

Exploring Prospective Preschool Teachers' Argumentation Skills on the Greenhouse Effect

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ABSTRACT

The purpose of this study is to explore the degree to which prospective preschool teachers can develop arguments regarding the main contributors to the greenhouse effect, the intensity of the phenomenon across the earth's surface and the consequences of global warming caused by the constant increase of the greenhouse effect. Participants were 93 students (prospective teachers) who had been provided with a number of data in order to be able to articulate claims and to develop reasoning to support them. Students' argumentation components were categorized according to their content suitability, and relevant paths from data to claims were constructed. Results provide evidence for the capability of students to develop arguments based on the information and data available to them, revealing a number of misunderstandings in relation to the greenhouse effect and insufficient reasoning regarding their argumentation skills. Relevant improvements that could take place in preschool education departments and implications for science education are also discussed.

Keywords: Argumentation, Greenhouse effect, prospective preschool teachers, reasoning paths.

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1. INTRODUCTION

The greenhouse effect is a phenomenon of paramount importance for everyone living on earth, and any action that contributes to maintaining it at the desirable levels should be supported (Niebert & Gropengießer, 2014; Reinfried & Tempelmann, 2014; Shepardson *et al.*, 2011; Varela *et al.*, 2020). The starting point for such actions is understanding the phenomenon, an issue where education plays the most dominant role. Developing and implementing any mitigation action presupposes citizens' broad acceptance and support. Education can raise awareness among citizens by providing them with all the necessary resources to understand the greenhouse effect. This should begin at younger ages, even at the preschool level.

As a result, preschool teachers are among those who contribute to an understanding of the phenomenon. How can a preschool teacher help young pupils understand the greenhouse effect (to an extent possible for their age) and persuade them of its implications for everyday life? Among the educational practices that could provide teachers with a reliable tool working in this direction is the development of argumentation skills (Deng & Wang, 2017; McDonald & McRobbie, 2012). Articulating an argument, an individual can support a particular claim with specific data

through reasoning that can sufficiently lead another individual to understand the truth behind his claim (McNeill, 2011; McNeill *et al.*, 2006). Thus, argumentation allows a preschool teacher to persuade young pupils of the truth concerning the greenhouse effect itself and its implications for life on earth.

Taking into account the above, the primary purpose of this study is to explore prospective preschool teachers' development of argumentation skills on issues related to the greenhouse effect itself and its implications for everyday life when they have been provided with the necessary information and data that enable them to understand the phenomenon to a significant degree.

1.1. Theoretical Background

1.1.1. Understanding the Greenhouse Effect

Research on the understanding of the greenhouse effect has revealed a number of problems in dealing with the prerequisite knowledge concerning the procedure, the mechanism, and the agents involved in the phenomenon. As a result, a number of misconceptions and alternative ideas have been recorded concerning the main characteristics of the phenomenon itself and its relation to other phenomena, such as the ozone layer depletion, as well



as related consequences on planet Earth, such as climate change and global warming (e.g., Jarrett & Takacs, 2020; Liu, 2021; Reinfried & Tempelmann, 2014; Varela *et al.*, 2020).

Regarding the main characteristics of the phenomenon, misconceptions originate from difficulty in recognizing the greenhouse gases and understanding the radiation absorption mechanism (e.g., Reinfried & Tempelmann, 2014; Shepardson *et al.*, 2011). The fact that ozone is among the greenhouse gases and the lack of distinction between stratospheric and tropospheric ozone has led to confusion between the greenhouse effect and ozone layer depletion. Thus, many students believe the greenhouse effect creates or contributes to ozone layer depletion (Niebert & Gropengießer, 2014; Varela *et al.*, 2020). On the other hand, the lack of distinction between the radiation types related to the phenomenon and the lack of understanding of the absorption-emission process has led to difficulty in understanding the meaning of terrestrial radiation and, consequently, the causal characteristics of its mechanism (Niebert & Gropengießer, 2014; Varela *et al.*, 2020).

As for the understanding of the consequences of the greenhouse effect on climate change and the corresponding mitigation actions, although there seems to be a positive connection to the understanding of the phenomenon itself, it is not clear whether the possession of adequate knowledge concerning the mechanism of the greenhouse effect necessarily means the complete comprehension or participation to mitigation actions (Varela *et al.*, 2020). However, there are strong indications that the understanding of the causal mechanisms of the phenomenon could lead, especially at older ages, to a willingness to change the behaviour into a more friendly context for the environment (Tasquier & Pongiglione, 2017) and to participate in carbon neutrality education, developing relevant responsibility (Zhang *et al.*, 2022).

1.1.2. About Argumentation

Although studies concerning the understanding of the greenhouse effect are numerous, those concerning argumentation skills on this phenomenon are somewhat limited. Of course, the conceptual understanding of a phenomenon and relevant argumentation skills are connected since one impacts the other (Cetin, 2014; Garcia-Mila *et al.*, 2013). However, when studying argumentation, the focus is on the investigation of the development of a subject's skills to use and draw on specific data (evidence) in order to articulate a claim (an assertion that one tries to justify) through a reasoning-making sense how those data can lead to the specific claim.

