A STUDY OF SCHOOL STUDENTS' KNOWLEDGE ABOUT CLIMATE CHANGE SCIENCE IN INDIA

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This paper can be considered a preliminary study to have an idea about the implementation of climate change education in India. An attempt was made to assess school students' knowledge about climate change science based on ten closed statements, some of which were part of the curriculum in some way, while the rest of the statements were related to important climate change science concepts. A comparison was also made to determine if students who have manifested interest in science have more knowledge about climate change science than the rest. The findings of the study are expected to be useful for curriculum developers and other stakeholders of school education in India to prepare a robust curriculum on climate change.

Keywords: Climate change education, climate change science, students' knowledge, curriculum

Introduction

Climate change is one of the major crises the world is facing in the 21st century (Cohen and Waddell, 2009). The challenges it poses are daunting and will continue to be a threat in the coming years and decades. It is, therefore, pertinent for the world community to come together to take the right measures and initiatives to limit, if not undo, the damage that we have brought on ourselves. This is going to be a long-drawn battle that probably will not be settled in this generation, and the struggle will be carried forward for a few more generations. Indeed mitigating climate change will happen in decadal time scales (Corner et al., 2015). In such a scenario, it is imperative that we educate our children and teenagers and sensitise them towards climate change issues as they will be responsible for dealing with the environmental and societal consequences of climate change (Kuthe et al., 2019). Students do learn about climate change from their personal experiences, imbibe from parents, teachers, and peers. Apart from all these, formal education will play a crucial role in addressing a complex and complicated issue like climate change, which stretches beyond a single industry, region, culture, or field of study. It is through education that we can ensure that there is a sustainable future for us. Although in a different context, what the former President of South Africa, Nelson Mandela, said is very relevant to climate change, "Education is the most powerful weapon to change the world" (Ratcliffe, S., 2017). The goal of such an education is that it should aid students in engaging in critical and thoughtful enquiry about the information they receive. It should act as an enabler to communities and individuals in making informed decisions in mitigating the climate

change problem and help in responding to its impeding effects (Chang and Pascua, 2017). Nobody could have put it better than UNESCO when it dubbed education as humanity's best hope of achieving sustainable development (UNESCO, 2012).

We are aware that curriculum is an important and integral part of education. The curriculum creates shared goals between teachers and students, standardises the learning for each grade, helps plan the education process or procedure, and provides a clear path for students to progress (Williams, 2019). Therefore, the quality of education imparted will depend on how robust the curriculum is. Further, Morgan and Moran (1995) elucidate that science education makes a significant difference in literacy on climate-related issues. Climate change is a buzzword today, and hence, as mentioned above, students are also informed about climate change from various sources. Keeping in view the urgency to address issues and problems related to climate change, it is necessary to prepare our students accordingly. The first and foremost task in this direction will be to provide appropriate knowledge about climate change science since this will drive students' opinions about this phenomenon and subsequently act as a driver for climate change policy development through the expression of pro-environmental constituents and behaviours (Harker-Schuch and Bugge-Henriksen, 2013; Kuthe et al., 2019). Several studies have shown that climate change education has become part and parcel of the curriculum in schools throughout the world, in some form or other (Kastens and Turrins, 2008; Chang and Pascua, 2017), including India (NCERT, 2006; NCERT, 2007; NCERT, 2008). Comprehensive studies have been conducted in many countries on the implementation of climate change in schools, as the one for the US by Plutzer et al. (2016). This paper aims to explore how much students in India know about the science related to climate change. The findings of the study will provide some insights which will be valuable to curriculum developers, educators, and other stakeholders in devising better educational programmes for a more meaningful climate change education.

