

PROFESSIONAL DEVELOPMENT IN CLIMATE CHANGE—INSIGHTS FROM TEACHERS IN THE UNITED STATES

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Preparedness of teachers will majorly decide effectiveness of climate change education in schools. Several studies have shown that teachers lack adequate knowledge about climate change. In addition of knowledge, how teachers deliver the concepts, concerns and controversies are equally important. Hence, tailoring professional development courses based on teachers need will be crucial for successful implementation of climate change education. This paper presents the views of teachers from the United States, about professional development in climate change.

Key words: Climate change education, United States, Professional Development, Teachers.

Introduction

Climate change is one of the most pressing issues facing the world today. Efforts are being made at various levels to tackle this. Climate change education stands out as one of the focus areas to tackle the issue of climate change as it is considered an enabler to communities and individuals in making informed decisions in mitigating the climate change problem and enhances adaptive capacities in responding to its impending effects (Chang and Pascua, 2017). 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; Plutzer *et al.*, 2016; Chang and Pascua, 2017) and climate change education has become increasingly important in many countries (Chang, 2013). The goal of climate change education is to nurture climate-literate citizenry—one who understands the essential principles of Earth climate system, knows how to assess scientifically credible

information about climate, communicates about climate and climate change in a meaningful way and is able to make informed and responsible decisions with regard to actions that may affect climate (USGCRP, 2009). However, studies from different parts of the world have shown that students understanding about climate change continues to be poor or superficial with erroneous information or misconceptions, for example, Singaporean students not able to connect its causes with impacts and hold misconceptions (Chang, 2014; Chang and Pascua, 2016), or poor knowledge exhibited amongst high school students in Austria and Denmark (Harker-schuch *et al.*, 2013), Sah and Bellad (2015) found that less than half of the students in their study area in Karnataka stated that greenhouse gases to be a major cause of global climate change. A significant reason for students poor understanding about climate change could be attributed to how teachers handle climate change in the classroom. This will be hugely influenced by teachers knowledge about the content and

pedagogy and what their beliefs are about climate change. Miler *et al.* (2012) pointed out that for a teacher to be able to teach climate change related topics effectively, it is imperative to have a basic knowledge about climate science that is, climate literate teachers. Further, it is not only students but also teachers who have misconceptions and misunderstandings about climate warming Papadimitriou (2004). This is supported by studies conducted by Reinfried *et al.*, (2012) which found that both students and teachers have gaps and misconceptions in their knowledge and understanding about climate change.

A review of literature on teachers knowledge and beliefs about climate change reveals that teachers invariably lack adequate knowledge. For example, Seroussi *et al.*, (2019) found that, teachers might understand the anthropogenic nature of climate change but still have little knowledge regarding the consequences and hold many misconceptions about the issue; a study conducted on Native American teachers by Liu *et al.* (2015), found that there were even teachers who held misconceptions about climate change. This also indicates 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. Plutzer *et al.* (2016, 2016a) also found that teachers are yet to develop a basic understanding about climate change science as found by amongst United States (U.S.) teachers. A study by Shimray (2019), also found teachers knowledge on climate change for different questions to be majorly poor. A naïve understanding of climate change and

climate change science amongst science teachers in the U.S. was also reported by Herman *et al.*, 2017. Other studies which found inadequate knowledge include that of Sousa *et al.* (2019); Anyanwu and Grange (2017); Chang and Pascua (2016); Monroe *et al.* (2017). Further, 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). The complex and controversial nature of climate change science influences the nature of instructional strategies utilised by teachers, leading to mixed messaging (Plutzer *et al.*, 2016, 2016a).

Objectives

The above discussions suggest that for effective climate change education, professional development of teachers is inevitable. Keeping this in view, this study was undertaken to find out U.S. teachers views about professional development with the following objectives:

1. To find out whether teachers in the U.S. are interested to attend professional development in climate change.
2. To find out U.S. teachers opinion about course content for professional development.

Methodology

A mixed method research was used to collect data from teachers—quantitative survey method and interviews. For recruitment of participants a convenient sampling method

was followed. The participants consisted of teachers teaching K-12 in any discipline.

- (i) For the survey, a link was generated on Qualtrics Survey platform and sent through different sources such as: Emailing list of teachers in different schools in selected Cooperative Educational Service Agency (CESA) in Wisconsin compiled by Wisconsin Center for Environmental Education (WCEE). This list included the complete list of teachers of the schools irrespective of the subjects they were teaching.
- (ii) Victoria Rydberg sent out to her emailing list consisting of teachers.
- (iii) Email sent out to Wisconsin Society of Science Teachers (WSST) listserv which would take them to the WSST website leading to the online survey link.
- (iv) Email was sent out to the National Science Teaching Association (NSTA) biology teachers emailing list which contained the survey link.

For interviews, a semi-structured interview schedule was prepared. Questions were related to their existing curriculum and how they teach, the challenges and their suggestions about how to incorporate climate change in the curriculum. However, in this paper, only those questions related to professional development is considered. Participants were recruited by sending out emails to teachers (science, biology, environmental science) whose details were randomly obtained from different schools

from websites. They were requested to participate in the interview. Hence their participation was voluntary.

Tool

The online survey had questions on participants information, knowledge and opinion about climate change. However, in this paper, only questions directly or indirectly pertaining to professional development are considered. The participants had the choice to skip any of the questions. The questions can be categorised as:

- Q1. What subject do you primarily teach?
Choose the best answer. (Subject primarily teaching) (Subject primarily teaching was further grouped into two such as 'Science' (the subject science alone) and 'Others' (all other subjects except science)
- Q2. Do you teach topics related to climate change? (Teach climate change)
- Q3. Would you be interested in professional development related to climate change? (Interest for professional development.