In the past, the relevant argumentation studies usually adopted Toulmin's Argumentation Pattern (TAP), where the components of an argument were claim and data and warrant (instead of reasoning), as well as qualifier, backing, and rebuttal (Toulmin, 1958, 2003). The qualifier is related to the conditions for the validation of the claim. The backing supports the warrant, whereas the rebuttal explains when the claim could be undermined. However, TAP proved to be difficultly applicable in analyzing school students' argumentation, whereas the distinction between warrant and backing was also difficult (e.g., Erduran

et al., 2004; Naylor *et al.*, 2007). Thus, researchers started to use more straightforward frameworks for the analysis of students' argumentation skills, usually including four components, where, apart from data and claim, the component of reasoning introduced as a combination of warrant and backing, whereas the component of rebuttal explained how or why an opposite or alternative claim was incorrect (McNeill *et al.*, 2006; McNeill & Krajcik, 2011). Further, rebuttal proved to be a quite difficult and problematic component in terms of its suitability and articulation by students (Angeloudi & Papageorgiou, 2022; Christenson & Chang Rundgren, 2015; McNeill & Krajcik, 2007).

Based on the above, researchers could evaluate a student's argument for the quality of its structure, taking into account the presence or absence of a particular component and formulating levels of the overall quality according to sufficient presence of the main components of the argument (Erduran *et al.*, 2004; Osborne *et al.*, 2004). However, the suitability of the content of a component is also of great importance for the quality of an argument. Many researchers support its importance (McNeill *et al.*, 2006; Sampson & Clark, 2006; Sandoval & Millwood, 2005) and suggest its evaluation based on the school version of scientific knowledge. Thus, there is a need for the development of analytical frameworks to evaluate the quality of an argument for both the structure and the content suitability revealed. Some of those frameworks suggest the evaluation of the quality of an argument separately for the structure and the content suitability (McNeill & Krajcik, 2007). In contrast, in other frameworks, the evaluation co-occurs for both (Chen *et al.*, 2016). The evaluation could be qualitative, or it can be quantified by the introduction of a particular scoring scale, as in the case of Chen *et al.* (2016), where a four-level scoring scale (0–3) was used for the evaluation of the content suitability based on the completeness and correctness of the components.

1.2. Rational of the Study

The primary purpose of this study is to explore prospective preschool teachers' development of argumentation skills on the greenhouse effect. However, although formulating an argument presupposes understanding the relevant concepts (Cetin, 2014; Garcia-Mila *et al.*, 2013), the students did not fully understand the phenomenon under study. Thus, the instrument used in the study included a general description of the phenomenon, together with relevant information and data. Of course, it was expected that any students' prior knowledge about the mechanism of the phenomenon, as for the characteristics of either the gases or the radiation, would probably affect their answers. However, the point for the students was to combine the necessary data in the instrument to understand the phenomenon to an extent that could enable them to articulate and support appropriate arguments in specific tasks. Thus, the main idea was to provide all students with the same pool of data in order to have a common basis for the construction of their arguments (reducing, to a certain degree, the advantage of those having prior relevant knowledge), and so, to be more reliable and realistic to explore how students can equitably develop their argumentation skills on this particular phenomenon.

In this context, the following research questions could be defined in this study:

1. To what extent can prospective preschool teachers draw on the provided information and data to understand issues related to the greenhouse effect to a degree that enables them to develop relevant arguments?
2. How can the content of the components of the students' arguments be categorized according to their suitability concerning the characteristics of the gases and the radiation involved in the phenomenon, as well as its implications for everyday life?

2. METHOD

2.1. Sample

The study took place in the Department of Education Sciences in Early Childhood, Democritus University of Thrace, Greece, during the academic year 2023–2024. Participants were 93 students of this department who were aware of the purpose of the study and its anonymity and voluntarily participated in the study. Prior to the study, informed consent was obtained from the head of the department, and permission was obtained from the department's Research Ethics Committee. All participants were asked to complete an anonymous test for a didactic hour (45 minutes).

2.2. Instrument

For the needs of the study, a paper-and-pencil test was specifically designed, including the following:

1. A general description of the basic characteristics of the greenhouse effect: *"The greenhouse effect is a natural phenomenon that maintains an average temperature of about 20°C on the surface of our planet (otherwise the temperature would drop to -19°C). However, due to human actions, the phenomenon has increased, and the temperature has started to rise, leading to the so-called global warming."*
2. A description of a relevant didactic experiment (Fig. 1), where *"two glass jars with thermometers adapted as shown in the figure, were illuminated in the same way by a lamp whose light may be considered to resemble the light of the sun. One jar contained air and the other carbon dioxide. After a while, the temperature inside the carbon dioxide jar was significantly higher than that in the air jar"*.
3. A table presenting particular data on the "concentration in the atmosphere" and the "potential to cause the phenomenon" for some gases (Table I).