Objectives of the Study

The present study was undertaken with the following objectives:

1. To find out whether school students have the basic knowledge about climate change science
2. To find out whether students with a manifested interest in science have better knowledge about climate change compared to other students

Review of Literature

A review of the literature reveals that many of the studies undertaken have been found to be on what students know about climate change or how aware they are. For example, Kuthe et al. (2019) studied the level of awareness using questionnaires that were administered to 760 teenagers (13–16 years old) from Germany and Austria. Shepardson et al. (2011) investigated students' conceptions of the greenhouse effect, global warming, and climate change by collecting qualitative data from 51 secondary students from three different schools in the midwest, USA. Further, Shepardson

et al. (2012) also conducted a study on what secondary students should know and understand about a climate system. Other studies on this aspect were also done by Boon (2010) and Liarakou et al. (2011); what are they taught, such as a study conducted by Kastens and Turrin (2008) which identified different aspects of climate change that was included in the curriculum in 49 states in the US such as the mention of anthropogenic climate change in science education standards, burning of fossil fuels as a contributor of climate change, deforestation in the context of changes to climate or atmospheres, etc.; what they want to learn as in the case of a study undertaken by Tolppanen and Aksela (2018) wherein they conducted a qualitative content analysis to examine 355 open-ended questions which were provided by 16-19-year-olds in a study to find out what students want to learn about climate change. A study in Singapore by Chang and Pascua (2017) discussed what is taught in Economics, Social studies, and Science related to climate change. Specific to India, studies have been done on the views about global warming among secondary (Chhokar et al., 2011) and senior secondary students (Chhokar et al., 2012). Many other studies point out the misconceptions (alternative conceptions) and confusions held by students on various concepts related to climate change, such as the greenhouse effect, global warming, ozone layer depletion, ozone hole, greenhouse gases, etc. (Boyes et al.,1993; Boyes and Stanisstreet, 1993; Harker-Schuch and Bugge-Henriksen, 2013; Rajeev Gowda et al., 1997; Papadimitriou, 2004; Sulistyawati et al., 2018; Bostrom et al., 1994; Read et al., 1994; Morgan and Moran, 1995; Kempton, 1991).

Methodology

Tool used

A simple questionnaire was prepared which had besides general demographic items such as class and State/UT they belong to, ten closed items (statements) related to climate change science which are given below:

1. Global warming is caused due to increase in the size of the ozone hole.
2. The incoming solar radiation has a longer wavelength than the reflected solar radiation.
3. Carbon monoxide released from vehicular exhaust contributes to climate change.
4. Chlorofluorocarbon (CFC) and water vapour are both greenhouse gases.
5. Oceans are important carbon sinks.
6. Changes in temperature over a week are due to climate change.
7. Increase in temperature contributes to sea level rise.
8. Position of Earth with respect to the Sun contributes to climate change.
9. Tsunamis are caused by climate change.
10. Greenhouse gases in the atmosphere absorb solar radiation and cause global warming.

Considering the syllabus and textbooks prepared by the National Council of Educational Research and Training (NCERT) as reference for this study, item Nos. 1, 3, 4, 6, and 10 are part of the curriculum till

Class X in some form in the textbooks, or it is expected that teachers would introduce students to such concepts. Concepts related to item No. 1 are in Science textbooks of Class VII (NCERT, 2007, p. 216), Class VIII (NCERT, 2008, p. 61, p. 73, pp. 242–243), Class IX (NCERT, 2006, pp. 198–200) and Class X (NCERT, 2007a, p. 244, p. 249, p. 279);. Item No. 3 is in Science textbooks of Class VII (NCERT, 2007, p. 216), Class VIII (NCERT, 2008, p. 61, p. 73, pp. 242–243), Class IX (NCERT, 2006, pp. 198–200), and Class X (NCERT, 2007a, p. 249, p. 279). Item No. 4 is in the Science textbooks of Class VII (NCERT, 2007, p. 216), Class VIII (NCERT, 2008, p. 61, p. 73, pp. 242–243), Class IX (NCERT, 2006, pp. 198–200), and Class X (NCERT, 2007a, p. 249, p. 279). Item No. 6 is in the Science textbook of Class VII (NCERT, 2007, pp. 68–79), and item no. 10 is in Science textbooks of Class VII (NCERT, 2007, p. 216), Class VIII (NCERT, 2008, p. 61, p. 73, pp. 242–243), Class IX (NCERT, 2006, pp. 198–200) and Class X (NCERT, 2007a, p. 244, p. 249, p. 279). In addition, students also learn about such topics in Class XII Biology (NCERT, 2007, pp. 280-281) and in some form in Geography in different classes unto Class XII. Item Nos. 2, 5, 7, 8, and 9 have been included since these will help identify their basic understanding of climate change science. Many of the concepts related to the items have also been used by different researchers in their studies. For example, item Nos. 1 (Boyes et al., 1993; Boyes and Stanisstreet, 1993; Rajeev Gowda, et al., 1997; Papadimitriou, 2004; Harker-Schuch and Bugge-Henriksen, 2013); Item No. 2 (Shepardson et al., 2011 and Shepardson et al., 2012); Item No. 4 (Harker-Schuch and Bugge-Henriksen, 2013); Item No. 7 (Sulistyawati et al., 2018); Item No. 10 (Papadimitriou, 2004). In their study about elementary science methods, students' understanding of global climate change in the US, Lambert et al. (2012) included questions related to item Nos. 1, 2, 4, 6, 7, and 8.

