A COMPARATIVE STUDY OF KNOWLEDGE AND BELIEFS ON CLIMATE CHANGE AMONG TEACHERS IN INDIA AND THE UNITED STATES

Chong Shimray[1]*, Jubilee Padmanabhan[2] and Pragya[2]**

[1]Department of Education in Science and Mathematics (DESM)
National Council of Educational Research and Training (NCERT)
New Delhi, India
[2] Department of Education
Central University of Punjab
Punjab, India

****Present Address:** DESM, NCERT, New Delhi, India
***Corresponding author Email:** cshimray@gmail.com

Climate change is a major concern globally due to the unprecedented increase in environmental degradation due to unsustainable production, consumption, disposal, transportation, etc., resulting in environmental changes in the form of global warming and the chain of impacts it has on the atmosphere, oceans, life, livelihood, health, agriculture, etc. It is a threat not only to the human population but also to all the creatures on the planet Earth. The impact of climate change is manifested in various forms such as heavy rain and flood, flash floods, earthquake, severe drought, more intense cyclones, extreme summers and winters, acid rain, to list a few. The present paper aims to compare the knowledge and beliefs on climate change of teachers with respect to their country of origin, level of teaching and the subject they teach. It also explores whether knowledge on climate change is a predictor of beliefs on climate change and vice versa. The data was collected from teachers teaching in the schools of India and the United States, i.e., 1013 teachers who were teaching in India and 323 teachers teaching in the United States. The data was collected using a knowledge test on climate change and a scale on beliefs on climate change. The data was analysed using statistical tool and is presented in the paper. The findings will provide a baseline information about the professional development programmes that can be taken up for teachers and at the same time give some direction to the curriculum developers and policy makers while taking decisions.

Keywords: Climate change, Knowledge, Beliefs, Teachers, Predictor, Professional Development and Training

Introduction

United Nations (n.d.) defines climate change as "long-term shifts in temperatures and weather patterns that can be natural, but since the 1800s, human activities have become the main drivers of climate change, primarily due to the burning of fossil fuels." The high levels of greenhouse gases in the atmosphere are considered to be a significant cause of climate change, which has had both natural and human contributions, where nature contributes by the emission of carbon dioxide (CO_2) by volcanos and, in the case of humans, the myriad of human activities like energy production, agricultural uses, industrial processes and transportation, that involve the use of fossil fuels like coal, oil, natural gas, etc., releases greenhouses gases

like carbon dioxide (CO_2) and methane into the atmosphere (Kaddo, 2016). Other natural causes of climate change include fluctuations in solar radiation, earth's orbital changes, etc. Further, human activities like deforestation, increased livestock farming, use of fertilisers containing nitrogen and the emissions of fluorinated gas are the causes of increased greenhouse gas emissions (European Commission, n.d.). The impacts of climate change are severe as warmer temperatures can increase health risks, especially in young children and the elderly and increase the spread of certain diseases; the rise in sea level is a threat to coastal ecosystems, and changes in rainfall patterns can affect water supplies and water quality; changes in ecosystems due to climate change affect the life cycle of many plants and animals and finally, it causes extreme weather changes giving rise to calamities like droughts and floods, causing disruption to the society (United States Environmental Protection Agency, n.d.).

Climate change is a pressing global issue with long-term consequences for the world. Individuals often relate to climate change based on personal experience, education, cost-benefit analysis and trust in social actors (Lorenzoni and Pidgeon, 2006). They may have differences in beliefs, opinions and perceptions regarding climate change and teachers' knowledge, beliefs and conceptions are considered to be essential, as teachers are the primary agents of change and can play a significant role in inculcating knowledge regarding climate change in learners. It has been observed that science teachers' beliefs that global warming is real and strongly predicted students' beliefs in the same (Stevenson *et al.,* 2016). Engaging in public discourse is positively linked to a strong belief in the reality of climate change (Shreck and Vedlitz, 2016). It has also been seen that pre-service teachers have low awareness and knowledge of climate change, as pre-service training programmes cannot include climate change education in their programmes (Competente, 2019). Moving towards the knowledge, beliefs and attitude of teachers towards climate change, teachers might understand the anthropogenic nature of climate change but still have little knowledge regarding the consequences and hold many misconceptions about the issue; however, a significant correlation exists between the knowledge regarding climate change and readiness to take action to slow it down (Seroussi *et al*., 2019). In a study conducted on Native American teachers, it was found that there were even teachers who were concerned about climate change held misconceptions about the same, indicating that teachers' attitudes and beliefs about global climate change may not be strong indicators of their level of knowledge, opening a discussion on the relationship between the beliefs and attitudes of the teachers and their knowledge regarding such environmental issues (Liu *et al.,* 2015). However, in another study, it was found that pre-service teachers had a low understanding of the impact of mitigative actions for climate change and because of this, no correlation between knowledge of the impact of actions and readiness to act was found, but when it came to confidence in the knowledge regarding mitigative actions for climate change the pre-service teachers had, it somewhat correlated with readiness to act for climate change (Tolppanen *et al.,* 2021).

In the context of the USA, while exploring the conceptions of climate change in science teachers, it was found that they had a naïve understanding of climate change and climate change science and neglected the social, political and economic dimensions of climate change in their teaching (Herman *et al.,* 2017). The issue of climate change has remained highly politicised in the US, and it was seen that science educators' support of climate change education and preferences in curricula content is influenced by the educators' cultural values (Kunkle and Monroe, 2019). Further, a significant relationship exists between the political views of the teachers and their beliefs in scientific consensus regarding the anthropogenic causes of climate change (Khalidi and Ramsey, 2021). The complex and controversial nature of climate change science influences the nature of instructional strategies utilised by teachers, even if the teacher has a strong belief in climate change, which may lead to confusion related to the concepts of climate change (Nation and Feldman, 2022).