Students were asked to draw on the available data provided in the test and to develop arguments responding to the following tasks:

1. What is the gas that contributes the most to the greenhouse effect?
2. Is the intensity of the phenomenon the same everywhere on earth?

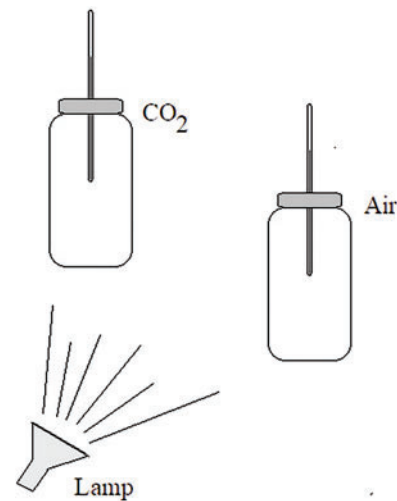


Fig. 1. The figure provided in the test to better understand the description of the experiment.

TABLE I: CONCENTRATION IN THE ATMOSPHERE AND POTENTIAL TO CAUSE THE GREENHOUSE EFFECT FOR SOME GASES

	CO ₂	CH ₄	O ₃	Freon12
Concentration in the atmosphere expressed in a particular unit (ppm)	400	2	0,03	4×10^{-4}
Potential to cause the phenomenon (comparison for equal volumes)	1	21	2000	15.800

3. What is the most serious consequence of global warming caused by the constant increase of the greenhouse effect?

In each one of the tasks, students were asked to fill in specific fields of the test, where the request was to:

- Articulate their aspect as a claim,
- Develop a reasoning justifying their aspect,
- Clarify the data leading to the above aspect.

The Cronbach's alpha reliability coefficient of the test was found to be 0.977.

2.3. Data Analysis Procedure

Since the formulation of claims, reasoning, and data was anticipated in the test for each one of the tasks, the focus of the analysis was on the content suitability of students' arguments rather than on their structure suitability. Thus, students' argumentation skills were evaluated on the basis of a qualitative content analysis, where particular categories of each one of the components were derived. The categorization took place initially separately from the two authors. After discussions between the two raters, discrepancies were reconciled, and after a number of revisions, a 100% total agreement was reached. On the basis of this categorization, particular schemes showing the paths from data to claims through particular reasoning were constructed, contributing to the extraction of conclusions responding to the research questions.

3. RESULTS AND DISCUSSION

Table II and Fig. 2 present a categorization of the students' argument components and the corresponding paths from data to claims concerning Task 1.

It seems that, although the majority of the students (61 out of 93) can articulate a correct claim for the main contributor to the greenhouse effect (C1), only 25 of them follow the reasoning that draws on all the necessary data provided in the first and second lines of Table I (12 students, R3 and 12 students, R4), whereas only one student also co-evaluated the experiment data (1 R6). Among the other claims, that of C2 (Freon12 is the main contributor) was based exclusively on the potential to cause the phenomenon (second line of Table I) by 21 students, whereas four further students tried unsuccessfully to use all the data from Table I (first and second lines) also concluding this incorrect claim. Similar insufficient or incorrect reasoning

could be seen throughout Table II, a fact that underlines the difficulty of students to develop acceptable reasoning, at least at the school version of the scientific level (e.g., Koulaidis & Dimopoulos, 2005; Koulaidis & Tsatsaroni, 1996) that draw on all the necessary data and lead to a correct claim for the main contributor to the greenhouse effect.

As for Task 2, Table III and Fig. 3 show the relevant categorization of the students' argument components and the corresponding paths from data to claims. Although the articulation of the correct claim (C1) holds true for the vast majority of the students (80 out of 93), their reasoning and the data on which they are based are quite disappointing. The majority of the students focus on D6 and D7, concluding C1 through R8 and R9, respectively (Fig. 3). In particular, about one-third of them (29 students) approaches Task 2 in a tautological way (Taber & Watts, 2000), where, according to their corresponding

TABLE II: CATEGORIZATION OF THE STUDENTS' ARGUMENT COMPONENTS CONCERNING TASK 1—CLAIMS (C), DATA (D), AND REASONING (R)

