference between the conditions was Cohen's $d=1.43$, 95% CI [.456 to 1.294], which is considered a large effect size.

Weaken-Other units. Addressing and weakening other-side arguments is a bigger challenge for students than building their own-side arguments, and many do not attempt to do so. Comparing the two conditions in the more skillful strategy of using evidence to weaken other's position, the experimental condition showed consistently, greater performance compared to the comparison condition, with a mean usage of 1.15 ($SD=1.02$) compared with the comparison condition's mean usage of .29 ($SD=.58$), a statistically significant difference, .86 95% CI [.558 to 1.162], $t(102)=5.64$, $p<.001$, with large effect size, Cohen's $d=.91$, 95% CI [.521 to 1.356]. Overall, although both conditions showed gains in their evidence-claim coordination, the experimental condition outperformed the comparison condition on both intervention and transfer topics. Notably, the experimental condition showed comparable performance in the transfer and the intervention topics, for example the mean of functional evidence used in the climate change topic was 3.88 ($SD=2.95$) and in the transfer topic was $M=3.62$ ($SD=2.42$). The ability of the experimental condition to show almost perfect transfer to a novel topic, shows the level of mastery they achieved not only in acquiring knowledge but in using newly acquired knowledge functionally to support their arguments.

Qualitative Data on Students' Use of Requested Information in Argumentation

In this section we provide illustrations from their dialogs to show how students made use of information requested and received via the Q&A cards as evidence in their argumentation. They made use of evidence both to support and to refute claims of their own and their peers. They also sought specific information for potential use in the opportunities they had to choose questions they would like answered. For example:

Is there a card about the efficiency of the tax program?

Is there a card showing where carbon tax money goes?

I'm looking for a card I can use to show that education is not effective.

These examples support our claim *that* students had ideas in mind of the purpose such information could serve.

Several excerpts from the dialogs illustrate ways in which students went on to use such information.

Excerpt 1

Student 1: *One study found that what people know, their attitudes and knowledge about the environment were the main factors predicting green behavior.*

Student 2: *But very few teachers in America reported that they received formal training on climate change when they were at university (fact from card).*

Here Student 2 uses the secured information in an attempted counterargument to Student 1's claim.

Excerpt 2

Student 1: *What do you think about climate change? We believe that taxation is a great way for people to comply to improve the issue of climate change.*

Student 2: *We believe that education will allow people to learn about climate change and raise awareness.*

Student 1: *We believe that it will take a long time for education (to be effective), we need more drastic action such as taxation.*

Student 2: *The training will allow students to convey what they learn about climate change to their parents.*

Student 1: *It will take a long time with education, because many educational institutions in Europe do not have enough knowledge on how to design innovative and attractive programmes for promoting formal literacy (fact from card)*

Student 2: *In the 20th century, when education became compulsory in Europe, people were more interested in the environment (fact from card)*

Student 1: *According to the cards, education doesn't get people to take action and may not be effective.*

Example 2 shows how students engaged in a series of counterarguments – employing information from the cards – responding to an opponent's counterargument by countering this counterargument, what is commonly referred to as a rebuttal. Student 1 provides counterarguments to student 2's claim that education will help to tackle climate change, while student 2 responds back to each of student 1's counterarguments, with another counterargument, trying to defend her initial claim.

Excerpt 3

Student 1: *With taxation, everyone will pay attention.*

Student 2: Who guarantees it?

Student 1: The results of all these years.

Student 2: Is there evidence that the carbon tax implemented so far has been effective in reducing carbon emissions?

Here Student 2 asks Student 1 to provide particular evidence that Student 2 recognizes is necessary to support Student 1's position.

Our purpose in citing these examples is simply to illustrate that participants did acquire and use information in the ways we characterize. We do not want to distract from the experimental purpose of the present study by engaging in more qualitative examination of how new ideas are adopted, something we are doing in other current work of a case study nature (Kuhn et al., 2025).

Discussion

The present study met its objective of demonstrating the power of learners anticipating how they can use knowledge in acquiring pertinent knowledge needed to undertake informed debate regarding an important and complex issue such as climate change. We hypothesized that information is best acquired and made use of if acquiring it possesses a clear, discernible purpose in the eyes of the potential user. To test this hypothesis, we followed a sample of young adolescents who over a period of weeks engaged deeply with the topic of how to address the problem of climate change. Activities in two conditions were identical except for the manner in which students secured information pertinent to the climate change topic. In the experimental

condition, information was requested and received in the form of selection of questions and securing of their answers on an as-requested basis.