The interview questions included their experience about professional development, if they had attended one, if they would be interested to attend and why and what content would they want in professional development courses.

The online survey had consent letter with it. Standard protocol of the University of Wisconsin-Stevens Point, WI was followed to obtain approval from the Institutional Review Board of the University to administer

the above mentioned research tools, that is, online survey tools and interview schedules

Results

Results of the online survey and the interviews are provided below.

I. Online survey

The online survey revealed that out of the 321 who responded, 242 (75.4%) indicated

their interest to attend professional development related to climate change while 79 were not interested (Table 1 and Figure. 1). Further, it was found that even those who were teaching subjects other than science also indicated their interest for professional development (Table 2). Similarly, those who do not teach climate change (84 teachers) also indicated their interest (Table 3 and Figure. 2).

Table 1: Interest to Attend Professional Development on Climate Change

Q45. Would You be Interested in Professional Development Related to Climate Change?	
	Frequency
Yes	242
No	79
Total	321

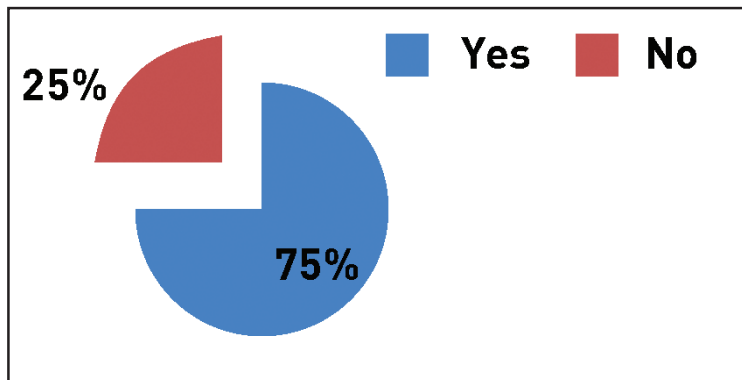


Fig. 1. Respondents interested to attend professional development on climate change

Table 2: Respondents Interested in Professional Development on Climate Change Based on Subject Primarily Teaching

Subject Primarily Teaching	Interested in Professional Development on Climate Change	Total
	Yes	
Math	9	9
Science	107	107
English Language Arts	16	16
Social Studies	16	16
Family and Consumer Science	2	2
Agriculture	6	6
Foreign Language	7	7
Music	4	4
Special Education	12	12
Art	4	4
Physical Education	5	5
Multiple Subjects	10	10
Technology and Engineering	4	4
Total	202	202

Table 3: Interest for Professional Development Based on Teaching Climate Change Related Topics

Yes		Interested in Professional Development on Climate Change	Total
Teaching climate change	Yes	158 (65.3%)	158
	No	84 (34.7%)	84
Total		242 (100%)	242

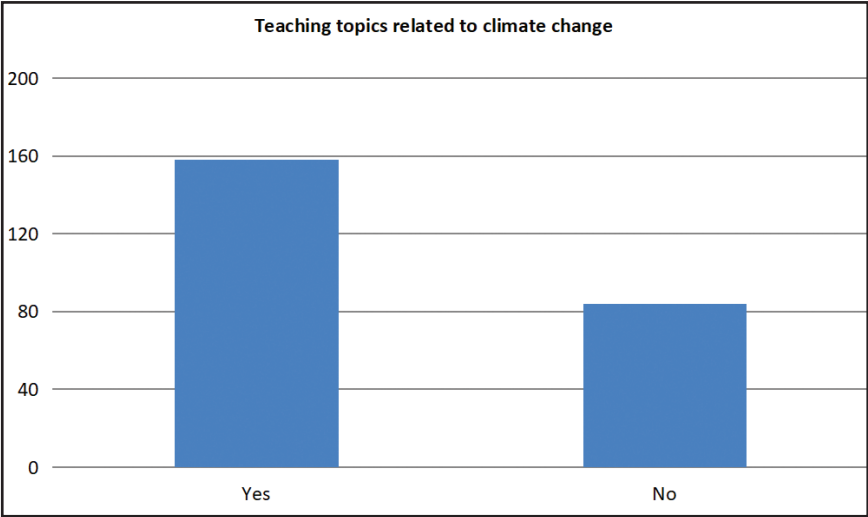


Fig. 2. Respondents interested in professional development on climate change based on teaching climate change

Professional development: (i) PD experience (ii) PD requirement (iii) Suggestions for PD course content (iv) Duration of PD and Frequency.

II. Interviews

On an average, the interviews went on for approximately 1 hour each. Sixteen teachers volunteered to take part in the interviews (Table 4).

Table 4: Profile of the Teachers Interviewed

Sl. No.	Name	State	Qualifications	Grades Currently Teaching	Subject(s) Currently Teaching	Teaching Experience
1.	Billie	Florida	Bachelor of Science in Biology; Ph.D. in Cell Molecular Biology	Middle School (7th grade); High School	Science; Environmental Science from 2018	8 years
2.	Lindsay	Delaware	Bachelor's degree in Conservation and Wildlife Management; Zoo-keeping	High School (9th grade)	Biology	3 years