From the above, it can be concluded that teachers' beliefs can influence the learners' beliefs; at the same time, there seems to be some association between the knowledge of climate change and beliefs in climate change among teachers, but in most cases, the knowledge may be marred with misconceptions. Further, in the context of the USA, it has been suggested that teachers have a limited understanding of climate change; the teachers' beliefs regarding the issue are rooted in the cultural context and political views they hold. There has also been a lack of studies from the Indian viewpoint on teachers' beliefs and knowledge of climate change.

From review of literature, it was also observed that there have been no studies undertaken to compare the beliefs and knowledge of teachers of India and the United States and to know the predictors of knowledge and beliefs on climate change. Further, keeping in view the much higher per capita emission of greenhouse gases in the United States (14.44 t CO_2) compared to India (1.69 t CO_2), it is necessary that United States takes a more stringent measures to reduce emissions. At the same time, since India is also a developing country, its per capita emission of greenhouse gases is also increasing and will continue to increase during the course of its development which is energy-intensive. Therefore, it is crucial for both the countries to empower its citizens with the appropriate knowledge and skills which is best done through education. However, as one would expect, teaching about climate change will be influenced by teachers' knowledge and beliefs. Hence, the present study tries to find out if the knowledge of climate change is a predictor of the beliefs in climate change among teachers in India and the USA and vice versa. This study will also provide some useful information on the need for professional development for teachers to enhance their attitudes and knowledge about climate change. The findings of the study will also be useful for curriculum developers and policy makers for climate change education.

The objectives of the study and the hypotheses associated with them are provided below.

Objectives of the Study

1. To compare the beliefs and knowledge of the teachers of India and the United States on climate change based on

parameters such as the subject and stage they teach

2. To find out whether knowledge on climate change is a predictor of beliefs on climate change among the teachers of India and the United States
3. To find out whether beliefs on climate change is a predictor of knowledge on climate change among the teachers of India and the United States
4. To identify the training needs on climate change for teachers of India and the United States

Hypotheses

1. The beliefs of the teachers of India and the United States on climate change do not differ significantly.
2. The knowledge of the teachers in India and the United States on climate change do not differ significantly.
3. There is no significant difference in the knowledge on climate change of science and non-science teachers from India and the United States.
4. There is no significant difference in the knowledge on climate change of elementary and secondary teachers from India and the United States.
5. There is no significant difference in the beliefs on climate change of science and non-science teachers from India and the United States.
6. There is no significant difference in the beliefs on climate change of elementary and secondary teachers from India and the United States.
7. Knowledge on climate change is a significant predictor of beliefs on climate change among the teachers of India and the United States.
8. Beliefs on climate change is a significant predictor of knowledge on climate change among the teachers of India and the United States.

Methodology

The present study adopts the survey method of descriptive research for collecting the data. A convenience sampling technique was used for collecting the data. The data was collected using online mode as well as in hard copies. For the online mode, Survey Planet and Qualtrics Survey softwares were used. There were a total of 1336 teachers, out of which 1013 teachers were from India and 323 teachers were from the United States. Out of 1013 teachers from India, 93 filled on the Survey Planet platform while all 323 teachers from the United States filled using the Qualtrics Survey platform. In order to ensure honest response, an anonymous survey was conducted.

Tool

The tool used for the study can be broadly grouped into two parts namely, the test of knowledge on climate change and the scale on beliefs on climate change. These two tools were used for collecting the data. In the test of knowledge on climate change there were 17 items having three options as 'Yes', 'No', 'Not sure'. The correct answers were given a score of one and wrong answers were scored as zero, whereas, the scale on beliefs about climate change had 14 items (Appendix 1) on a five-point Likert scale having the scales

as 'Strongly agree', 'Agree', 'Undecided', 'Disagree', 'Strongly Disagree'. There were nine items that were positive and five items as negative items. The positive items were scored as 5, 4, 3, 2, 1 for 'Strongly agree', 'Agree', 'Undecided', 'Disagree', 'Strongly Disagree', respectively and the negative items were scored as 1, 2, 3, 4, 5 for 'Strongly agree', 'Agree', 'Undecided', 'Disagree', 'Strongly Disagree', respectively.

The items for the tool were prepared keeping in view the following parameters or criteria:

1. For the knowledge-based questions, basic or fundamental concepts related to climate change which a teacher need to know to effectively transact climate change were considered.
2. For beliefs-based questions, the following two parameters were considered: (i) teachers' beliefs about climate change as a critical global issue, and (ii) teachers' beliefs about climate change education.

A few other questions were included pertaining to general information about teachers' profession and their professional needs related to climate change. The complete tool administered for the study is provided as appendix.

Results

Based on the four objectives mentioned earlier, the results are being presented under the following heads:

1. Comparison in the beliefs of the teachers in India and the United States on climate change
2. Comparison in the beliefs of the science and non-science teachers in India and the United States on climate change
3. Comparison in the beliefs of the Elementary and Secondary teachers of India and the United States on climate change
4. Knowledge of the teachers in India and the United States on climate change
5. Comparison on the knowledge in the teachers of India and the United States on climate change
6. Comparison on the knowledge of the science and non-science teachers in India and the United States on climate change
7. Comparison in the knowledge of the elementary and secondary teachers of India and the United States on climate change
8. Knowledge on climate change as a predictor of beliefs on climate change among the teachers of India and the United States
9. Beliefs on climate change as a predictor of knowledge on climate change among the teachers of India and the United States
10. Requirement of professional development on climate change for teachers of India and the United States

1. Comparison in beliefs of teachers in India and the United States on climate change

In order to test the hypothesis, independent sample t-test was used by comparing the scores obtained on the beliefs on climate

Table 1: Difference in the Beliefs on Climate Change in US and Indian Teachers

Teachers (Country)	N	Mean	SD	t-value	df	Level of Significance
Indian Teachers	903	54.22	5.05	8.829	1215	0.00
US Teachers	314	57.26	5.79			

change of US and Indian school teachers. The results of the analysis are presented in Table 1.