As expected, based on previous research involving this intervention program, both groups showed acquisition and subsequent use of knowledge gained from the information made available to them, as well as argumentation skill gains, to extents consistent with earlier work (see Iordanou & Rapanta, 2021, for review). The present findings also confirm that both knowledge and skill gains are achievable in the same intervention (Iordanou et al., 2019; Asterhan & Schwarz, 2016). The focus of the present study is how the difference across conditions in mode of knowledge acquisition affected outcomes with respect to both argument skill and knowledge.

Although both groups benefited from their engagement, the experimental group showed greater gains, as evidenced in their performance on a concluding knowledge assessment on the climate topic, informed by information made available to them in the intervention. Participants in the experimental condition demonstrated knowledge scores roughly twice as high as those of participants in the comparison condition on multiple outcome measures. The experimental group in addition outperformed the comparison group in coordinating evidence with claims in writing a final argumentive essay, not only on the climate topic but also on a new, unstudied topic. Skill gains in argumentation on a new topic are significant because they suggest that something was gained that went beyond the specific topic studied. Skilled arguers have been shown to appreciate the purpose of argumentation and evidence more than do novices (Felton & Crowell, 2022). In the present study, once they gained this appreciation in the context of a particular topic, they were able to see it as well in the context of a new topic.

The focus of the present investigation is on knowledge acquisition, and the implications of our findings with respect to knowledge acquisition extend well beyond the topic of climate change. It is thus worthwhile to attempt to pinpoint as specifically as possible what advantage the method of information access conferred on the experimental group. One idea, not original to us, is that information is more easily digested in small bits. Contrary to what is most often the case, however, in the present study information, once presented, remained readily available to be consulted as wished. Memory was not at issue, nor were memory strategies such as chunking. The fact that the experimental group did not have all information available from the start, and accessed it only gradually, if anything gave the comparison group an advantage. Hence, block vs. segmented display of information is not enough to account for the difference in performance across conditions.

A related explanation is that the segmentation into small units rendered the information more accessible to participants. Neither was this the case, however. In one condition, the question cards remained in an unordered pile (unless a student had imposed some order on it). In the other, the text comprised a series of discrete sentences in a logical, sequential, content-informed order. The information in these two differing formats remained equally physically present to their respective potential users throughout the activity. In both conditions students were instructed at the outset that this information would be important to the activity they were to embark on.

What then accounts for the card information appearing three times more frequently, as a participant's evidence for or against a claim, among participants in the experimental (card) condition? The answer, in our view, lies in the fact that students needed to do quite a bit more than *locate* the information. In a word, they needed to recognize that it could be relevant and

useful, which would then motivate their search for it if needed. Being prompted to identify a question at least implicitly conveyed to the experimental participants the suggestion that seeking its answer could be useful. That they had to choose what question to ask heightened awareness of this possibility, personally engaging them in it and its potential. In choosing questions as informative, they likely anticipated probable answers. They also had opportunities to discuss both question choice and the subsequent answers with their peer partner.

This is far more than "facilitating access" – making it accessible is one thing, appreciating its value quite another. Still more, beyond appreciating its value participants had to go on to act on that recognition, by making use of the information in their argumentation. On each of these various indicators, the experimental group outperformed the comparison group.

Still another aspect of the choice that the questioning group experienced, one that further differentiated the two conditions, is that the experimental condition participants, in undertaking and collaborating with a peer in the knowledge selection process, developed some personal investment in this knowledge. They now owned it. Fully as important, they experienced agency in choosing to access and possess it, a circumstance likely to increase its value. Increasingly, researchers and educators are coming to appreciate the critical role of agency in learning (Carlson, 2023; Patall et al., 2008). Students in our comparison condition who read the presented text likely had no other reason to do so than regarding it as an entrance ticket to what they hoped would be more the interesting activities to follow.