3.	Carlos	Washington	Bachelor's degree; Master in Biological Sciences	High School (9th grade)	Biology	6 years
4.	Juan	Indiana	Bachelor's degree in Biology (double major in Biology and Education); Master in Environmental Education	High School	Biology 1; Senior AP Environmental Science	23 years
5.	Johanna	Wisconsin	Bachelor's degree in Biology; Master in Plant Pathology; Certified teacher	High School	Earth Science, Biology	7 years
6.	Grigor	California	Teaching credentials in Science and Multiple Subjects	Middle School (6th, 7th and 8th grades)	Science	13 years
7.	Lucie	California	Bachelor's degree in Earth System Science and Policy; Credential in Science and Master in Education	High School (9th grade)	Science	8 years
8.	Andy	Kansas	Bachelor's degree in Biology Education; NGSS certified state trainer	High School (9th grade)	AP Biology	11 years
9.	Marin	New York	Bachelor's degree in Liberal Arts; Master in Elementary Education	Upper Elementary and Middle School (5th and 8th grades)	Science	12 years

10.	Edmund	Wisconsin	Bachelor's degree in Biology and Environmental Science; Post Baccalaureate teachers license; Master's degree in Natural Resources and Environmental Education	High School (9th to 12th grades)	Biology and AP Environmental Science	3rd year in current school (total 5 years)
11.	Stan	Connecticut	Bachelor's degree English major, Master's degree in English, Ph.D. in English	High School (Junior High)	American Literature, Environmental Literature, Environmental Research Methods	2nd year in current school
12.	Taylor	Florida	Bachelor's degree in Psychology; Master's degree in Teaching Science; Certified teacher	High School (11th and 12th grades)	Honors Marine Biology	3rd year in current school (total 24 years including 10 years middle school)
13.	Angelique	Minnesota	Undergraduate degree in Socio-cultural Anthropology; Graduate degree in Curriculum Instruction in Science Education	Upper Elementary School (4th, 5th and 6th grades)	Science	5 years

14.	Justine	Oregon	Bachelor's degree in Biology and Chemistry; Master in Education	Middle School (7th grade)	Science	3rd year in current school, 5 years in High school, 2 years in Middle school
15.	Jelena	Kansas	Bachelor's degree in Science Education, Minor in Spanish	High School (9th grade)	Biology	5 years
16.	Jo	Minnesota	Undergraduate degree in Biology; Two years Master's Programme to get license to teach	Middle and High School (7th, 10th, 11th and 12th grades)	Biology	20 years

(ii) Professional development (PD) experience

Teachers were asked, if they had any professional development experience. To this, about half of the teachers interviewed, said that they have attended PD on climate change, or where there were sessions related to climate change. Jo, Angelique, Billie and Juan were those who attended PD on climate change. While Taylor conveyed, "I haven't seen a PD on climate change" or as Lindsay shared, "but I have not really found one in my local area that has been like gung-ho about climate change."

(iii) PD requirement

When asked, if they would be interested or feel the need for teachers in general to attend PD on climate change almost all the teachers responded positively. However, interestingly, the reasons provided by each of them were

found to be different for example, Jo said, "I would hope that all of our social studies teachers and all of our science teachers are learning about this," emphasising that it is not just science teachers but social studies teachers needs it equally. While some like Angelique thought "that's important to keep learning more and I am sure that there will be new tools and things and so if it's certainly something that were offered and that were in my schedule and it was affordable then I would definitely do it," others like Carlos wanted to attend "just because it's not been a huge part of my formal education, I'm not like formally environmental scientist, I'm not a climate scientist, I haven't taken courses through those people," or as Andy said, "I mean, I would like a chance to have a regular time to just go back and dive deeper into current information if I had that time I would love that." But it is true that most of the teachers want to attend such

PD not because they need to but because they want to attend with the hope that there would be something they could learn out of every such programme. For example, as Carlos stated, "I think, I do fair justice to it but I know, I am not, I am sure someone an actual climate... look at the way I organise the curriculum and look at all the things I am doing. I'm sure they'll have a lot to say and lot to how to do better at so of course I would always want to get better," or as Edmund put it, "I don't know if I need to but in terms of just professional development I mean those courses are helpful." This is not very surprising because as mentioned earlier, those interviewed are very enthusiastic teachers who are passionate about climate change amongst which is a couple of teachers who is already a trainer or who would be a trainer for example, Stan, who said, "I actually lead a summer institute for, like a professional development institute for other teachers. So that is something that is rewarding and I at least sort of get a lot out of that, helping other teachers do this kind of work in more classrooms," or Billie who is "actually going to be a master teacher for that same programme that she had attended on climate change."

From the above responses it is clear that almost all the teachers want to attend PD provided it fits their schedule and is affordable as Angelique mentioned. Some of the reasons why they would want to attend can be summarised as follows:

- They want to learn new tools.
- Climate change was not a huge part of their formal education.
- They are not formally environmental scientist nor a climate scientist.
- They want to dive deeper into current information.
- Experts in PD will have a lot to say and lot to how to do better at (what they have been doing) and they would always want to get better.

(iii) Suggestions for PD course content

The teachers were then asked what do they think PD course should be like. A wide range of response were received. The summary of their responses are provided in Table 5. To read the context of the summary, the full transcript of their response is provided in Appendix 1.