C1: CO ₂ contributes the most
C2: Freon12 contributes the most
C3: CH ₄ contributes the most
C4: O ₃ contributes the most
C5: Freon12 and CO ₂ contribute the most
D1: Based on the data provided concerning the concentration of some gases in the atmosphere
D2: Based on the data provided concerning the potential of some gases to cause the phenomenon
D3: Based on the data provided concerning the concentration of some gases in the atmosphere and their potential to cause the phenomenon
D4: Based on general knowledge
D5: Based on the data provided concerning the experiment
D6: Based on the data provided concerning the experiment and the concentration of some gases in the atmosphere
D7: Based on the data provided concerning the experiment, the concentration of some gases in the atmosphere and their potential to cause the phenomenon
R1: Since the concentration of CO ₂ in the atmosphere is higher than the other gases, CO ₂ contributes the most to the greenhouse effect
R2: Due to the data provided in the 2 nd line of the Table, CO ₂ could cause more heat, and so, CO ₂ contributes the most to the greenhouse effect
R3: Co-evaluating the concentration of gases in the atmosphere and their potential to cause the phenomenon, the multiplication product is bigger in the case of CO ₂ . So, CO ₂ contributes the most to the greenhouse effect
R4: Co-evaluating the concentration of gases in the atmosphere and their potential to cause the phenomenon, CO ₂ contributes the most to the greenhouse effect
R5: Since the concentration of CO ₂ in the atmosphere is higher than the other gases, and in the experiment, the CO ₂ could increase significantly the temperature, so CO ₂ contributes the most to the greenhouse effect
R6: Co-evaluating the concentration of gases in the atmosphere and their potential to cause the phenomenon, as well as the fact that in the experiment the CO ₂ could increase significantly the temperature, CO ₂ contributes the most to the greenhouse effect
R7: Since in the container with the CO ₂ [experiment], the temperature was increased more than in the other with the air, CO ₂ contributes the most to the greenhouse effect
R8: Due to the fact that CO ₂ can trap solar radiation and increase the temperature, CO ₂ contributes the most to the greenhouse effect
R9: CO ₂ contributes the most to the greenhouse effect because anthropogenic actions constantly produce CO ₂
R10: Since Freon12 has a higher potential to cause the phenomenon compared to the other gases, Freon12 contributes the most to the greenhouse effect
R11: Co-evaluating the concentration of gases in the atmosphere and their potential to cause the phenomenon, Freon12 contributes the most to the greenhouse effect
R12: Since CH ₄ has 21 times more potential to cause the phenomenon compared to the other gases, CH ₄ contributes the most to the greenhouse effect
R13: Co-evaluating the concentration of gases in the atmosphere and their potential to cause the phenomenon, CH ₄ contributes the most to the greenhouse effect
R14: Co-evaluating the concentration of gases in the atmosphere and their potential to cause the phenomenon, O ₃ contributes the most to the greenhouse effect
R15: Evaluating the concentration of gases in the atmosphere, it seems that CO ₂ contributes the most to the greenhouse effect, whereas evaluating their potential to cause the phenomenon, it seems that Freon12 contributes the most to the greenhouse effect. Thus, both CO ₂ and Freon12 contribute the most to the greenhouse effect

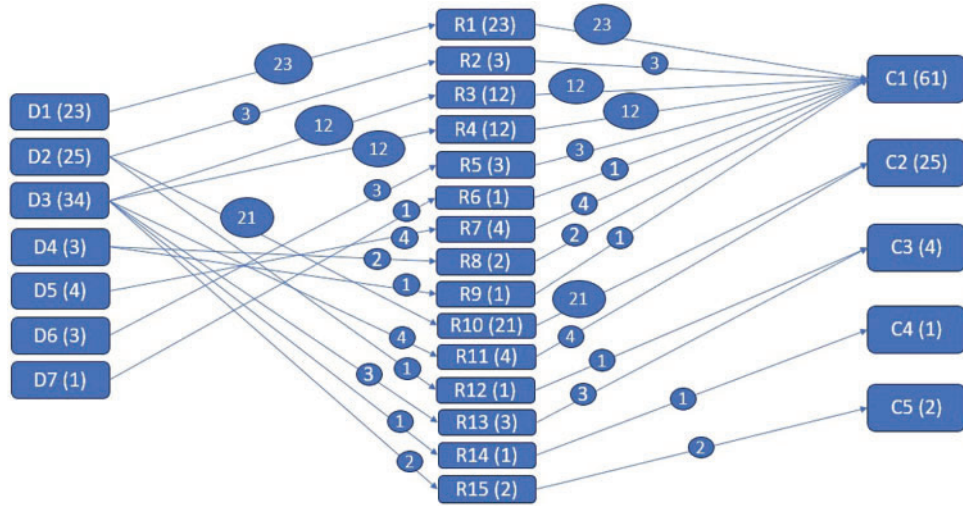


Fig. 2. Paths from data to claims concerning task 1.

reasoning, the different temperature at different latitudes is something known that exist, justifying the different intensity (i.e., temperature) of the phenomenon at different latitudes. A similar percentage of students (27 students) try to justify their claim based exclusively on the emissions of greenhouse gases through a reasoning that ignores the role of radiation in the phenomenon. Among the remaining students of the C1 category, there is only a small number of students (14 out of 93), which are close to an acceptable

argument for the school version of scientific knowledge, although there is not any reference to the rise of the temperature observed during the experiment provided in the instrument. According to them, either the differences in the intense of solar radiation across the earth's surface can justify the corresponding differences in the intensity of the phenomenon (8 students, R1 and 2 students, R2) or both differences in solar radiation and emissions of greenhouse gases at different latitudes can justify this difference in

TABLE III: CATEGORIZATION OF THE STUDENTS' ARGUMENT COMPONENTS CONCERNING TASK 2–CLAIMS (C), DATA (D), AND REASONING (R)