This said, the limitations of the present study require acknowledgement. The relatively small sample size, necessitated by the labor-intensive intervention in an authentic classroom setting, reduces the power of the study. In addition, assignment to condition at the class instead of the individual level — rendering the design as a quasi-experiment — also constitutes a

potential threat to the internal validity of the study. Both of these limitations, however, are common ones in educational research, especially among studies conducted in an authentic setting of real classrooms. This is especially the case in the present study, given its requirement of substantial class time over an extended number of weeks. Instituting the manipulation within a classroom rather than between classrooms would have required separate protocols for subgroups of the class and been too disruptive of classroom procedures. Similarly, the intervention was too labor-intensive than to do other than have existing intact class sizes determine condition size. That said, it will be important to replicate this study with larger, more diverse samples to enhance statistical power and to establish the generalizability of the present findings beyond the particular cultural, age, and educational sample who participated in the study reported here.

Also, the design of the present study compared the Q&A form of presentation of information with an advance text containing the same information, aiming to keep the latter condition as close as possible to typical classroom practice. Future research could further probe the present findings, examining, for example, whether other variations of information presentation, such as including subsections within a single text, would prove as effective as the Q&A format used in our experimental condition.

We nonetheless believe that the broad aspects of the present findings that pertain to tools of knowledge acquisition have potential applicability beyond the program devoted to argumentation skill development in which we examined them. We acknowledge that we have not provided evidence here for the generality of these findings, yet we hope that these findings will be of wide enough interest to promote exploration of their generalizability.

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Appendix

Detailed sequence of activities that make up the argument curriculum

Session 1. Participants in both conditions were presented with a scenario on Climate Change which proposed either educating people about Climate Change's dangers or by charging a high tax on purchase of fuels that contribute to the problem as the best way to reduce Climate Change. Participants were asked to indicate their position by choosing among options: "Tax,'' ''Education,'' and ''Undecided'' and then to "Write the argument you would make to convince someone who did not agree that your position is the better one. Make the best argument you can." Students who chose the undecided option – about a quarter — usually reported "I don't know" or gave reasons supporting both options. Those students were randomly assigned to the tax or the education position – supported by 40% and 60% accordingly – in a way that served to equate the number of participants on each option.

Session 2. At the beginning of this session, students were provided with background knowledge on the topic. In the experimental condition they worked in same-side pairs and each pair together chose six questions from a list of 34 that they would like answers to in order to assess them in their argumentation; they were provided short answers to these six in the form of Q&A cards that then remained available. In the comparison condition, students were provided a text to read containing information identical to that contained in all 34 of the Q&A items that the experimental condition participants would ultimately see (see Appendix). Then, students in both conditions assembled into same-side small groups of 5–6 students. Students were asked to generate reasons supporting their team's side, record them on individual cards, and share them

with one another. Then, they discussed their reasons and ranked their reasons with respect to their strength.

Sessions 3-8. During sessions 3-8, students remained in their assigned pairs within their same-side team who shared the same position on the topic. Pairs remained together as collaborating partners throughout these sessions. The text presented to students in the comparison condition remained available to them throughout sessions 3-8. At each of these sessions, pairs in the experimental condition chose from the six questions to secure answers to (except session 8 when only four cards remained).

At each session, the pair engaged in an electronic dialog with a new pair who held the opposing position. The Dialogs took place via an instant-messaging platform. After engaging in three dialogs, the pair was asked to reflect on the electronic transcript of their preceding dialogs, making use of two written guides to do so: The ‘‘Other Argument” Reflection Sheet guide prompted students to reflect on a counterargument they had provided to an opposing pair’s argument. Their task was to reflect on the effectiveness of the counterargument they made, whether they used evidence to support their counterargument, and to consider possible improvements to this counterargument. The “Own Argument” Reflection Sheet guide prompted students to reflect on how they responded to a counterargument made by the opposing side to their own argument (i.e., their rebuttal) and to consider possible improvements to their rebuttal.

Session 9. At this session, same-side groups of 5-6 were formed to work together to prepare for the Showdown to follow in the next session. The group had available the reflection sheets they had prepared in the previous sessions and were asked to review them and draw on them to prepare their best counterarguments and rebuttals to use in the Showdown. Students used different colored cards to depict arguments, counterarguments, and rebuttals, these serving as a

visual representation of the structure of different components of their arguments. An adult coach facilitated these discussions.