Table 5: Summary of Response of Teachers about Professional Development Course

Sl. No.	Name	Suggestion for PD course	Summary
1.	Jo	That provides new information, which can be applied (in their teaching), mentoring (continuous feedback)	Continuous feedback
2.	Angelique	Team-taught course between a political scientist and a columnist and a climate scientist who was an ecologist, not taught sequentially but truly integrated or interdisciplinary way; not just geared towards science teachers	Team-taught, truly integrated or interdisciplinary

3.	Billie	Thin package of most recent data which is kept up-to-date	Recent data or information
4.	Carlos	Course credit on climate or climate science with free registration fee	Credit course Free registration fee
5.	Andy	That offers real world examples that your students can relate with on different areas; the experts continue to work with you in your teaching practices; content and pedagogy-focused	Continuous feedback Content and pedagogy Relatable examples
6.	Edmund	Three go-to lesson which is a collect of big issues; that provides tools/ materials that I could personalise for my students such as specific data set or specific case study	Recent data or information Case study Materials that can be personalized
7.	Grigor	That has science behind climate change and how to teach or incorporate the nature of science, critical thinking, publishing data	Content and pedagogy
8.	Juan	Content knowledge especially for elementary level teachers	Content-based
9.	Johanna	That provides materials that can be used in classroom; that informs current research, what people are doing or talking about	Materials to be used in classroom Recent data or information (Current research) Current solutions
10.	Justine	Content-based	Content-based
11.	Jelena	That teachers how to take students outside and engage in activities; how to interpret what's going on in the news and using that in your classroom; how to look at recent scientific articles and how to use that knowledge in the classroom	Recent data or information Interpreting news How to use in classroom
12.	Lindsay	That focusses on trends and correlations; that provides more information about everything related to global climate change and not just temperature	Content-based Recent data or information
13.	Lucie	On project-based teaching; not content but more pedagogy	Project-based More pedagogy

14.	Martin	That is taught by scientists doing climate science on most current research; lesson to be supplemented with workshops on specific pedagogy	Recent data or information Workshops on specific pedagogy
15.	Stan	Both content and pedagogy	Content and pedagogy
16.	Taylor	That presents examples that has worked in the classroom showing the whole process	Tried and tested examples

The table shows that their views are fairly spread ranging from only content-based (3) to content and pedagogy (3) to only pedagogy (2) to where there is continuous interaction and mentoring from the PD (2) to distribution of materials that can be used in classroom such as tried and tested resources, personalisable and relatable examples (4) to PD that is based on recent data (6) to team-teaching (1) to credit-based course (1) to project-based (1) to one that teaches how to interpret news, data, information and use it in classroom (1).

(iv) Duration of PD and Frequency

The teachers were also asked what they think should be the duration of PD and frequent it should be held. There were variations in the number of days and frequency suggested for PD programmes which could be seminars, workshops, lab related, etc. It ranged from one full day once a year since that's "kind of a sweet spot" as Andy suggested; One day every one or two months as suggested by Taylor; Full week once a year as suggested by Angelique who was of the view that "a full week is intense but I think it's really difficult to kind of immerse yourself if you are doing less than a full week." She said "there were multiple teachers that came back three years, four years in a row because they really like the community feeling" but she added "I think

that would actually be really nice if there were a PD that there would be a chance for people to kind of reconnect and touch base and reflect together in person," or as Jelena opined, "I would say, may be as far as the one that I said about the news that could be done yearly if anything just because you could have so much change in science, in science there are going to be so much change year to year... that would be cool if that was a weeklong one."; Full week once in five years as Carlos suggested "because I think so much about science changes."; or a series "like four Saturdays and it was like spread over October, December, February, March and May; once in three years...because three years on in that course there's going to be new information they could embrace," as suggested by Edmund. But he also added, "it will depend on how much I was getting out of it. So if it was like, if I was getting like one or two ideas, I would kind of anticipate that would be like a day of PD. If I was getting like more than that, if I was getting like three to six ideas then to me that's like a two day PD." While Juan proposed, "...and maybe earning some sort of certificate you know like oh I've got this training every five years that sort of things, you know may be have some incentives that sort of things...," Lucie said, "I'll like go to like maybe a weekend or like... atleast once a

year...”, while Billie stated, “I like webinars... some of them are taped and online and I’ll go back to something like that and look to what they’ve done as a reminder, as a refresher. I don’t have to have my face glued to it. I can be

cleaning or whatever and have it on and just try to find the pieces that I wanted. But, yeah, webinars are good.”

The duration for PD specified by the teachers is provided in Table 6.

Table 6: Duration PD Suggested by Teachers

Name of teacher	Duration
Angelique	Full week once a year
Billie	Webinars
Carlos	Full week once in five years
Andy	One full day once a year since that’s “kind of a sweet spot”
Edmund	Once in three years
Juan	Certificate every five years
Jelena	Weeklong one every year
Lucie	A weekend atleast once a year
Taylor	One day every one or two months

Discussions and Conclusion

The results of the study clearly indicates U.S. teachers interest for PD in climate change with the online survey showing that out of the 321 who responded, 242 (75.4%) indicated their interest. This interest for PD is plausible keeping in view the poor knowledge in climate change observed amongst teachers by different researchers in the U.S. (Shimray, 2019; Plutzer *et al.*, 2016; Liu *et al.*, 2015). Shimray (2019), had found that only 25 per cent in an online survey amongst U.S. teachers have attended PD. What is interesting to find out from the study is that, this interest for PD is not limited to science teachers or only those teachers who teach

climate change as part of their curriculum or course. Teachers interested in PD spread across all subjects. Even teachers who did not teach climate change were interested for PD (34.7%). Similar observations were made in the case of teachers who were interviewed. Almost all mentioned interest for PD. These teachers were already teaching climate change in some form or the other. This corroborates the findings of Plutzer *et al.* (2016a) in a study conducted for schools across the U.S. wherein they found that two-thirds of teachers irrespective of their beliefs in anthropogenic causes of climate change said they would be interested in continuing education “entirely focused on climate change.” They also attribute the gaps in the knowledge amongst teachers to

limited training. Wise (2010), also suggested that all science teachers would benefit from professional development focused on climate science, best practices in climate instruction and climate communication. Based on their online survey on teachers understanding of climate change in Czech Republic, Miler *et al.* (2012), also suggested that training primary and secondary school teachers in climate change education methods is crucial. The findings of this study are not surprising since climate change in the U.S. is such a controversial issue and these teachers who participated in the study could be from the lot that strongly feels about climate change. This indication of the teachers for PD is also justified keeping in view the inadequate knowledge that teachers in the U.S. possess on climate change which have been pointed out by several studies from the U.S. and elsewhere such as Wise (2010), Shimray (2019), Seroussi *et al.* (2019), Liu *et al.* (2015), Plutzer *et al.* (2016, 2016a), Herman *et al.* (2017), Sousa *et al.* (2019), Anyanwu and Grange (2017), Chang and Pascua (2016), Monroe *et al.* (2017).