C1: The intensity of the phenomenon varies from place to place on earth
C2: The intensity of the phenomenon is the same everywhere on earth
D1: Based on the aspect that solar radiation varies from place to place on earth
D2: Based on the aspect that solar radiation and emissions of greenhouse gases vary at different latitudes
D3: Based on the data provided in the experiment and the aspect that emissions of greenhouse gases vary at different latitudes
D4: Based on the data provided in the experiment and the aspect that there are different temperatures at different latitudes
D5: Based on the aspect that every place on earth has different characteristics
D6: Based on the aspect that there is different temperature at different latitudes
D7: Based on the aspect that emissions of greenhouse gases vary from place to place on earth
D8: Based on the aspect that any external factor distributes its effect in the same way globally
R1: Since solar radiation is stronger at the equator than at the poles (due to the equator being closer to the sun/the radiation lasting longer during the year/different ray slopes), the intensity of the phenomenon varies from place to place on earth
R2: Since every place on earth is irradiated differently by the sun, the intensity of the phenomenon varies from place to place
R3: Since solar radiation and emissions of greenhouse gases vary at different latitudes, the intensity of the phenomenon varies from place to place on earth
R4: Since during the experiment, CO ₂ caused the temperature to rise to a higher degree, and due to CO ₂ emissions varying at different latitudes, the intensity of the phenomenon varies from place to place on earth
R5: Due to the increase in temperature observed during the experiment and because of the different temperature that exists at different latitudes, the intensity of the phenomenon varies from place to place on earth
R6: Due to the increase in temperature observed during the experiment and due to emissions of greenhouse gases varying at different latitudes, the intensity of the phenomenon varies from place to place on earth
R7: Since every place on earth has different characteristics, the intensity of the phenomenon varies from place to place on earth
R8: Due to the different temperatures existing at different latitudes, the intensity of the phenomenon varies from place to place on earth
R9: Since emissions of greenhouse gases vary from place to place on earth, the intensity of the phenomenon also varies from place to place
R10: Since the earth is spinning, all places on earth are affected the same, and so, the intensity of the phenomenon is the same everywhere
R11: Since the greenhouse gases are distributed in the same way globally, the intensity of the phenomenon is the same everywhere on earth
R12: Every factor on earth distributes its effect almost in the same way, and so, the intensity of the phenomenon is the same everywhere

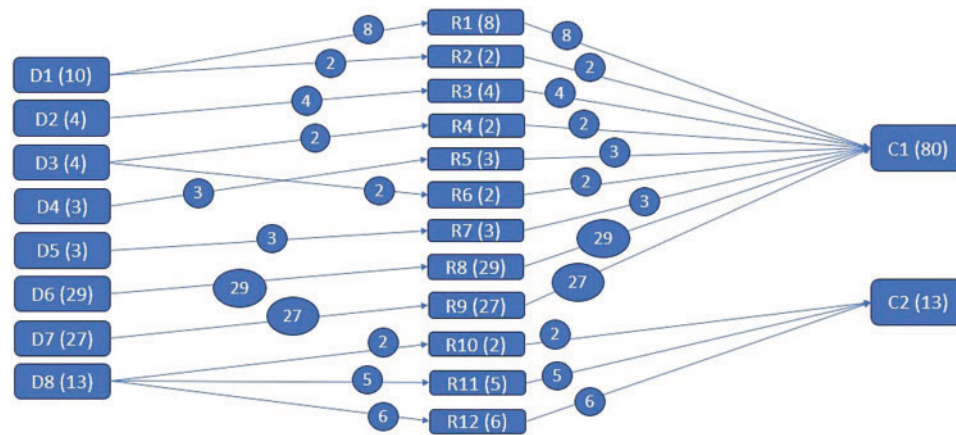


Fig. 3. Paths from data to claims concerning task 2.

TABLE IV: CATEGORIZATION OF THE STUDENTS' ARGUMENT COMPONENTS CONCERNING TASK 3—CLAIMS (C), DATA (D), AND REASONING (R)