Session 10. At the Showdown session, students remained in their small groups and teams, with the first half of the session involving two small groups (one from each of the opposing teams) and the second half the other two, thereby providing students the opportunity for greater participation. Each team's participants were seated in different rooms and communicated through a chat tool. The electronic dialog was projected onto a wall screen in each room. One member of each team was designated as a typist, while all members collaborated to come to an agreement on the text to be communicated to the opposing side.

Session 11. The researchers prepared an argument map representing the electronic dialog produced in the Showdown session. Points were awarded for effective argumentative moves, namely counterarguments and rebuttals, and for use of evidence. This session offered students the opportunity to reflect on their discourse, particularly on whether they paid attention and addressed others' arguments and whether they used evidence to support their position or critique the other's position. Points were summed and a winner declared.

Session 12. The culminating event of the intervention was to write a Letter to the Editor of a newspaper on the topic of climate change. Instructions were the following: "Is climate change best reduced by educating people about its dangers or by charging a high tax on purchase of fuels that contribute to the problem? Write a Letter to the Editor of a newspaper on this issue. Try to give as full an idea of the issue as you can for someone who hasn't thought about the topic."

Information on Climate Change (Q&A) provided to the Experimental Condition

EDUCATION

Is education related to more environmentally friendly attitudes? If so, how?
Yes, individuals with higher education levels tend to be more environmentally friendly. A study found that the increase in compulsory education in 20th century in Europe is associated with individuals being more concerned with social welfare and to accordingly behave in a more environmentally friendly manner.

Is education related to people being more concerned about climate change?
No, research findings from the US show that people with the highest degrees of scientific literacy were *not* the most concerned about climate change.

Which factors determine green behavior (behaviour that minimises harm to the environment)?
A study found that one's awareness and attitudes and learning about the environment were the main predictors of green behavior.

Do social norms influence green behavior (behaviour that minimises harm to the environment)?
A study found that motivation and social norms (what members of society understand as acceptable behavior) were less common influences on green behavior.

Does providing information about climate change make people behave in a more environmentally friendly way?
There are mixed findings. For some people this might be true but for others not. Some research shows that individuals' political views influence more the way they think and behave, rather than information they receive. Some individuals may not change beliefs by reading information. However, the way the information is presented also influences the way they perceive it.

Are any educational efforts effective to reduce or prevent climate change?
Some studies report effectiveness. University students who attended a four-month course on environmental management showed pro-environmental behaviour.

Do many people in Europe know about climate change?
Yes, more than nine in ten Europeans see climate change as a serious problem and support action to tackle it.

Do people who know about climate change, show more pro-environmental behaviour?
Even though many European know about climate change, it is not always clear what action needs to be taken.

Might education affect climate change?
A research study claims that if only 16 percent of high school students in high- and middle-income countries received climate change education, there could occur a nearly 19 gigaton reduction of carbon dioxide by 2050.

Are educational programmes on climate changes always successful?
No, designing such programme is challenging. Groups are sometimes hostile to such messages if they see them as contrary to their political and cultural identity.

Can public school teachers teach about climate change?
Very few teachers receive formal training on the topic of Climate Change while in college. A study found that teachers in Finland hold different kinds of views of what the best practices to deal with climate change are.

How possible is scientific literacy education in Europe?
A research study for European parliament shows that many education providers in Europe do not have sufficient knowledge to innovate and create engaging learning environments to foster scientific literacy.

Does learning scientific facts about climate change lead people take action on climate change?
No, methods of climate change education focused primarily on the depth and conclusiveness of scientific evidence may not be effective. Education needs to also promote individuals' critical thinking.

Do younger individuals take more personal actions to fight climate change, compared to older ones?
No, in the Eurobarometer survey report, younger people (15-24 year-olds) less often said they have taken personal action to fight climate change, compared to 40-54 year-olds.

What's European Union's position on education for climate change?
The European Union is encouraging the education and training sector to take action on education for climate change. According to European Union learners of all ages need to be able to develop the knowledge, skills and attitudes to live more sustainably, change patterns of consumption and to contribute to a greener future.