Out of the total 1013 Indian teachers and 323 US teachers, few teachers were excluded as their data was incomplete and hence finally only 903 Indian teachers and 314 US teachers were considered for the analysis. From Table 1, it is observed that the mean score on beliefs on climate change of Indian teachers and US teachers are 54.22 and 57.26, respectively. It is also found that the standard deviation of scores on beliefs on climate change of Indian teachers and US teachers are 5.05 and 5.79, respectively. The t-value was found to be 8.829 which is significant at 0.05 level of significance. Hence, the null hypothesis stating that the beliefs on climate change of the teachers of India and the United States do not differ significantly is rejected and an alternative hypothesis stating that there is a significant difference in the beliefs on climate change between the teachers of India and the United States is accepted. Table 1 also reveals that the mean score of teachers of the United States is higher than that of Indian teachers which means that the teachers of the Unites States have a stronger belief about climate change than the Indian teachers.

2. Comparison of beliefs of science and non-science teachers of India and the United States on climate change

In order to test the hypothesis, independent sample t-test was used by comparing the scores obtained on the beliefs on climate change of science and non-science teaching teachers in US and India. The results of the analysis are presented in Table 2.

Table 2: Difference in the Beliefs on Climate Change of Science and Non-science Teachers from India and the United States

Category of Teachers	N	Mean	SD	t-value	df	Level of Significance
Non-science teachers	793	53.89	5.66	6.934	1196	0.00
Science teachers	405	56.27	5.54			

Out of a total of 1336 teachers, few teachers were excluded as their data was incomplete and hence, finally only 1198 teachers (793 non-science teachers and 405 science teachers) were considered for the analysis. From Table 2, it is observed that the mean score of beliefs on climate change of non-science and science teachers are 53.89 and 56.27, respectively. It is also found that the standard deviation of scores of beliefs on climate change of non-science and science teachers are 5.66 and 5.54, respectively. The t-value was found to be 6.934 which is significant at 0.05 level of significance. Hence, the null hypothesis stating that there is no significant difference

in the beliefs on climate change of science and non-science teachers from India and the United States is rejected and an alternative hypothesis stating that there is a significant difference in the beliefs on climate change of science and non-science teachers from India and the United States is accepted. Table 2 also reveals that the mean score of science teachers is higher than that of non-science teachers which means that the science teachers have a stronger belief about climate change than the non-science teachers.

Out of the total of 1336 teachers, few teachers were excluded as their data was incomplete and hence finally only 1278 teachers (388 elementary teachers and 890 secondary teachers) were considered for the analysis. From Table 3, it is observed that the mean score of beliefs on climate change of elementary and secondary teachers are 54.22 and 54.88, respectively. It is also found that the standard deviation of scores of beliefs on climate change of elementary and secondary teachers are 6.11 and 5.53, respectively. The

Table 3: Difference in the Beliefs on Climate Change of Elementary and Secondary Teachers from India and the United States

Teaching Level	N	Mean	SD	t- value	df	Level of Significance
Elementary level	388	54.22	6.11	1.901	1276	0.058
Secondary level	890	54.88	5.53			

3. Comparison in beliefs of Elementary and Secondary teachers of India and the United States on climate change

Since levels are named differently in India and the US, here, the term 'Elementary teachers' represent those teaching at the Elementary level (Class I –VIII) in India and those teaching at the Elementary (Class I–V) and Middle level (Class VI–VIII) in the US. While the term Secondary teachers, here, represent those teachers teaching at the Secondary (Class IX–X) and Higher Secondary level (Class XI–XII) in India and those teaching at the High School (Class IX–XII) in the US.

In order to test the hypothesis, independent sample t-test was used by comparing the scores obtained on the beliefs on climate change of elementary and secondary teachers in the US and India. The results of the analysis are presented in Table 3.

t-value was found to be 1.901 which is not significant at 0.05 level of significance. Hence, the null hypothesis stating that there is no significant difference in the beliefs on climate change of elementary and secondary teachers from India and the United States is accepted. Hence, the elementary and secondary teachers have equal belief about climate change.

4. Knowledge of teachers of India and the United States on climate change

From the item-wise analysis of the test on knowledge on climate change as provided in Table 4, it was found that for the item 'Greenhouse gases in the atmosphere trap the ultraviolet rays reflected from the earth thus causing global warming', majority of the US and Indian teachers answered incorrectly. It may be because of their lack of content clarity with respect to the nature of solar radiation and its property resulting in

Table 4: Analysis of the Response on Knowledge on Climate Change of Teachers of India and the United States

Item No.	Item	Country	Yes	No	Not sure
1.	Greenhouse gases in the atmosphere trap the ultraviolet rays reflected from the earth thus causing global warming.	India	81.20%	10.53%*	6.9%
		US	66.11%	10.19%*	12.12%
2.	Water vapour is a potential Greenhouse gas but is not considered seriously because of its short life cycle in the atmosphere.	India	67.52%*	13.48%	15.35%
		US	36.36%*	16.25%	35.81%
3.	Methane has more heat-trapping ability per molecule than carbon dioxide.	India	55.94%*	18.21%	24.3%
		US	50.69%*	3.31%	35.26%
4.	Greenhouse gases are essential to sustain life on earth.	India	70.18%*	17.03%	10.97%
		US	56.75%*	6.89%	25.07%
5.	Chlorofluorocarbon is an ozone layer destructor and also a Greenhouse gas.	India	82.87%*	4.04%	10.77%
		US	49.59%*	8.82%	30.3%
6.	The reradiated solar radiation has a shorter wavelength than the incoming solar radiation.	India	41.93%	17.22%*	36.66%
		US	17.36%	12.40%*	58.4%
7.	Increase in Greenhouse gases in the atmosphere enhances melting (thawing) of permafrost releasing additional carbon dioxide and methane into the atmosphere.	India	67.22%*	8.07%	20.95%
		US	62.53%*	2.20%	23.42%
8.	Albedo effect is a measure of the reflectivity of a surface such as snow, rooftops, buildings, etc.	India	49.70%*	12.70%	31.92%
		US	40.50%*	0.55%	46.56%
9.	Seawater becomes more basic due to absorption of carbon dioxide.	India	37.99%	30.91%*	27.17%
		US	12.12%	32.78%*	42.98%
10.	Earth's ocean has been able to absorb and hold a majority of the heat from Earth's atmosphere due to its high heat capacity.	India	64.86%*	11.61%	19.76%
		US	45.18%*	6.06%	36.09%