Two options (Yes or No) were provided to choose their response to the items (statements).

The questionnaire was anonymous. Student participation was voluntary, and consent was obtained from all participants in this research.

Sampling

Two groups of students were considered for this study. One group included 96 students who had attended Jawaharlal Nehru National Science, Mathematics and Environment Exhibition for Children (JNNSMEE) held in Ahmadabad, Gujarat, in 2018. They were grouped as "Science" for the purpose of this study. Due to their participation in this exhibition, they were considered to have manifested interest in science. National Council of Educational Research and Training (NCERT), New Delhi, an apex body for school education in India, in collaboration with various state governments, organises this prestigious exhibition every year, where students showcase their talents in science and mathematics and their applications in different areas related to everyday life through their innovative models. However, this exhibition is open only to a select few students who have been screened from the cluster-level, block-level, district-level, and state-level exhibitions. These students answered the questionnaire in pen and paper mode. The demography of the students based on their class is provided in Table 1.

Table 1
Demography of students based on their class

Sl. No.	Class	Number of students
1.	VI	1
2.	VII	4
3.	VIII	5
4.	IX	17
5.	X	21
6.	XI	17
7.	XII	31
	Total	**96**

The second group of participants included 1817 students from different schools located in different States and UTs. Since this population of 1817 was heterogenous, i.e., a different number of students in a different class, we first used stratified sampling to divide the heterogenous population into homogenous strata class-wise, and then by applying simple random sampling from these strata using Excel, we sampled 96 students to make the number of students equal in both the groups and also in terms of the number of students from a given class as listed in Table 1. This group of students was grouped as "Others" in the study. Their response was obtained online via the Survey Planet platform (149 students participated) as well as by offline mode, which was administered in schools through different state functionaries (1668 students participated) during 2018–19.

Analysis of data

Objective 1 was inspected within each group of students, and Objective 2 was examined between the two groups of students —"Science" and "Others."

A simple statistical analysis was done to find out the performance of students in terms of correct or incorrect responses, and a T-test was employed to compare the performance of the two groups of students in the study for which online tools available on different websites were used such as in easycalculation.com and graphpad.com.

Results and Discussions

I. Results and discussions are provided herewith based on objectives. The first objective of the study was to find out whether students have the basic knowledge related to climate change science. For this, we calculated the performance of the students in terms of the number of students whose responses were correct or incorrect, as provided in Table 2 and Fig. 1.

As we can see in Table 2, except for items Nos. 2, 6, and 9, more than 50 per cent of students (Overall) responded correctly for all the items, with the percentage as high as 78.5, 80 and 78 for item nos. 3, 7 and 10, respectively.

Table 2
Knowledge of students about climate change science based on their response

Item No.	Correct response			Incorrect response		
	Science (%)	Others (%)	Overall (%)	Science (%)	Others (%)	Overall (%)
1.	80 (83)	24 (25)	104 (54)	16 (17)	72 (75)	88 (46)
2.	54 (52)	30 (31)	84 (41.5)	42 (48)	66 (69)	108 (58.5)

3.	86 (90)	64 (67)	150 (78.5)	10 (10)	32 (33)	42 (21.5)
4.	58 (60)	59 (61)	117 (60.5)	38 (40)	37 (39)	75 (39.5)
5.	74 (77)	58 (60)	132 (68.5)	22 (33)	58 (40)	80 (36.5)
6.	35 (36)	28 (29)	63 (32.5)	61 (64)	68 (71)	129 (67.5)
7.	81 (84)	73 (76)	154 (80)	15 (16)	23 (24)	38 (20)
8.	65 (68)	69 (72)	134 (70)	31 (32)	27 (28)	58 (30)
9.	42 (44)	41 (43)	83 (43.5)	54 (56)	55 (57)	109 (56.5)
10.	83 (80)	73 (76)	156 (78)	13 (20)	23 (24)	36 (22)