What is the EU doing for education on climate change?
The European Union is tackling climate change through a range of educational initiatives: the Education for Climate Coalition is a growing community of learners and teachers active on climate change and sustainability issues a proposal for a Council Recommendation on learning for environmental sustainability aims to support Member States in their efforts and to encourage more cooperation at the EU level in this field

the new European sustainability competence framework sets out knowledge, skills and attitudes learners of all ages will need for the green transition

Can young learners get involved in research on climate change?

Researchers at Schools initiative allows young researchers to engage with teachers and pupils on climate change and sustainable development

TAX

Can a tax on carbon use damage a country's economy or the competitiveness of its products?

Governments increasing the price of carbon by adding a tax, if appropriate, can send a price signal to citizens, encouraging low-carbon practices. In developed countries, evidence suggests that higher carbon pricing has improved productivity and innovation, rather than having a negative effect on economic development. There has also been little evidence to date that carbon pricing has damaged competition.

Can carbon tax alone be an effective measure to protect the climate?

Its effectiveness may be limited unless it is used with other policies to complement it by tackling other climate change challenges involving.

Is carbon pricing adequate on its own to reach net-zero emissions?

Carbon pricing can play a role in reaching net-zero emissions but on its own will not be sufficient to reach net-zero emissions. Other policies are needed to drive research and development, unlock noneconomic barriers to mitigation, and target emissions reductions.

How can the current carbon tax plans help in tackling climate change in the future?

A 2021 analysis found that implementation of current commitments would lead only to a 0.5% reduction in global carbon emissions by 2030 compared to 2010 levels, far short of the 45% reductions needed to limit global temperature increase to 1.5°C.

Do governments charge enough carbon tax today, to address the climate change issue?

A majority of carbon prices still remain far below the USD 40–80/tCO2e range needed in 2020 to meet the 2°C temperature goal of the Paris Agreement — only 3.76% of global emissions are covered by a carbon price at and above this range. Even higher prices will be needed over the next decade to reach the 1.5°C target.

Who controls the price of carbon?

Explicit carbon pricing policies are enacted by a government mandate that imposes a price based on carbon content.

Can governments charge enough taxes to eliminate the threat of climate change?

Governments find it politically difficult to charge enough to reduce emissions significantly. By making fossil fuels more expensive, it imposes a harsher burden on those with low incomes. They will pay a higher percentage of their income for necessities like gasoline, electricity, and food. They can't afford to switch to electric vehicles.

Is there evidence showing that carbon tax implemented thus far has an effect on reducing carbon gas emissions?
By 2017, the EU had reduced its emissions by almost 22% compared to 1990, reaching its 2020 emission reduction target three years ahead of schedule**.**

What percentage of gas emissions, which are causing climate change, are covered by carbon pricing?
In 2021, 21.5% of global greenhouse gas emissions are covered by carbon pricing instruments in operation, representing a significant increase in 2020, when only 15.1% of global emissions were covered. This increase is largely due to the launch of China's national emissions trading system.

Do countries in Europe follow EU's recommendations for carbon taxing?
Yes. Some countries in Europe also have additional measures, such as the Netherlands that has an additional fee for waste incinerators and facilities emitting large amounts of nitrous oxide that are not covered under the EU Emissions Trading System. Also, Luxembourg has an additional carbon tax, which covers emissions from transport, shipping, and buildings.

Has the covid-19 pandemic introduced changes in legislation to tackle carbon emissions?
Despite the global pandemic, the momentum toward adopting net-zero targets has not stopped but accelerated. As of April 2021, 29 countries have enshrined net-zero targets in laws or policy documents or have proposed legislation to do so. The majority of targets aim for achieving net zero by 2050, though China and Ukraine are aiming for 2060 and 2070, respectively, while a handful of European nations are targeting earlier dates. Suriname and Bhutan have already achieved net zero.

How is it still feasible with covid-19 to impose a carbon tax?

A few jurisdictions have explicitly linked carbon pricing to their COVID-19 recovery packages. The EU, for instance, announced the European Green Deal in December 2019, setting out a new growth strategy to tackle both the economic recession and the climate challenge. Carbon pricing helps support low-carbon products, which can generate additional jobs. In addition, carbon pricing can generate much needed government revenue to support additional stimulus and investment programs.

Where does carbon tax money go?