In addition to climate change knowledge, it will be crucial for PD to focus on other finer aspects in terms of strategies adopted for it. For example, Plutzer *et al.* (2016a) pointed out, "Our data suggest that, especially for political or cultural conservatives, simply offering teachers more traditional science education may not lead to better classroom practice. Education efforts will need to draw on science communication research and acknowledge resistance to accepting the science and addressing its root causes." Further, 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). Plutzer *et al.* (2016), also mention that the complex and controversial nature of climate change science influences the nature of instructional strategies utilised by teachers, leading to mixed messaging. Hence, not surprisingly, Wise (2010), included a question, "Do you use any specific strategies when teaching about global warming, due to the fact that it is publicly controversial?" in her study.

Such PD offered to teachers are expected to have positive impacts on their climate change knowledge as have been found in several studies such as Shimray (2019), amongst U.S. teachers; Chang (2013), from a workshop conducted for Geography teachers in Singapore; Liu *et al.* (2015), based on workshop of nineteen teachers from Native American communities; Drewes *et al.* (2018), in a case study. This is also true with preservice teachers as found by Bozdogan (2011), wherein gaps and misconceptions were found to be rectified after intervention. Based on their study on PD and its effects on teaching practices in mathematics and science, Desimone *et al.* (2002), found that, PD focused on specific instructional practices increases teachers use of those practices in the classroom.

Based on the interviews, the reasons for their interest for PD were mainly to learn new tools, climate change was not a huge part of their formal education, they are not formally environmental scientist nor a climate scientist, they want to dive deeper into current information and they want to do better through interactions and listening to experts

in PD. Plutzer *et al.* (2016a), had also found in their study that fewer than half of the teachers report any formal instruction in climate science in college.

As far as the course content for PD was concerned, based on the interviews with the teachers, there are differing views. Some suggested purely content-based, some pedagogy-based, some both content and pedagogy and so on. This could be due to their prior exposure to climate change in the higher education or based on their prior attendance of PD or due to the grades they are teaching. Teacher characteristics have been found to have an influence on the knowledge of teachers on climate change (Anyanwu and Grange, 2017; Shimray, 2019). However, there were a few different and interesting views from the teachers. For example, there was a suggestion that PD should be team-taught which makes a lot of sense keeping in view the interdisciplinary nature of climate change. Teachers in most cases, have to teach all aspects of climate change. Through team-teaching, not sequentially teaching different aspects of climate change, teachers will be able to understand how exactly they can apply to their own classroom. A couple of teachers were also of the view that PD should not end with the duration of the PD but the interactions with the experts need to be continuous with experts acting as mentors and providing regular feedback to improve classroom transactions. Another suggestion was on giving away resources that are relatable to students, examples that are tried and tested resources. Plutzer *et al.* (2016a), also suggest the need for teacher-tested, standards-aligned educational materials, high-quality, vetted, and up-to-date online instructional resources.

Based on their studies, researchers also suggest different aspects that need to be considered in PD. Some researchers suggest focussing on knowledge of climate science. For example, Liu *et al.* (2015), suggest that future professional development should consider placing more emphasis on providing scientific information to teachers in order to enhance their capacity and confidence in implementing climate change education. Similarly, according to Plutzer *et al.* (2016a), PD should be to “improve teachers’ knowledge of climate science, so as to distinguish what is scientifically uncertain (e.g., exactly how quickly sea levels will rise) from what is well supported (e.g., that sea levels have risen and are rising more quickly owing to human-caused climate change). Teachers must expect and be equipped to counter, specific misinformation and misconceptions about climate change likely to be voiced by students.” Chang (2013), also suggests that teachers will need to consider their own subject-matter knowledge about climate change and to consider the relationship between the different cognitive and affective domains of learning with regard to Singapore teachers. In addition to knowledge, it will be crucial to address other aspects such as values (Plutzer *et al.*, 2016a).

Teachers views about the duration for the PD also varied ranging from one full day every one or two months to week long every year.

This study suggests that training needs are highly subjective, influenced by various factors—qualification, experience, availability of time, grade and subject that they teach, cost of PD. This suggests that PD is about individual teacher experience (Desimone *et al.*, 2002).

Nevertheless, the observations and findings of this study will provide some useful insights while designing PD not just for teachers in the U.S. but in other countries as well.

Limitations and Suggestions for Future Research

The sample size was small for the online survey. Future research may take this aspect into consideration during sampling. The participants were also recruited on volunteer basis and hence they constitute teachers who are highly concerned and passionate about climate change. Sampling may also take into consideration to ensure equal participation of teachers with conservative and liberal views about climate change.