11.	El Nino is a phenomenon caused by global warming.	India	61.02%	13.09%*	22.23%
		US	24.24%	45.45%*	18.46%
12.	Melting sea ice has the potential to raise sea level by several feet.	India	80.71%	7.87%*	9.19%
		US	71.35%	8.82%*	7.99%
13.	Reflectivity of ice caps and ice sheets are reduced due to algae formation thereby increasing atmospheric temperature.	India	54.92%*	13.39%	27.96%
		US	23.97%*	14.05%	49.59%
14.	Thermohaline circulation refers to deep-ocean currents driven by differences in the water's density which is controlled by temperature and salinity.	India	56.59%*	5.91%	32.94%
		US	36.91%*	1.65%	48.21%
15.	Changes in plate tectonics, changes in earth's orbit, and changes in sun's strength are the natural causes of climate change.	India	56.79%*	20.08%	19.37%
		US	38.02%*	17.91%	31.68%
16.	Thermal expansion of sea water along with glacier melting causes sea level rise.	India	82.97%*	5.51%	8.50%
		US	59.23%*	4.41%	23.69%
17.	Oceans are important carbon sinks.	India	58.07%*	13.48%	23.9%
		US	47.93%*	1.65%	38.29%

**Correct answer*

their inability to differentiate the properties of infrared rays and ultraviolet rays and their roles in global warming. For the item 'Water vapour is a potential Greenhouse gas but is not considered seriously because of its short life cycle in the atmosphere' many US teachers were not sure about the answer. This also shows that there is lack of content clarity with respect to the contribution of various greenhouse gases on global warming. Many of the US teachers have also answered as 'not sure' for the item 'Methane has more heat-trapping ability per molecule than carbon dioxide'. Majority of the Indian teachers answered incorrectly for the item 'The reradiated solar radiation has a shorter wavelength than the incoming solar radiation' whereas majority of the US teachers answered as 'not sure' for the same item both indicating their lack of content knowledge. For the item 'Albedo effect is a measure of the reflectivity of a surface such as snow, rooftops, buildings, etc.', which is a simple and basic concept related to global warming, majority of the US teachers were not sure about the answer. For the item, 'Seawater becomes more basic due to absorption of carbon dioxide' majority of the Indian teachers answered incorrectly and majority of the US teachers answered as 'not sure' for the item. It shows that teachers lack even a basic chemistry knowledge about

reactions. Majority of the Indian teachers answered incorrectly for an item 'El Nino is a phenomenon caused by global warming' and El Nino is not directly associated with global warming, but it is when the sea water gets warm up along the equator. A vast majority of the teachers answered incorrectly for the item 'Melting Sea ice has the potential to raise sea level by several feet.' It may be because the teachers lack clarity with respect to melting of land ice and sea ice as the melting of land ice causes the sea level to increase, but in case of sea ice, the volume of water they displace as ice is about the same as the volume of water they add to the ocean when they melt. As a result, sea level does not rise when sea ice melts. For the items 'Reflectivity of ice caps and ice sheets are reduced due to algae formation thereby increasing atmospheric temperature'. 'Thermohaline circulation refers to deep-ocean currents driven by differences in the water's density which is controlled by temperature and salinity' and 'Oceans are important carbon sinks', majority of the US teachers were not sure of the correct answer.

There was a total of 1336 teachers (1013 Indian teachers and 323 US teachers) whose data was considered for the analysis. From Table 5, it is observed that the mean score of knowledge on climate change of Indian teachers and US teachers are 8.51 and 7.39, respectively. It is also found that the standard deviation scores of knowledge on climate change of the Indian teachers and that of the teachers of the United States are 3.01 and 4.52, respectively. The t-value was found to be 5.128 which is significant at 0.05 level of significance. Hence, the null hypothesis stating the knowledge on climate change of the teachers of India and the United States do not differ significantly is rejected. And an alternative hypothesis stating that there is a significant difference in the knowledge on climate change between the teachers of India and the United States is accepted. Table 5 also reveals that the mean score of the Indian teachers is higher than that the teachers of the United States, which means that the Indian teachers have a higher awareness or knowledge about climate change than the teachers from the United States.

Table 5: Difference in the Knowledge on Climate Change in US and Indian Teachers

Teachers (Country)	N	Mean	SD	t-value	df	Level of Significance
Indian Teachers	1013	8.51	3.01	5.128	1334	0.00
US Teachers	323	7.39	4.52			

5. Comparison of knowledge of teachers of India and the United States on climate change

In order to test the hypothesis, independent sample t-test was carried out by comparing the scores obtained on the test of knowledge on climate change of the teachers in India and the United states. The results of the analysis are presented in Table 5.

6. Comparison of knowledge of science and non-science teachers of India and the United States on climate change

In order to test the hypothesis, independent sample t-test was used by comparing the scores obtained on the knowledge on climate change of science and non-science teaching teachers in India and the United States. The results of the analysis are presented in Table 6.

Table 6: Difference in the Knowledge on Climate Change of Science and Non-science Teachers from India and the United States

Category of Teachers	N	Mean	SD	t- value	df	Level of Significance
Non-science Teachers	793	7.61	3.33	13.52	1196	0.00
Science Teachers	405	10.20	2.74			

Out of the total of 1336 teachers, few teachers were excluded as their data was incomplete and hence finally only 1198 teachers (793 Non-science teachers and 405 science teachers) were considered for the analysis. From Table 6, it is observed that the mean score of knowledge on climate change of non-science and science teachers are 7.61 and 10.20, respectively. It is also found that the standard deviation of scores of knowledge on climate change of non-science and science teachers are 3.33 and 2.74, respectively. The t-value was found to be 13.52 which is significant at 0.05 level of significance. Hence, the null hypothesis stating that there is no significant difference in the knowledge on climate change of science and non-science teachers from India and the United States is rejected and an alternative hypothesis stating that **there is a significant difference in the knowledge on climate change of science and non-science teachers from India and the United States** is accepted. Table 6 also reveals that the mean score of science teachers is higher than that of non-science teachers, which means that the science teachers have a better knowledge about climate change than the non-science teachers.