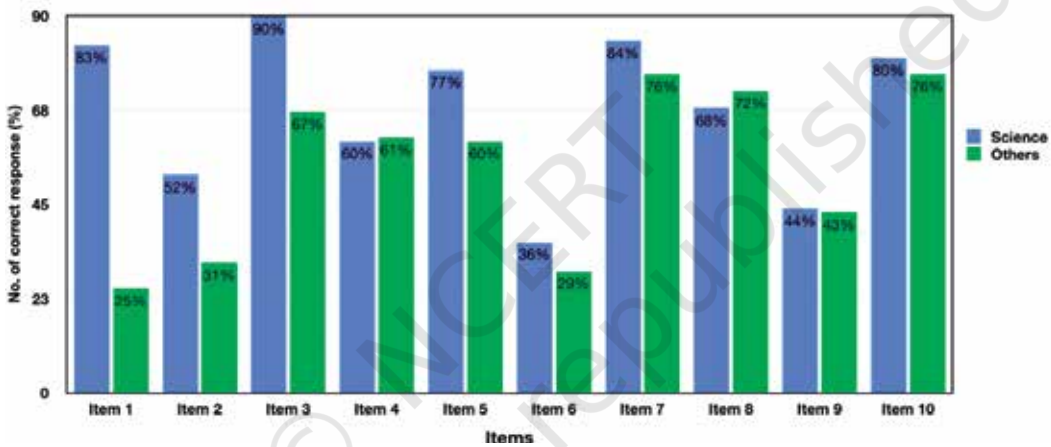

Fig. 1 Item-wise comparison of students' response

The low percentage of the correct answer of Overall students for item no. 1 (54%) with an even lower percentage (25%) amongst "Others" is found to be in line with the previous studies (Boyes et al., 1993; Boyes and Stanisstreet, 1993; Rajeev Gowda et al., 1997, Leiserowitz, 2006; Grant and Featherstone, 2009; Boon, 2010; Liarakou et al., 2011; Shepardson et al., 2012; Lambert et al., 2012; Harker-Schuch and Bugge-Henriksen, 2013; Tolppanen and Aksela, 2018). In most cases, this is largely attributed to the misconception held by students that the ozone hole lets more radiation from the sun to enter the atmosphere, thereby warming the Earth, or due to the trapping of solar radiation by the ozone layer, which causes global warming (Koulaidis and Christidou, 1999). Since the concept related to the item is expected to have been studied by students as part of their curriculum, a correct response would have been expected, which is not the case. However, the performance of the Science group was found to be very good, with 83 per cent having correctly answered. This could be due to a clearer understanding of the concept due to their natural inclination to Science.

For item no. 2, only 41.5 per cent of students (Overall), 52 per cent (Science), and 31 per cent (Others) gave the correct answer. This could be because most students are unfamiliar with the concept since it is not part of their curriculum. A study conducted by Papadimitriou (2004) found that none of the students in his study made any connection with the long-wave radiation emitted from the Earth's surface when describing the process of the greenhouse effect. This explains the importance of having a clear idea about various radiations in order to understand climate change. Shepardson et al. (2011, 2012) also found a lack of understanding about different radiations amongst secondary students in their study to prepare a climate system framework. Boyes and Stanisstreet (1997, 1998), in their studies among the 13-14-year-olds, also found a stark lack of clarity about UV-rays and heat rays. Koulaidis and Christidou (1999) also found a lack of clarity on the part of students about the nature of radiations, although the participants of their study belonged to 11–12 years. The lack of understanding about the types of radiations and their role in the greenhouse effect was also pointed out by Lambert et al. (2012) in their study about elementary science methods students' understanding of global climate change in the US. This reveals the need to include basic concepts of the electromagnetic spectrum, their source (active and passive) as well as wavelength with more thrust in the curriculum.