The EU provides the largest amount of public money to developing countries to fund climate projects. In 2018, for example, the EU and its member countries collectively provided EUR 21.7 billion to help them tackle climate change. EU Member States also contributed almost half of the 2016 USD 10 billion pledged to the UN's new Green Climate Fund, which is also supporting developing countries.

Does a carbon tax ensure that carbon emissions will be reduced? If no, Why not?

No, because carbon tax while it sets a price for carbon emissions, it does not set a cap. As long as polluters are willing to pay, emissions may therefore continue to increase.

How does carbon tax affect carbon-based fuel sales?
A carbon tax would increase the price of carbon-based fuels and any resulting goods or services. Research shows that putting a price on carbon-based fuels, in the form of a fee or tax, is an effective way of motivating companies to switch to clean energy (from renewable, zero emission sources that do not pollute the atmosphere when used) and therefore reduce pollution levels.

What happened to countries which had carbon tax programme and then stopped it?
While emissions dropped almost immediately after Australia introduced its tax carbon programme, carbon emissions began to rise again almost immediately when the programmed was dumped, because of political reasons.

How can carbon tax affect transportation?
A carbon tax would make it more expensive to buy and drive gasoline cars. The end result is fewer cars on the road that are powered by polluting energy sources and more electric vehicles. In the UK, electric vehicles bring down carbon emissions to lowest level ever. Though only 12% of new sales were electric vehicles, emissions fell by 11.2% in 2021.

Information on Climate Change (Text) provided in the Comparison Condition

Climate Change

Some individuals suggested that we can tackle climate change through education. Education is related to more environmentally friendly attitudes. Individuals with higher education levels tend to be more environmentally friendly. A study found that the increase in compulsory education in 20th century in Europe is associated with individuals being more concerned with social welfare and to accordingly behave in a more environmentally friendly manner. Other studies found that one's awareness and attitudes and learning about the environment were the main predictors of green behavior, while motivation and social norms (what members of society understand as acceptable behavior) were less common influences on green behavior.

More than nine in ten Europeans see climate change as a serious problem and support action to tackle it. However, even though many European know about climate change, it is not always clear what action needs to be taken. When asked in the Eurobarometer survey report, younger people (15-24 year-olds) less often said they have taken personal action to fight climate change, compared to 40-54 year-olds.

Some studies report that educational efforts were effective to reduce climate change. University students who attended a four-month course on environmental management showed pro-environmental behaviour. A research study claims that if only 16 percent of high school students in high- and middle-income countries received climate change education, there could occur a nearly 19 gigaton reduction of carbon dioxide by 2050. Yet, learning scientific facts about climate change does not always lead people to take action on climate change. Methods of climate change education focused primarily on the depth and conclusiveness of scientific evidence may not be effective. Education needs to also promote individuals' critical thinking. Some individuals may not change beliefs by reading information. However, the way the information is presented also influences the way they perceive it. Some other research findings from the US show that people with the highest degrees of scientific literacy were not the most concerned about climate change. Individuals' political views influence more the way they think and behave, rather than information they receive, according to some research findings.

The European Union is encouraging the education and training sector to take action on education for climate change. According to European Union, learners of all ages need to be able to develop the knowledge, skills and attitudes to live more sustainably, change patterns of consumption and to contribute to a greener future. The European Union is tackling climate change through a range of educational initiatives such as the Education for Climate Coalition is a growing community of learners and teachers active on climate change and sustainability issues, a proposal for a Council Recommendation on learning for environmental sustainability aims to support Member States in their efforts and to encourage more cooperation at the EU level in this field and the new European sustainability competence framework sets out knowledge, skills and attitudes learners of all ages will need for the green transition. Researchers at Schools initiative is an

initiative that allows young researchers to engage with teachers and pupils on climate change and sustainable development.
Designing educational programmes on climate change is challenging. Groups are sometimes hostile to such messages if they see them as contrary to their political and cultural identity. In addition, very few teachers reported to have received formal training on the topic of Climate Change while in college. A study found that teachers in Finland hold different kinds of views of what the best practices to deal with climate change are. Furthermore, many education providers in Europe do not have sufficient knowledge to innovate and create engaging learning environments to foster scientific literacy, a research study for European parliament reported.