C1: The melting of ice in poles
C2: Sea level rise/flooding
C3: Climate Change
C4: Water shortage/Desertification
C5: Harm/death to living organisms
C6: Fires will increase/destruction of natural landscapes
C7: Global Warming/Temperature rise
C8: Emission of dangerous gases
C9: Increasing ozone hole
C10: vague or irrelevant
D1: Based on the information and data of the instrument
D2: Based on information from the internet and media
D3: Based on the fact that greenhouse gases cause the phenomenon
D4: Based on the fact that there is global warming
D5: Based on the fact that greenhouse gases cause ozone depletion
D6: Based on the fact that the ice is melting in the poles
D7: Based on the information that anthropogenic activities increase CO ₂
D8: Based on the information that anthropogenic activities increase temperature
D9: Based on the fact that the increase in temperature causes the evaporation of water
D10: Vague or irrelevant
R1: Due to the temperature rise, the ice in the poles melts
R2: Due to the increase of CO ₂ , temperature rises, ice melts, water levels rise, so there are floods
R3: Due to the temperature rise, the ice melts, the water level rises, so there are floods
R4: Due to the information provided [instrument], the sea level rises
R5: Since the temperature rises, the ice melts, the sea level rises
R6: Due to the increase of CO ₂ , more radiation is trapped, temperature increases and ice melts, so there are floods
R7: Since the temperature rises, the ice melts, the sea level rises, so the climate changes
R8: Since the temperature rises, the climate changes
R9: Since the temperature rises, the climate changes, and there are droughts in some places and floods in others
R10: Due to the increasing anthropogenic activities, the temperature increases, and the climate changes
R11: Since the temperature increases, water evaporates, so there is a water shortage
R12: Since CO ₂ increases, the temperature increases, so living organisms suffer
R13: Since the temperature rises, living organisms suffer
R14: Since greenhouse gases cause the temperature rise, living organisms are harmed
R15: Since greenhouse gases increase, the temperature rises, so fires and the destruction of natural landscapes take place
R16: Due to the temperature rise, there is global warming, so the destruction of natural landscapes takes place
R17: According to the data of the table, the CO ₂ increases, so global warming happens
R18: Due to the increasing anthropogenic activities, the greenhouse gases increase, and so the temperature increases
R19: Since the information and data of the instrument hold true, many dangerous gases are produced
R20: Since more greenhouse gases that can harm ozone are emitted, the ozone hole increases
R21: Vague or irrelevant

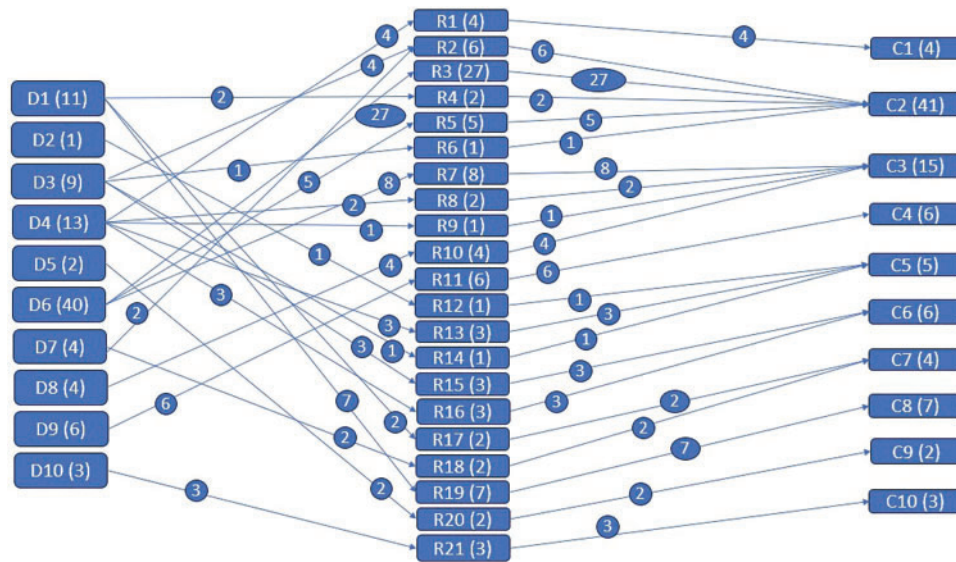


Fig. 4. Paths from data to claims concerning task 3.

the phenomenon (4 students, R3). Please note that only one student out of the eight in the R1 category developed reasoning where the sun's ray slope varies in relation to the latitude, justifying why the radiation is stronger at the equator than at the poles. As for those students supporting claim C2 (13 students), there are a number of reasons justifying the homogenous distribution of the greenhouse effect on the earth according to their reasoning (Table III).

Regarding Task 3, the relevant categorization of the students' argument components and the corresponding paths from data to claims are presented in Table IV and Fig. 4, respectively. As shown, there is a large distribution in reporting consequences where the lack of complete reasoning starting from data provided by the effect itself (the rise of the temperature) towards a particular result is rather apparent. For instance, there are students (41) who can see the increase of the sea level due to the melting of ice in the poles (C2) but without including in their reasoning the thermal expansion of the water at higher temperatures, whereas the reasoning of others (4 students) ends to the melting of ice in the poles (C1). Similarly, climate change as a consequence (15 students) is also a claim (C3) insufficiently supported by reasoning justifying how particular data led to that end. Also, there are cases where students reported that they based on data which, however, do not appear as the starting point in their reasoning, as in the case of the 27 students falling in the R3 category (their reasoning begins from the rise of the temperature) who reported that they had based on D6 (the ice is melting in poles). In addition, in Task 3, students think in a tautological way. These 4 students support claim C7 ending at the rise of the temperature without any thinking of further consequences, through circular reasoning (2 students, R17 and 2 students, R18) similar to that reported by Taber and Watts (2000) in cases of students' explanations of chemical phenomena. It is also worth noting that there are two students (R20) supporting the aspect that the greenhouse effect contributes to the ozone layer depletion, confirming the existence of this misunderstanding reported in the

literature (e.g., Niebert & Gropengießer, 2014; Varela *et al.*, 2020).