Students performed well for item no. 3 as we look at the number of students who responded correctly (Overall = 78.5%; Science = 90%; Others = 67%). This could be attributed to their exposure to this concept at some point in their curriculum. Earlier studies have not specifically focused on this concept while conducting studies on school students' knowledge about climate change.

For item no. 4, students were found to perform decently considering the number of students who responded correctly (Overall = 60.5%; Science = 60%; Others = 61%). Again, this could be attributed to their exposure to this concept at some point in their curriculum. Earlier studies (Harker-Schuch and Bugge-Henriksen, 2013; Boon, 2010; Lambert et al., 2012) have also included this aspect, and it was observed that students lacked clarity regarding the types of greenhouse gas and their role in the greenhouse effect or global warming.

Similarly, students have performed well for item no. 5 with the correct response in the order of Overall = 68.5%; Science = 77%; Others = 60%). Although this is not directly part of their curriculum, it is likely that students have been exposed to this concept from other sources such as print and electronic media (Carbon Sources and Sinks, National Geographic Society, n.d.), talks by scientists, and public conversations.

Item no. 6 is fundamental to understanding climate change. Yet it is discouraging to find that the least number of students responded correctly of all the items (Overall = 32.5%; Science = 36%; Others = 29%). As is evident from the result, Science students performed equally poorly. The result is more surprising because this concept is dealt with in detail in the curriculum in Class VII based on the NCERT syllabus and textbook. It is also disappointing because this concept is fundamental if one has to understand climate change. However, this confusion was also observed even amongst student-teachers (Lambert et al., 2012).

Although item no. 7 is not directly part of the curriculum, most of the students responded correctly (Overall = 80%; Science = 84%; Others = 76%). Similar results are found in a study conducted amongst adolescents in Indonesia (Sulistyawati et al., 2018). Boon (2010), Shepardson et al. (2011), and Liarakou et al. (2011) also found similar results but with varying degrees. This could be because of the popularity of the idea of sea level rise with climate change. However, Lambert et al. (2012) found a lack of clarity amongst student-teachers on the cause of sea level rise.

Most of the students responded correctly (Overall = 70%; Science = 68%; Others = 72%) for item no. 8. Although this is not directly part of the curriculum in terms of climate change, students study about the position of the sun, rotation, and revolution of the Earth in Geography through which they would have gained some idea. In one of their questions to find out the cause of changing seasons on Earth from student-teachers, Lambert et al. (2012) also found similar results (94%), indicating that natural reasons for climate change are a relatively easy concept to grasp.

For item no. 9, less than 50 per cent of students responded correctly (Overall = 43.5%; Science = 44%; Others = 43%). This could be because the concept is not part of the curriculum. However, this observation to relate Tsunamis with climate change is not uncommon. Lambert et al. (2012) also found in their study that many student-teachers had also linked the two phenomena. That "Tsunamis are caused by climate change" could also be considered a misconception held by students.

Of all the items in the questionnaire, maximum number of students responded correctly to item no. 10 (Overall = 78%; Science = 80%; Others = 76%). This could be because the concept is included at some stage in the curriculum. Whatever the reason for their knowledge, it is an important finding because at least we can conclude that students know that greenhouse gases are responsible for global warming. The concept related to this was also included by Papadimitriou (2004) in a study related to climate change.

As we observed in the result, students generally have some knowledge about climate change science, although a much better performance would have been encouraging. The fact that students did not have extensive knowledge about climate change science could be because the existing curriculum is not robust enough to drive students to be climate literate. It is important to mention here that the existing NCERT syllabus (NCERT, 2005; NCERT, 2005a) and textbooks were prepared from 2006 to 2008 (NCERT, 2006; NCERT, 2007; NCERT, 2007a; NCERT, 2007b; NCERT, 2008). The focus on climate change then and now has changed drastically, with tremendous attention shifting towards climate change today. In addition, the major misconceptions that seem to exist among Indian students based on the result are a major concern. However, such misconceptions are commonly found to exist amongst students globally, as we have discussed in some cases earlier. Curriculum developers and other stakeholders may take note of such misconceptions so that the resources that are developed address those concerns or that teachers are prepared accordingly. Besides such items, which indicate misconceptions, the remaining items

included in the questionnaire are equally important to be addressed in the curriculum since they are crucial for understanding climate change science. As mentioned earlier, appropriate knowledge and views about climate change are crucial for the expression of pro-environmental constituents and behaviours amongst students (Harker-Schuch and Bugge-Henriksen, 2013; Kuthe et al., 2019).