7. Comparison of knowledge of elementary and secondary teachers of India and the United States on climate change

Since levels are named differently in India and the US, here, the term 'Elementary teachers' represent those teaching at the Elementary level (Class I–VIII) in India and those teaching at the Elementary (Class I–V) and Middle level (Class VI–VIII) in the US. While the term *Secondary teachers,* here, represent those teachers teaching at the Secondary (Class IX–X) and Higher Secondary level (Class XI–XII) in India and those teaching at the High School (Class IX–XII) in the US.

In order to test the hypothesis, independent sample t-test was used by comparing the scores obtained on the knowledge on climate change of elementary and secondary teachers in US and India. The results of the analysis are presented in Table 7.

Out of the total of 1336 teachers, few teachers were excluded as their data was incomplete and hence finally only 1278 teachers (388

Table 7: Difference in the Knowledge on Climate Change of Elementary and Secondary Teachers from India and the United States

Teaching Level	N	Mean	SD	t-value	df	Level of Significance
Elementary Level	388	7.01	3.55	8.805	1276	0.00
Secondary Level	890	8.83	3.33			

elementary teachers and 890 secondary teachers) were considered for the analysis. From Table 7, it is observed that the mean score of knowledge on climate change in elementary and secondary teachers are 7.01 and 8.83, respectively. It is also found that the standard deviation of scores on knowledge on climate change in elementary and secondary teachers are 3.55 and 3.33, respectively. The t-value was found to be 8.805 which is significant at 0.05 level of significance. Hence, the null hypothesis stating that there is no significant difference in the knowledge on climate change of elementary and secondary teachers from India and the United States is rejected and an alternative hypothesis stating that **there is a significant difference in the knowledge on climate change of elementary and secondary teachers from India and the United States** is accepted. Table 7 also reveals that the mean score of secondary teachers is higher than that of elementary teachers which means that the secondary teachers have a better knowledge about climate change than the elementary teachers.

8. Knowledge on climate change as a predictor of beliefs on climate change among the teachers of India and the United States

The scores of beliefs on climate change was taken as the dependent variable and their scores of knowledge on climate change was taken as the independent variable for calculating linear regression. There was a total of 1336 teachers from both India and the United States from whom these data were collected. A detailed description of the results is presented in Table 8.

Table 8 depicts that the t-value of knowledge on climate change as a predictor for beliefs on climate change is 2.941, which is significant

Table 8: Linear Regression of Beliefs on Climate Change of Teachers of India and US

Variables	Regression Coefficient	Standard Error of Regression Coefficient	t-value	Sig
(Constant)	53.546	0.402	133.261	0.000
Knowledge on Climate Change	0.132	0.045	2.941	0.003
N	1336			
R	0.080[a]			
R2	0.006			
Adjusted R2	0.006			
F	8.648 (Sig at 0.03[b])			
Standard Error of Estimate	5.72205			

a. Dependent Variable: Beliefs on climate change
b. Predictors: (Constant), Knowledge on climate change

at 0.05 level of significance. Therefore, the results indicate that the knowledge on climate change is a significant predictor of beliefs on climate change. Therefore, the linear regression equation predicting the beliefs on climate change (Y) in terms of knowledge on climate change (X1) was found to be as: Beliefs on climate change (Y) = 0.132 (X1) +53.546.

There exists a definite but only slight relationship between beliefs on climate change and knowledge on climate change as depicted by the value of R, which is found to be 0.080. The co-efficient of multiple determination of R2 value was found to be 0.006, which connotes that 0.6 per cent variations in the beliefs on climate change can be explained by their knowledge on climate change.

The F value was found to be 8.648 (degree of freedom 1 and 1337) which is significant at 0.05 level of significance. Therefore, the hypothesis stating that **knowledge on climate change is a significant predictor of beliefs on climate change among the teachers of India and the United States** is accepted.

The standard error of the estimate was found to be 5.72, which indicates that every time the regression equation is used to predict the beliefs on climate change, the chances to predict their beliefs on climate change will not miss their actual beliefs on climate change by more than ±5.72.

The results for whether knowledge on climate change is a predictor of beliefs on climate change among the teachers of India and the United States is presented here separately.

(i) Knowledge on climate change as a significant predictor of beliefs on climate change among the teachers of India

The scores of beliefs on climate change was taken as the dependent variable and their scores of knowledge on climate change was taken as the independent variable for calculating linear regression. There was a total of 1013 teachers from India from whom these data were collected. A detailed description of the results is presented in Table 9.

Table 9 depicts that the t-value of knowledge on climate change as a predictor for beliefs on climate change is 4.104, which is significant at 0.05 level of significance. Therefore, the results indicate that the knowledge on climate change is a significant predictor of beliefs on climate change. Therefore, the linear regression equation predicting the beliefs on climate change (Y) in terms of knowledge on climate change (X1) was found to be as: beliefs on climate change (Y) = 0.232 (X1) + 51.846.

There exists a slight relationship between beliefs on climate change and knowledge on climate change as depicted by the value of R, which is found to be 0.128. The coefficient of multiple determination of R2 value was found to be 0.016, which connotes that 1.6 per cent variations in the beliefs on climate change can be explained by their knowledge on climate change.

The F value was found to be 8.648 (degree of freedom 1 and 1014) which is significant at 0.05 level of significance. Therefore, the hypothesis stating that **knowledge on climate change is a significant predictor of beliefs on climate change among teachers of India** is accepted.

The standard error of the estimate was found to be 5.44, which indicates that every time the regression equation is used to predict the beliefs on climate change, the chances to predict their beliefs on climate change will not miss their actual beliefs on climate change by more than ±5.44.