4. CONCLUSIONS AND IMPLICATIONS FOR SCIENCE EDUCATION

According to the above results, it is apparent that the number of prospective preschool teachers who can draw on the provided information and data in order to understand issues related to the greenhouse effect is quite limited. Even in Task 1, where the main point was a co-evaluation of the data provided in Table I, less than one-third of them could lead to a correct claim through acceptable reasoning. Things went even worse in the other two tasks, 2 and 3, where, apart from the information provided in the instrument, students had to combine general prior knowledge about earth or thermal phenomena. It seems that such prior knowledge, like the differences in intensity of solar radiation at different latitudes of the earth or how the rise of the temperature affects expansion phenomena or the climate on earth, was quite limited for the majority of the students. Thus, only students who co-evaluated the information provided in the instrument and such prior knowledge reached a level of understanding of the related issues that enabled them to articulate acceptable arguments.

Thus, an overall estimation of the students' understanding of the issues related to the greenhouse effect leads to the conclusion that it was not at a satisfying level. Thus, since the understanding of a concept or phenomenon has an impact on the articulation of relevant arguments (Cetin, 2014; Garcia-Mila *et al.*, 2013), it was quite expected for the students to have problems in their argumentation. Even in cases where necessary data were available, most of the students did not exploit them to a sufficient degree, or they unsuccessfully used them, leading them to incorrect arguments. Apparently, there are a number of misconceptions held by students that contributed to this result, for instance, the aspect that the greenhouse effect causes ozone layer depletion (e.g., Niebert & Gropengießer, 2014;

Varela *et al.*, 2020). Generally, it seems that students base their arguments on what they think is logical to hold true or convenient for the articulation of a claim. Tautology seems to be convenient at this point, with the characteristic examples of the temperature rise as a consequence of the phenomenon and the pre-existing difference in temperature at different latitudes to justify the difference in the intensity (i.e., temperature) of the phenomenon at different latitudes. As Taber and Watts (2000) report, a tautological way of thinking like this is present in such circular arguments, as well as in similar efforts to explain phenomena reported as pseudo-explanations.

Furthermore, as Tables II–IV, and Figs. 2–4 show, there is a large variety in students' argumentations since there are many starting points, i.e., data and information available in the instrument and prior knowledge as well, whereas the paths from data to claim, through particular reasoning, are also differentiated. Please note that, in Task 3, this variety in articulating arguments is increased compared to those in Tasks 1 and 2, following the increasing data, information, and prior knowledge that should be co-evaluated by the students. Among those, students' prior knowledge seems to play a more significant role as we are moving to Task 3, whereas any provided information about the phenomenon itself (e.g., the capability of a greenhouse gas to increase the temperature, as presented in the experiment of Fig. 1) affects their reasoning a little or not at all. Nevertheless, taking into account the complexity of students' argument components presented in Figs. 2–4, and the fact that only a small part of students' argumentation components in each one of the tasks 1, 2, and 3 presents suitability acceptable at the school version of the scientific level (as discussed earlier), it is apparent that there is a quite extensive difficulty of the prospective preschool teachers in the development of arguments relevant to the greenhouse effect.

Consequently, it is quite obvious that there are strong indications that prospective preschool teachers face difficulties in developing arguments regarding issues related to the greenhouse effect itself and its implications for everyday life. The reasons seem to be a lack of ability to exploit data and information available, a limited background in relevant prior knowledge, and a limited development of argumentation skills. As a result, the incorporation of a more systematic teaching of argumentation in departments of preschool education, along with the teaching of the basic knowledge related to the greenhouse effect and relevant concepts, appears to be a necessity. Since a preschool teacher plays one of the most important roles in the building of the basic knowledge background of young pupils in relation to significant science concepts and phenomena, an educational system where the necessary practices to persuade young pupils of the significance of those phenomena and its implications for everyday life, should be sufficiently provided. The results of the present study advocate the aspect that one of those practices should concern the development of argumentation skills.

CONFLICT OF INTEREST

The authors declare that they do not have any conflict of interest.