II. The second objective was to find out whether students from "Science" (students with a manifested interest in Science) have better knowledge about climate change compared to "Others" (randomly selected students from different states and UTs).

For this, we performed a t-test to compare the response of the two groups of students—"Science" and "Others."

The null hypothesis for this study is that the two groups of students have equal knowledge about climate change science. The alternative hypothesis is that both groups of students have different knowledge about climate change science.

Level of significance: α=0.05

We found the p-value of the t-test to be 0.0501, which is slightly more than α=0.05 (i.e., p $\rightarrow$ .05) (Table 2). This means that the null hypothesis cannot be rejected, i.e., the difference in the knowledge about climate change science in both the groups of students—"Science" and "Others" is not quite statistically significant.

It can be concluded that "Science" students (students with a manifested interest in science) do not have better knowledge about climate change science compared to "Others" students.

It was expected that the performance of "Science" students would be better and statistically significant compared to students from the group "Others" because "Science" students have manifested interest in science, and hence one would expect them also to show an inclination to learn about climate change science. However, the result from the study did not validate the same. This also indicates, to some extent, that the source of information whatsoever for all the students on climate change may be similar. Unfortunately, there are limited research on the sources of information from where students or teachers learn about climate change. Nevertheless, we can list some general sources of information such as the Internet; government sources; mass media (print and electronic); and professional development courses, and most importantly, for students, it is the teachers who serve as the major source of information. Therefore, teachers play an important role in transmitting information, knowledge, and skills related to climate change, and rightly so, teachers have been described as 'gatekeepers of information (Kunkle and Monroe, 2019). Consequently, it becomes important to understand teachers' source of information since this will impact their interaction with students. It is also crucial for teachers to have expertise in the subject since this will help them filter information appropriately, which are available on different platforms or sources (McNeal et al., 2017). At the same time, there is a need to re-visit the curriculum content with regard to climate change.

Table 2
T-test to compare the response of the two groups of students—"Science" and "Others"

Variable	Mean	Standard Deviation	SEM	95% Conf. Interval
Science	5.75	1.49385	0.1524654	-0.0001999 0.8335399
Others	5.33333	1.43392	0.1463488	
Mean (diff) = Mean (Science - Others) = 0.4166700				
t = 1.9716				
Df = 190				
Standard error of the difference of means of samples = 0.211				
P value = 0.0501				

Conclusion

The present paper can be considered a preliminary study to assess the implementation of climate change education in India. From the study, we can conclude that climate change education is undoubtedly part of the curriculum, but much is wanting for its effective and meaningful implementation. The study also revealed that the greenhouse effect and global warming have been included in several places in the curriculum from Class VI to XII. However, the result revealed that inclusion of the concept did not lead to an understanding of the concept. This is despite the fact that most students who participated in the study belonged to higher classes (above Class VIII) and, therefore, have been introduced to climate change-related concepts over the years in their curriculum. It is worth mentioning here that in many instances, the concepts were merely included as a passing statement and, therefore, are left to the mercy of the teachers to teach the way she/he best perceives. In addition, many important concepts related to climate change that were included in the study are yet to find a place in the curriculum. Therefore, the first step in the direction of climate change education will begin with the systematic inclusion of appropriate concepts and contents in the curriculum in different classes and subjects. Towards this end, the development of appropriate resources which are contextualised, relevant and relatable to students will be crucial. Along with this, the preparation of teachers and their professional development must also be prioritised, which caters to climate change education. Moreover, the National Education Policy-2020* also focuses on, and is committed to, achieving the different targets of Sustainable Development Goals (SDGs), of which, climate is a major area with direct relation to Goal 13: Climate Action and also linked with all other SDGs as well. The role of curriculum developers, policymakers, teacher educators, teachers, and other stakeholders will be indispensable for its successful implementation.

*The original reference was Draft NEP-2019 but by the time of publication of this issue, NEP-2020 was published and hence modified accordingly.

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