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References

- ANYANWU, R. AND LE G. LESLEY 2017. The Influence of Teacher Variables on Climate Change Science Literacy of Geography Teachers in the Western Cape, South Africa, *International Research in Geographical and Environmental Education*. Vol 26, No. 3. pp. 193–206. DOI: 10.1080/10382046.2017.1330039
- BOZDOGAN, A. E. 2011. The Effects of Instructional with Visual Materials on the Development of pre-Service Elementary Teachers Knowledge and Attitudes Towards Global Warming. *The Turkish Online Journal of Educational Technology*. Vol 10, No 2. pp. 218–233.
- CHANG, C. H. 2013. Advancing a Framework for Climate Change Education in Singapore Through Teacher Professional Development. *HSSE Online*. Vol 2, No 1. pp. 28–35.
- CHANG, C. H. AND L. PASCUA, 2016. Singapore Students Misconceptions of Climate Change. *International Research in Geographical and Environmental Education*. Vol. 25, No. 1. pp. 84–96.
- CHANG, C. H. AND L. PASCUA 2017. The Curriculum of Climate Change Education: A Case for Singapore. *Journal of Environmental Education*. Vol 48, No 3. pp. 172–181. (<https://doi.org/10.1080/00958964.2017.1289883>)
- CHANG, C. H. 2014. Climate Change Education: Knowing, Doing and Being. Abingdon: Routledge.

DESIMONE, L. M., A. C. PORTER, M. S. GARET, K. S. YOON AND B. F. BIRMAN 2002. Effects of Professional Development on Teachers' Instruction: Results from a Three-year Longitudinal Study. *Educational Evaluation and Policy Analysis* Vol. 24 pp. 81–112.

DREWES, A., J. HENDERSON AND C. MOUZA 2018. Professional Development Design Considerations in Climate Change Education: Teacher Enactment and Student Learning. *International Journal of Science Education*. Vol 40, No 1. pp. 67–89, DOI: 10.1080/09500693.2017.1397798

HARKER-SCHUCH, I., C. BUGGE-HENRIKSEN. 2013 Opinions and Knowledge About Climate Change Science in High School Students. *AMBIO*, 42. pp.755–766

HERMAN, B. C., A. FELDMAN AND V. VERNAZA-HERNANDEZ. 2017. Florida and Puerto Rico Secondary Science Teachers' Knowledge and Teaching of Climate Change science. *International Journal of Science and Mathematics Education*, Vol 15, pp. 451–471. (<https://doi.org/10.1007/s10763-015-9706-6>)

KASTENS, K., M. AND TURRIN. 2008. What are Children being Taught in School about Anthropogenic Climate Change? In Bud Ward's Communicating on Climate Change: An Essential Resource for Journalists, Scientists, and Educators. Metcalf Institute for Marine and Environmental Reporting.

KUNKLE, K. A. AND M. C. MONROE. 2019. Cultural Cognition and Climate Change Education in the US: Why Consensus is not Enough. *Environmental Education Research*. Vol. 25, No. 5. pp. 633–655. (<https://doi.org/10.1080/13504622.2018.1465893>)

LIU, SHIYU, G. ROEHRIG, D. BHATTACHARYA AND K. VARMA 2015. "In-service Teachers' Attitudes, Knowledge and Classroom Teaching of Global Climate Change." *Science Educator*. Vol 24, No 1. pp. 12–22.

MILÉŘ, TOMÁŠ, J. HOLLAN, J. VÁLEK AND P. SLÁDEK 2012. Teachers' Understanding of Climate Change, *Procedia - Social and Behavioral Sciences*. Vol. 69. pp. 1437–1442, ISSN 1877-0428

MONROE, C. MARTHA, R. P. RICHARD, A. OXARART, A. BOWERS AND A. C. WILLANDIA. 2017. Identifying Effective Climate Change Education Strategies: A Systematic Review of the Research. *Environmental Education Research*. DOI: 10.1080/13504622.2017.1360842

PAPADIMITRIOU, V. 2004. Prospective Primary Teachers' Understanding of Climate Change, Greenhouse Effect, and Ozone Layer Depletion. *Journal of Science Education and Technology*. Vol. 13, No. 2. pp. 299–307.

PLUTZER, E., A. LEE HANNAH, J. ROSENAU, M. S. McCAFFREY, M. BERBECO AND A. H. REID. 2016. Mixed Messages: How Climate is Taught in America's Schools. Oakland: *National Center for Science Education*. (<http://ncse.com/files/MixedMessages.pdf>)

PLUTZER, E., M. S. McCAFFREY, LEE J. HANNAH, J. ROSENAU, M. BERBECO. A. H. REID. 2016a Climate confusion among US teachers. *Science*. Vol. 351. pp. 664–665

REINFRIED, S., U. AESCHBACHER AND B. ROTTERDAM. 2012. Improving Students Understanding of the Greenhouse Effect Using Theory-Based Learning Materials that Promote Deep Learning. *International Research in Geographical and Environmental Education*. Vol 21, No 2. pp. 155–178.

SEROUSSI, D. E., N. ROTHSCCHILD, E. KURZBAUM, Y. YAFFE AND T. HEMO. 2019. Teachers' Knowledge, Beliefs, and Attitudes about Climate Change. *International Education Studies*. Vol. 12, No. 8. pp. 33–45. (<https://doi.org/10.5539/ies.v12n8p33>)

SHIMRAY, C. 2019. A Study of K-12 Teachers' Climate Change Knowledge in the United States. *School Science*. Vol. 57, No 1. pp. 49

SOSA, L. O. DE, E. A. HAY AND D. LIEBENBERG 2019. Teachers' Understanding of the Interconnectedness of Soil and Climate Change When Developing A Systems Thinking Concept Map for Teaching and Learning. *International Research in Geographical and Environmental Education*. 28:4, 324–342, DOI: 10.1080/10382046.2019.1657684

U.S. GLOBAL CHANGE RESEARCH PROGRAM (USGCRP), Climate Literacy: The Essential Principles of Climate Science, 2009.