REFERENCES

- Angeloudi, A., & Papageorgiou, G. (2022). Primary students' argumentation skills on evaporation: A teaching intervention. *Preschool and Primary Education*, 10(1), 1–24.
- Cetin, P. S. (2014). Explicit argumentation instruction to facilitate conceptual understanding and argumentation skills. *Research in Science & Technological Education*, 32(1), 1–20.
- Chen, H. T., Wang, H. H., Lu, Y. Y., Lin, H. S., & Hong, Z. R. (2016). Using a modified argument-driven inquiry to promote elementary school students' engagement in learning science and argumentation. *International Journal of Science Education*, 38(2), 170–191.
- Christenson, N., & Chang Rundgren, S. N. (2015). A framework for teachers' assessment of socio-scientific argumentation: An example using the GMO issue. *Journal of Biological Education*, 49(2), 204–212.
- Deng, Y., & Wang, H. (2017). Research on evaluation of Chinese students' competence in written scientific argumentation in the context of chemistry. *Chemistry Education Research and Practice*, 18(1), 127–150.
- Erduran, S., Simon, S., & Osborne, J. (2004). Taping into argumentation: Developments in the application of Toulmin's argument pattern for studying science discourse. *Science Education*, 88(6), 915–933.
- Garcia-Mila, M., Gilabert, S., Erduran, S., & Felton, M. (2013). The effect of argumentative task goal on the quality of argumentative discourse. *Science Education*, 97(4), 497–523.
- Jarrett, L., & Takacs, G. (2020). Secondary students' ideas about scientific concepts underlying climate change. *Environmental Education Research*, 26(3), 400–420.
- Koulaidis, V., & Dimopoulos, K. (2005). The co-deployment of visual representations and written language as resources for meaning making in Greek primary school science textbooks. *International Journal of Learning*, 12(10), 243–254.
- Koulaidis, V., & Tsatsaroni, A. (1996). A pedagogical analysis of science textbooks: How can we proceed? *Research in Science Education*, 26(1), 55–71.
- Liu, S. C. (2021). Using drawings to examine undergraduate students' mental models of the greenhouse effect: A factor analysis approach. *International Journal of Science Education*, 43(18), 2996–3017.
- McDonald, C. V., & McRobbie, C. J. (2012). Utilising argumentation to teach nature of science. In B. J. Fraser, K. Tobin, & C. J. McRobbie (Eds.), *Second international handbook of science education* (pp. 969–986). Netherlands: Springer.
- McNeill, K. L. (2011). Elementary students' views of explanation, argumentation, and evidence, and their abilities to construct arguments over the school year. *Journal of Research in Science Teaching*, 48(7), 793–823.
- McNeill, K. L., & Krajcik, J. (2007). Middle school students' use of appropriate and inappropriate evidence in writing scientific explanations. In M. Lovett, & P. Shah (Eds.), *Thinking with data* (pp. 233–265). Taylor & Francis.
- McNeill, K. L., & Krajcik, J. S. (2011). *Supporting Grade 5–8 Students in Constructing Explanations in Science: The Claim, Evidence, and Reasoning Framework for Talk and Writing*. Pearson Allyn & Bacon.
- McNeill, K. L., Lizotte, D. J., Krajcik, J., & Marx, R. W. (2006). Supporting students' construction of scientific explanations by fading scaffolds in instructional materials. *The Journal of the Learning Sciences*, 15(2), 153–191.
- Naylor, S., Keogh, B., & Downing, B. (2007). Argumentation and primary science. *Research in Science Education*, 37(1), 17–39.
- Niebert, K., & Gropengießer, H. (2014). Understanding the greenhouse effect by embodiment-Analyzing and using students' and scientists' conceptual resources. *International Journal of Science Education*, 36(2), 277–303.
- Osborne, J., Erduran, S., & Simon, S. (2004). Enhancing the quality of argumentation in school science. *Journal of Research in Science Teaching*, 41(10), 994–1020.
- Reinfried, S., & Tempelmann, S. (2014). The impact of secondary school students' preconceptions on the evolution of their mental models of the greenhouse effect and global warming. *International Journal of Science Education*, 36(2), 304–333.
- Sampson, V., & Clark, D. (2006). Assessment of Argument in Science Education: A Critical Review of the Literature. In S. A. Barab, K. E. Hay, & D. T. Hickey (Eds.), *Proceedings of the 7th International Conference of the Learning Sciences (Issue 1958)*, pp. 655–661). International Society of the Learning Sciences.
- Sandoval, W. A., & Millwood, K. A. (2005). The quality of students' use of evidence in written scientific explanations. *Cognition and Instruction*, 23(1), 23–55.
- Shepardson, D. P., Choi, S., Niyogi, D., & Charusombat, U. (2011). Seventh grade students' mental models of the greenhouse effect. *Environmental Education Research*, 17(1), 1–17.

- Taber, K. S., & Watts, M. (2000). Learners' explanations for chemical phenomena. *Chemistry Education Research and Practice*, 1(3), 329–353.
- Tasquier, G., & Pongiglione, F. (2017). The influence of causal knowledge on the willingness to change attitude towards climate change: Results from an empirical study. *International Journal of Science Education*, 39(13), 1846–1868.
- Toulmin, S. E. (1958). *The Uses of Argument*. Cambridge University Press.
- Toulmin, S. E. (2003). *The Uses of Argument*. Updated ed. Cambridge University Press.
- Varela, B., Sesto, V., & García-Rodeja, I. (2020). An investigation of secondary students' mental models of climate change and the greenhouse effect. *Research in Science Education*, 50, 599–624.
- Zhang, J., Tong, Z., Ji, Z., Gong, Y., & Sun, Y. (2022). Effects of climate change knowledge on adolescents' attitudes and willingness to participate in carbon neutrality education. *International Journal of Environmental Research and Public Health*, 19(17), 1–16.