Table 9: Linear Regression of Beliefs on Climate Change of Teachers of India

Variables	Regression Coefficient	Standard Error of Regression Coefficient	t-value	Sig
(Constant)	51.846	0.509	101.910	0.000
Knowledge on Climate Change	0.232	0.056	4.104	0.000
N	1013			
R	0.128[a]			
R2	0.016			
Adjusted R2	0.015			
F	16.85 (Sig at 0.00[b])			
Standard Error of Estimate	5.44353			

a. Dependent Variable: Beliefs on climate change
b. Predictors: (Constant), Knowledge on climate change

(ii) Knowledge on climate change as a significant predictor of beliefs on climate change among the teachers of the United States

The scores on beliefs on climate change was taken as the dependent variable, and their scores of knowledge on climate change was taken as the independent variable for calculating linear regression. There was a total of 323 teachers from the United States from whom the data were collected. A detailed description of the results is presented in Table 10.

Table 10 depicts that the t-value of knowledge on climate change as a predictor for beliefs on climate change is 1.957, which is significant at 0.05 level of significance. Therefore, the results indicate that the knowledge on climate change is a significant predictor of beliefs on climate change. Therefore, the linear regression equation predicting the beliefs on climate change (Y) in terms of knowledge on climate change (X1) was found to be as; beliefs on climate change (Y) = 0.138(X1) + 56.194.

There exists a definite but only slight relationship between beliefs on climate change and knowledge on climate change as depicted by the value of R, which is found to be 0.109. The coefficient of multiple determination of R2 value was found to be 0.012, which connotes that 1.2 per cent variations in the beliefs on climate change can be explained by their knowledge on climate change.

The F value was found to be 3.83 (degree of freedom 1 and 322) which is significant at 0.05 level of significance. Therefore, the hypothesis stating that **knowledge on climate change is a significant predictor of beliefs on climate change among the teachers of the United States** is accepted.

The standard error of the estimate was found to be 5.73, which indicates that every time

Table 10: Linear Regression of Beliefs on Climate Change of Teachers of US

Variables	Regression Coefficient	Standard Error of Regression Coefficient	t-value	Sig
(Constant)	56.194	0.612	91.803	0.000
Knowledge on Climate Change	0.138	0.071	1.957	0.05
N	323			
R	0.109[a]			
R2	0.012			
Adjusted R2	0.009			
F	3.83 (Sig at 0.05[b])			
Standard Error of Estimate	5.73154			

a. Dependent Variable: Beliefs on climate change
b. Predictors: (Constant), Knowledge on climate change

the regression equation is used to predict the beliefs on climate change, the chances to predict their beliefs on climate change will not miss their actual beliefs on climate change by more than ±5.73.

9. Beliefs on climate change as a predictor of knowledge on climate change among the teachers of India and the United States

The scores on knowledge on climate change was taken as the dependent variable, and their scores on beliefs on climate change was taken as the independent variable for calculating linear regression. There was a total of 1336 teachers from both India and the United States from whom these data were collected. A detailed description of the results is presented in Table 11.

Table 11 depicts that the t-value of beliefs on climate change as a predictor for knowledge on climate change is 2.941, which is significant at 0.05 level of significance. Therefore, the results indicate that the beliefs on climate change is a significant predictor of knowledge on climate change. Therefore, the linear regression equation predicting the knowledge on climate change (Y) in terms of beliefs on climate change (X1) was found to be as: Knowledge on climate change (Y) = 0.049 (X1) +5.572.

There exists a definite but only slight relationship between knowledge of climate change and beliefs on climate change as depicted by the value of R, which is found to be 0.080. The coefficient of multiple determination of R2 value was found to be 0.006, which connotes that 0.6 per cent variations in the knowledge on climate change can be explained by their beliefs on climate change.

The F value was found to be 8.648 (degree of freedom 1 and 1337) which is significant at 0.05 level of significance. Therefore, the hypothesis stating that **beliefs on climate change is a significant predictor of knowledge on**

Table 11: Linear Regression of Knowledge on Climate Change of Teachers of India and US

Variables	Regression Coefficient	Standard Error of Regression Coefficient	t-value	Sig
(Constant)	5.572	0.908	6.135	0.000
Belief on Climate change	0.049	0.017	2.941	0.003
N	1336			
R	0.080[a]			
R2	0.006			
Adjusted R2	0.006			
F	8.648 (Sig at 0.003[b])			
Standard Error of Estimate	3.46900			

a. Dependent Variable: Knowledge on climate change
b. Predictors: (Constant), Belief on climate change

climate change among the teachers of India and the United States is accepted.

The standard error of the estimate was found to be 3.469, which indicates that every time the regression equation is used to predict the knowledge on climate change, the chances to predict their knowledge on climate change will not miss their actual knowledge on climate change by more than ±3.469.

The results to analyse the beliefs on climate change as a predictor of knowledge on climate change is presented separately for India and United States.

(i) Beliefs on climate change as a significant predictor of knowledge on climate change among the teachers of India

The scores of knowledge on climate change was taken as the dependent variable, and their scores on beliefs on climate change was taken as the independent variable for calculating linear regression. There was a total of 1013 teachers from India from whom these data were collected. A detailed description of the results is presented in Table 12.

Table 12 depicts that the t-value of beliefs on climate change as a predictor for knowledge on climate change is 4.104, which is significant at 0.05 level of significance. Therefore, the results indicate that the beliefs on climate change is a significant predictor of knowledge on climate change. Therefore, the linear regression equation predicting the knowledge on climate change (Y) in terms of beliefs on climate change (X1) was found to be as: knowledge on climate change (Y) = 0.071(X1) + 4.693.