WISE, S. B. 2010. Climate Change in the Classroom: Patterns, Motivations and Barriers to Instruction Among Colorado Science Teachers. *Journal of Geoscience Education*. Vol. 58, No. 5. pp. 297–309. (<https://doi.org/10.5408/1.3559695>)

Appendix 1: Detailed response of teachers about their suggestion for professional development course

Jo: So when I think of PD I always feel that sort of based on how teachers feel they are needing strengthening or have an interest and so, I don't think of it as, I think it would be great to have opportunities to have like Summer Institute for me was awesome. As far as mandating that all teachers take that I don't think you can get enough people I would think that make sense (but) it would be valuable. I think ideally from what I know about PD and what kind of the best model or one of the better models would be where you are able to take new information, be able to apply it, have somebody else give feedback at how you doing applying it you know kind of mentoring you in it and then be able to respond to that feedback and kind of

grow that way but that takes fair amount of resources and time and it's just...

Angelique: Well, I really like the course, there was this course that I was enrolled in and that was like...it was a team-taught course between a political scientist and a columnist and a climate scientist, he was an ecologist. And I really like that because there was a really good piece about their communication part, which I think is really important like how to be able to communicate about climate and then there was a part about sort of some of global political perspective and there was a part that was about just like the science content and so I think a course that I would really like would be a course that didn't kind of do them sequentially but looked at them like in their truly integrated or interdisciplinary way because like I'm not a science teacher, I teach everything and I think that that's what's really amazing about climate change is that

it's a really rich topic to approach from a lot of different disciplinary angle and so I would be really excited about a course that was geared to a wide audience and not just geared towards science teachers that was really trying to involve a lot of different perspectives in the topic.

Billie: I think what honestly would help teachers a lot is a thin package of data that hits the main points, but is kept recent. I think something that's becoming hard and I appreciate why it's happening. But, there is just so much data now that you can spend forever looking for the best. There's really like 10 pieces that are really powerful and if that was put together as a package and kept up to date, that would help teachers a lot. Then they could spend their time thinking about other stuff.

Carlos: I think one thing is like if I want to make sure I'm teaching students this (like) the right stuff, I need to (like) myself learn the right thing. So, I think a perfect course or a perfect training would be one that teachers get like a course credit or something to actually take a climate class or a climate science class, look for university whatever the case may be. Once they know science themselves then we actually go about teaching the science because teaching something is very different than knowing something which is what makes teaching so hard often... and then you are talking like are they going on their own dime or something, is it like a neutral cost or they don't have to pay like a free registration that they just have to use their time, is there some sort of stipend. So all of those have huge impacts for them too.

Andy: I suggest you, find a thing that is local to you, a company or a research institute or

somebody who can offer real world examples like discreet examples like how climate impacts your area. Because it's more powerful for students to see it like this is happening in our state or in our city. They used to feel like well this is happening 20,000 miles at the other end of the world. Here is the problem. So, I recommend you try to find something that's local to you and try to find something that's going to teach you something new. So, like don't just confirm something that you already know like if you are really confident and be impact on aquatic systems don't go constantly working for information on aquatic systems. Try to find somebody that might be in agriculture. So, there's all kinds of companies in research institutions looking at how it's affecting the plants that we can grow and look into that because more diverse knowledge base is going to help you as a teacher meets the needs of a larger subset of your students. If you can find one that will do both (content and pedagogy) that's always preferable. So, like I like to work with groups that will present you with information and content and then work with you to connect it to your teaching practices but those things takes time, and most teachers are guarded with their time, they don't like to give up two weeks where they can just go and take one day or two days even though the two weeks programme is going to be better for them that's a large amount of their kind of personal time that they are giving up for that. For example, there is this thing in Kansas done by Kansas corn commission who will do like a two week programme where it's couple of hours a day and you are looking at growing corn and different conditions and how changing conditions affect the agriculture of that thing.

Edmund: I think content based and then with some illustration of (like) the pedagogy

that would best support that content. So like if I'm going to PD it's best when I can walk away with some concrete ideas about (like) specific ways that I can apply that to my own classroom. So (like), if I went to a climate change PD it will be great to walk away with (like) literally with a lesson or tools worth of materials that I could then personalise in a way that will be meaningful for my students so like if that was (like) an investigation on a specific data set or (like) a specific case study that they can look at and some ideas of maybe how to get them to analyse data or present it graphically or engage in a simulation or bottling activity (like) to go to a PD and walk away with two or three of those and like know how to present it that will be great. If I had (like) three go-to thing (like) experiences for my students where it was like really (like) I had an introductory level of lesson where it was (like) here's a collection of kind of (like) an overview of the big issues and then maybe (like) a deep dive into atmosphere and oceanic CO₂ levels over time and then wrap it up with in-depth case study of (like) one specific thing that will be pretty powerful PD if somehow somebody was able to create that.

Grigor: I think the best thing for a new teacher and I don't know they get this enough is to go through a microcosm of a unit. So for instance if they took the test that I would give before teaching part of this unit they could see how much they know. And obviously you don't know much to yourself and you know that you need to hone up on the content. Or maybe you know it but most inservice teachers need more training on the pedagogy and they obviously need training on, but don't get it and are just thrown into the water, how to manage the classroom you know, how to not lose your cool and new teachers are, probably you know

a lot of them, don't have a science background and they are kind of like me and they kind of feel, they might feel insecure about it oh I don't know that much and you know I better learn a little bit more. You just have to focus on the process skills...not necessarily something on all the science behind climate change but more about how to teach and how to incorporate the nature of science, critical thinking, discussion, publishing a data, you know how science works. I think that would be the best focus for the in-service teachers in my opinion. And the content knowledge is something that you just pick up by yourself.