Another way to deal with climate change is to tax carbon. Carbon pricing policies are enacted by a government mandate that imposes a price based on carbon content. A carbon tax would increase the price of carbon-based fuels and any resulting goods or services. Research shows that putting a price on carbon-based fuels, in the form of a fee or tax, is an effective way of motivating companies to switch to clean energy (from renewable, zero emission sources that do not pollute the atmosphere when used) and therefore reduce pollution levels. By 2017, the EU had reduced its emissions by almost 22% compared to 1990, reaching its 2020 emission reduction target three years ahead of schedule**.** Some countries in Europe have additional measures, such as the Netherlands that has an additional fee for waste incinerators and facilities emitting large amounts of nitrous oxide that are not covered under the EU Emissions Trading System. Also, Luxembourg has an additional carbon tax, which covers emissions from transport, shipping, and buildings.

Governments increasing the price of carbon by adding a tax, if appropriate, can send a price signal to citizens, encouraging low-carbon practices. In developed countries, evidence suggests that higher carbon pricing has improved productivity and innovation, rather than having a negative effect on economic development. There has also been little evidence to date that carbon pricing has damaged competition. A carbon tax would make it more expensive to buy and drive gasoline cars. The end result is fewer cars on the road that are powered by polluting energy sources and more electric vehicles. In the UK, electric vehicles bring down carbon emissions to lowest level ever. Though only 12% of new sales were electric vehicles, emissions fell by 11.2% in 2021. When Australia introduced its tax carbon programme emissions dropped almost immediately, but carbon emissions began to rise again almost immediately when the programmed was dsumped, because of political reasons.

Yet, a 2021 analysis found that implementation of current commitments would lead only to a 0.5% reduction in global carbon emissions by 2030 compared to 2010 levels, far short of the 45% reductions needed to limit global temperature increase to 1.5°C. A majority of carbon prices still remain far below the USD 40–80/tCO2e range needed in 2020 to meet the 2°C temperature goal of the Paris Agreement — only 3.76% of global emissions are covered by a carbon price at and above this range. Even higher prices will be needed over the next decade to reach the 1.5°C target. Governments find it politically difficult to charge enough to reduce emissions significantly. By making fossil fuels more expensive, it imposes a harsher burden on those with low incomes. They will pay a higher percentage of their income for necessities like gasoline, electricity, and food. They can't afford to switch to electric vehicles.

Carbon tax effectiveness may be limited unless it is used with other policies to complement it by tackling other climate change challenges involving. Carbon pricing can play a role in reaching net-zero emissions but on its own will not be sufficient to reach net-zero emissions. Other policies are needed to drive research and development, unlock noneconomic barriers to mitigation, and target emissions reductions. In 2021, 21.5% of global greenhouse gas emissions are covered by carbon pricing instruments in operation, representing a significant increase in 2020, when only 15.1% of global emissions were covered. This increase is largely due to the launch of China's national emissions trading system. However, while carbon tax while it sets a price for carbon emissions, it does not set a cap. As long as polluters are willing to pay, emissions may therefore continue to increase.

A few jurisdictions have explicitly linked carbon pricing to their COVID-19 recovery packages. The EU, for instance, announced the European Green Deal in December 2019, setting out a new growth strategy to tackle both the economic recession and the climate challenge. Carbon pricing helps support low-carbon products, which can generate additional jobs. In addition, carbon pricing can generate much needed government revenue to support additional stimulus and investment programs. Despite the global pandemic, the momentum toward adopting net-zero targets has not stopped but accelerated. As of April 2021, 29 countries have enshrined net-zero targets in laws or policy documents or have proposed legislation to do so. The majority of targets aim for achieving net zero by 2050, though China and Ukraine are aiming for 2060 and 2070, respectively, while a handful of European nations are targeting earlier dates. Suriname and Bhutan have already achieved net zero.

The EU with the carbon tax money provides money to developing countries to fight climate change. EU provide the largest amount of public money to developing countries to fund climate projects. In 2018, for example, the EU and its member countries collectively provided EUR 21.7 billion to help them tackle climate change. EU Member States also contributed almost half of the 2016 USD 10 billion pledged to the UN's new Green Climate Fund, which is also supporting developing countries.