There exists a slight relationship between knowledge on climate change and beliefs on climate change as depicted by the value of R, which is found to be 0.128. The coefficient of multiple determination of R2 value was found to be 0.016, which connotes that 1.6 per cent variations in the knowledge on climate change

Table 12: Linear Regression of Knowledge on Climate Change of Teachers of India

Variables	Regression Coefficient	Standard Error of Regression Coefficient	t-value	Sig
(Constant)	4.693	0.931	5.040	0.000
Belief on Climate Change	0.071	0.017	4.104	0.000
N	1013			
R	0.128[a]			
R2	0.016			
Adjusted R2	0.015			
F	16.845 (Sig at 0.000[b])			
Standard Error of Estimate	3.00729			

a. Dependent Variable: Knowledge on climate change
b. Predictors: (Constant), Belief on climate change

can be explained by their beliefs on climate change.

The F value was found to be 16.845 (degree of freedom 1 and 1014) which is significant at 0.05 level of significance. Therefore, the hypothesis stating that beliefs on climate change is a significant predictor of knowledge on climate change among teachers of India is accepted.

The standard error of the estimate was found to be 3.00729, which indicates that every time the regression equation is used to predict the knowledge on climate change, the chances to predict their knowledge on climate change will not miss their actual knowledge on climate change by more than ±3.00729.

(ii) Beliefs on climate change as a significant predictor of knowledge on climate change among the teachers of United States

The scores on knowledge on climate change was taken as the dependent variable and their scores on beliefs on climate change was taken as the independent variable for calculating linear regression. There was a total of 323 teachers from the United States from whom these data were collected. A detailed description of the results is presented in Table 13.

Table 13 depicts that the t-value of beliefs on climate change as a predictor for knowledge on climate change is 1.957, which is significant at 0.05 level of significance. Therefore, the results indicate that the beliefs on climate change is a significant predictor of knowledge on climate change. Therefore, the linear regression equation predicting the knowledge on climate change (Y) in terms of beliefs on climate change (X1) was found to be as: knowledge on climate change (Y) = 0.085 (X1) + 2.513.

There exists a definite but only slight relationship between knowledge on climate change and beliefs on climate change as depicted by the value of R, which is found to be 0.109. The coefficient of multiple determination of R2 value was found to be 0.012, which connotes that 1.2 per cent variations in the knowledge on climate change can be explained by their beliefs on climate change.

Table 13: Linear Regression of Knowledge on Climate Change of Teachers of the United States

Variables	Regression Coefficient	Standard Error of Regression Coefficient	t-value	Sig
(Constant)	2.513	2.503	1.004	0.316
Belief on Climate Change	0.085	0.044	1.957	0.05
N	323			
R	0.109[a]			
R2	0.012			
Adjusted R2	0.009			
F	3.830 (Sig at 0.05[b])			
Standard Error of Estimate	4.49618			

a. Dependent Variable: Knowledge on climate change
b. Predictors: (Constant), Belief on climate change

The F value was found to be 3.830 (degree of freedom 1 and 322) which is significant at 0.05 level of significance. Therefore, the hypothesis stating that beliefs on climate change is a significant predictor of knowledge on climate change among teachers of the United States is accepted.

The standard error of the estimate was found to be 4.49618, which indicates that every time the regression equation is used to predict the knowledge on climate change, the chances to predict their knowledge on climate change will not miss their actual knowledge on climate change by more than ±4.49618.

10. Requirement of professional development on climate change for teachers of India and the United States

Two questions were included in the study to find out the need for professional development amongst the participating teachers. From Table 14, for the item on 'Have you attended any professional development course of any duration on climate change?', out of 1013 Indian teachers, 12 per cent answered that they have attended professional developmental course on climate change, 83 per cent responded that they have not attended any professional developmental course on climate change and 5 per cent of Indian teachers did not respond. Out of 323 teachers from the United States, 22 per cent answered that they have attended professional developmental course on climate change, 67 per cent responded that they have not attended any professional developmental course on climate change and 11 per cent of US teachers did not respond to the item.

For the item on 'Would you be interested in professional development related to climate change?', out of 1013 Indian teachers, 74 per cent responded that they were interested in professional development related to climate change, 22 per cent responded that they were not interested in professional development related to climate change and 4 per cent of

Table 14: Analysis of Data on Professional Development on Climate Change

Item No.	Item	Country	Yes	No	Not Answered
1.	Have you attended any professional development course of any duration on climate change?	Indian	12%	83%	5%
		US	22%	67%	11%
2.	Would you be interested in professional development related to climate change?	Indian	74%	22%	4%
		US	67%	22%	11%

Indian teachers did not respond. Out of 323 US teachers, 67 per cent responded that they were interested in professional development related to climate change, 22 per cent responded that they were not interested in professional development related to climate change and 11 per cent of US teachers did not respond to the item.

Discussions and Conclusion

The study revealed some interesting results about beliefs, knowledge and professional development amongst the teachers of India and the United States and how each aspect could influence the other in some way. It was found that there is a significant difference in the beliefs on climate change between the teachers of India and the United States. Further, the mean score of teachers in the United States was higher than that of the Indian teachers which means that teachers in the United States have stronger beliefs about climate change than teachers in India. A significant difference in the beliefs on climate change was also found amongst science and non-science teachers from India and the United States in which the mean score of science teachers was found to be higher than that of non-science teachers which means that the science teachers have stronger beliefs about climate change than the non-science teachers. Further, no significant difference was found in the beliefs on climate change amongst elementary and secondary teachers from India and the United States. In their study, Seroussi *et al.* (2019) found that majority of teachers believed in climate change. The result of the present study amongst teachers in the United States confirms this while the result for teachers in India do not support the same.