Juan: Well, I would hope that people who are teaching at high school level would have a class that focuses, you know, a large chunk focuses on climate change. What I've noticed in our community is that K through 6 teachers really struggle with teaching science because they are not comfortable with material, they are afraid, they are going to get things wrong, they are afraid, they are going to give kids misinformation. We are dealing with that right now and trying to help those, I've actually worked with a curriculum director to try to help these teachers gain confidence that they can share this information. I mean they are literally trying to... that they just skip science you know. They are focusing on reading, they are focusing on math because that's what we are testing and kids are not getting it. It makes me so sad and they just tell us we don't even know...we had one teacher who said I don't even know what STEM is and I was flabbergasted by that. I had no idea that you could be a teacher in United States right now and not know what STEM was... So, I would require professional development training every five years for teachers and that also that every state in the United States adopt

what's called the Environmental Literacy Plan and we are trying to do this year in the state of Indiana and it's not working out very well through our Environmental Education Association and but the idea is like here are things that you should be doing as teachers, these are not extra standards like to add necessarily, this is the way to incorporate the environmental learning in your current standards and here is how they apply but have that adopted by the state, we are a state that's concerned about the environment and that's promoted with our teachers by giving them professional development time. And maybe earning some sort of certificate you know like oh I've got this training every five years that sort of things, you know, may be have some incentives that sort of things. It's all about I think yes introducing at the undergraduate level but then consistently reinforcing it throughout their entire career... both (content knowledge and pedagogy). But I think, especially at the elementary level, they need a content knowledge. You know I think, again if I am running the planet, (like) a first year teacher like the first five years focus on the content, may be next five years focus on the content, maybe next five years more pedagogy you know, kind of scale it up like you already know this stuff we are not going to make you relearn these things. Now, how can we implement best practices in their classrooms.

Johanna: Well, I mean, I like the courses where they give us materials that we can actually use in the classroom and how we can use them. So (like) I want to be able to take a lot back with me when I go to a course. I have a lot of things, I just like the newest stuff. I want new conversation so, that would be nice. Just like, you know, current research and you know, what people are doing, what people

are talking about. That's what I would be interested in. How changes happen in like the last 20 years...Something like that.

Justine: Content based...(teachers should be able to handle pedagogy)...I think it's important (pedagogy), but I think the training is...the content based, yes.

Jelena: I would say having them (like) relating to the kids first, like relating that problem to the kids and not in a way where (like) what I was talking about how they are desensitised to the information the kids are as far as (like) you know, if you don't do this you are going to be doomed. That's not working I think. It's just been way over done. But honestly in a way (like) teaching teachers how to get kids outside to experience it and I think that's going to be your biggest, how to use outside in the classroom, how's that, that's my biggest thing I think... I think, part of that might just be, I think I would take use of this too is learning how to interpret what's going on in the news and using that in your classroom. Not even just the news but you know science, how to look at recent scientific articles and how to use that knowledge in the classroom because that's something always changing... Yeah, I've never seen a PD course like that. So that will be kind of cool.

Lindsay: Definitely things about trends and correlations. Either it could be like the trends in, what's the best what for me to say this? Not just trends in temperature, everyone always focuses on the temperature aspect. There's so much more than that. Like when it comes to the correlation between ocean currents and climate or even mountains in climate, my kids were like why is it that the middle of the United States environment is so different from the west coast and us. Because

there are mountains. The mountains control the climate and they're like what. I was like yeah they prevent things from like moving or they move things up and down. They don't get that. And they also don't understand like the movie "*The Day After Tomorrow*..." When they talk about the ocean currents affecting the temperature of like England and the United States and things like freeze over. They don't understand like that could kind of happen. Maybe not that quickly, but those types of trends do occur and I feel like teachers could also learn more about, like everyone is talking about the effects like ocean temperature or overall temperature in the air, but like I don't know, I just feel like in general there is so much misconception out there like oh global climate change is only about temperature and it's not, just anything that's not related to temperature would be really beneficial. And seeing, I mean you can always relate it back to temperature and the correlation between that, but I feel like we need a lot more about like everything else.

Lucie: I don't know if I need more training in terms of like understanding the topic or anything. But like more experience and PD will be more like project based teaching. I think that will be more the direction I'd want to go...(not content, more pedagogy)...it should be like a PD, I mean I'd be, if I'm going to do it as an external entity that I'll like go to like maybe a weekend or like... atleast once a year...I could imagine myself say going and doing something maybe over the summer as like a summer institute and then giving myself some time to like practice, which should take a few years, a year or two atleast and then maybe if I saw like I needed more instruction

or you know like having some place to like meet with the cohort of people that I was in the PD with or if there is some kind of cohort that would need, kind of like a writing group that more like a curriculum development group so it's focus on that will be like once a quarter or like just to be able to like cement with other people that are trying to go down the same road...really need...I can do that (content) on my own. Like I understand the content enough.

Martin: Climate-specific PD would be most appropriate, taught by scientists doing climate science so that we can be exposed to the most current research. These lessons should be supplemented with workshops by excellent educators who can provide climate specific pedagogy to deliver this challenging content.

Stan: I mean, my goal is to reach out and connect with teachers who do not teach climate change at all, who do not teach environmental issues at all, but who vaguely care or want to do those things, but don't know how and to give teachers a basis, a starting place, a grounding into how to begin incorporating environmental and specifically climate related issues and topics into their classes...Yes both content and pedagogy.

Taylor: ...show effective teaching...Don't sit there and lecture to us. That's not what I want to hear. I want you to show me something that you've seen that worked. Show me the whole thing, the whole process. Don't have somebody stand in front of me and say oh my kids love this...Show me what you did. Show me your paperwork. Show me what their work was. Show me that.