Knowledge on climate change was found to be lacking in general amongst teachers in India as well as in the United States. Similar results were found in other studies as well, such as Seroussi *et al.* (2019); Liu *et al.* (2015) and Plutzer *et al.* (2016). However, some similarity was found amongst teachers of both the countries with respect to their response to different questions. For example, teachers from both the countries did very well for questions, such as *'Increase in Greenhouse gases in the atmosphere enhances melting (thawing) of permafrost releasing additional carbon dioxide* and *methane into the atmosphere.'* and *'Thermal expansion of sea water along with glacier melting causes* sea level rise.' While

they scored poorly for questions, such as 'Greenhouse gases in the atmosphere trap the ultraviolet rays reflected from the earth thus causing global warming.', 'The reradiated solar radiation has a shorter wavelength than the incoming solar radiation.', and 'Melting sea ice has the potential to raise sea level by several feet.' Further, lack of clarity in their understanding about climate change was also evident amongst the teachers from both the countries as majority of them responded 'Not sure' for questions, such as 'The reradiated solar radiation has a shorter wavelength than the incoming solar radiation.', 'Albedo effect is a measure of the reflectivity of a surface such as snow, rooftops, buildings, etc.', and 'Thermohaline circulation refers to deep-ocean currents driven by differences in the water's density which is controlled by temperature and salinity.'

It was observed that there was a significant difference in the knowledge on climate change between the teachers in India and the United States and the mean score of the Indian teachers is higher than that of the teachers in the United States, which means that the Indian teachers have a higher awareness or knowledge about climate change than the teachers from the United States.

There was a significant difference in the knowledge on climate change of science and non-science teachers from India and the United States and the mean score of science teachers is higher than that of non-science teachers which means that the science teachers have a better knowledge about climate change than the non-science teachers which is expected based on the questions asked. Earlier studies have found that many secondary school science teachers in the United States seem to have a naïve understanding of climate change (Herman, *et al.,* 2017). In another study by Dawson (2012), science teachers, strong understanding of climate change, especially regarding greenhouse gases and their relationship with temperature was seen. This combined with the findings of the present study suggests that science teachers in the United States may have a limited understanding of climate change, however, irrespective of the nation, science teachers possess a better knowledge on climate change when compared to non-science teachers. A significant difference in the knowledge on climate change of elementary and secondary teachers from India and the United States was also found in the present study and the mean score of secondary teachers was higher than that of elementary teachers which means that the secondary teachers have a better knowledge about climate change than the elementary teachers. This finding about secondary teachers confirms a study by Karami, *et al.* (2017), where it was seen that lower secondary school teachers had a moderate to high level of knowledge regarding climate change and were well aware of the basics and causes of climate change.

In this present study, knowledge on climate change was found to be a significant predictor of beliefs on climate change among the teachers of India and the United States. This is consistent with a study where it was seen that people who have a greater knowledge of global warming and climate change also tend to believe in the occurrence of climate change and show concern regarding it (Milfont, 2012; Guy, *et al.,* 2014). Beliefs on climate change was also a significant predictor of knowledge on climate change among the teachers of India and the United States. However, this

contradicts the findings of Seroussi *et al.* (2019), in which they found that majority of teachers believed in climate change, however, they had misconceptions and gaps in knowledge regarding the various aspects of climate change. Similarly in another study by Liu, *et al.* (2015), it was found that the majority of teachers believed that climate change was mainly the result of human activities and were concerned about the consequences of climate change. However, their beliefs and attitudes were not a strong indicator of their knowledge on climate change as their knowledge was marred by misconceptions, but when professional development programmes were introduced, their basic knowledge on climate change improved.

With regards to professional development, it was found that majority of the teachers have not attended any professional development programme in climate change and the majority of them wish to attend some professional development programmes on climate change to enhance their competency. It has been seen that pre-service teachers' literacy on climate is related to their beliefs in global climate change (Papadimitriou, 2004). It has also been seen that teachers' values and beliefs significantly influence their support for climate change education (Kunkle and Monroe, 2019). Therefore, strengthening the capacity of teachers in terms of knowledge will be crucial, since knowledge is an indicator of beliefs as found in the present study. The findings of this present study inform that teachers do believe in climate change and have some knowledge related to climate change and with professional development programmes, their understanding of it can be improved as found in a study mentioned above. Another encouraging finding of the present study is that, majority of teachers indicated their interest in professional development. However, this study also found a significant difference in the knowledge between science and non-science teachers and between elementary and secondary teachers. Therefore, it will be appropriate that the professional development programmes may be tailored differently for science and non-science teachers and for elementary and secondary teachers. Curriculum developers and policy makers can also refer to the findings of the study as it will provide some useful information while taking measures or decisions related to climate change education.

Limitations and Future Research Directions

The current study has certain limitations. First, systematic sampling was not done in terms of the number of teachers participating in the study who are teaching different subjects. Second, although the nature of courses offered in India and the US, especially for teacher preparation are not similar, this has not been taken into consideration in this study. Future research could focus on the course content of professional development programmes and the kinds of training that need to be provided to teachers teaching different subjects and in different stages to make climate change education effective and meaningful.

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Appendix-1

Teachers' Beliefs About Climate Change

Please select the answer that matches your opinion (please tick ONLY ONE)

1. Climate change is a serious issue that needs immediate attention.

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
○	○	○	○	○

2. Human lifestyle contributes significantly to climate change.

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
○	○	○	○	○

3. Only scientists and technologically skilled people can solve climate change related problems.

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
○	○	○	○	○

4. Climate change cannot be taught effectively in KG to class 12 (schools) because the topic is still debated among scientists.

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
○	○	○	○	○

5. Climate change must be included in the school curriculum.

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
○	○	○	○	○

6. Students will more fully understand climate change if it is taught as a standalone (separate) unit.

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
○	○	○	○	○

7. Climate change should be taught only in science in schools.

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
○	○	○	○	○

8. Climate change involves complex processes and phenomena, and therefore it should be taught only in secondary and higher secondary stages.

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
○	○	○	○	○

9. Teaching climate change in schools will help prepare students toward its mitigation and adaptation.

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
○	○	○	○	○

10. School students can contribute in mitigating climate change.

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
○	○	○	○	○

11. Teaching climate change in schools can influence students' beliefs about climate change.

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
○	○	○	○	○

12. Values education should be a part of climate change education.

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
○	○	○	○	○

13. Teachers' beliefs about climate change influences the effectiveness of her/his teaching the topic.

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
○	○	○	○	○

14. Teachers need special training to teach climate change related topics.

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
○	○	○	○	○