

# Pakistani Chemistry Teachers' Understanding, Beliefs and Teaching Practice About Climate Change

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**Abstract:** Teachers' personal beliefs and understanding about science topics play a vital role in students learning. This is especially relevant for the teaching of climate change, which is a scientifically complicated topic that can also be influenced by personal and political views. Semi-structured interviews were conducted with thirteen Pakistani chemistry teachers (grades 10 & 12) to understand their knowledge about the science of climate change as well as their beliefs and practices related to the teaching of climate change. We found that teachers believe it is important to teach climate change in schools. They report that they teach climate change with relevant topics and do not face any obstacles doing so. No consensus was found regarding the appropriate grade levels and disciplines in which climate change should be taught. We also found that teachers have insufficient scientific knowledge about climate change (e.g., they think that any change in environment is climate change and climate change is related to pollution and ozone layer depletion). Our results suggest that there is a need to include climate change in in-service refresher courses and preservice teacher training programs, so the teachers have better understanding of the science of climate change. Further, there should be more climate change content in high school chemistry and biology.

**Keywords:** *Chemistry teachers; Climate change teaching; Knowledge and beliefs; Pakistani schools*

## Introduction

Teachers' perceptions about teaching a topic as well as their content knowledge are important personal characteristics that impact classroom practices (Shulman, 1987; Haney, Czerniak, & Lumpe, 1996). Teachers with good content knowledge are more effective at presenting the subject matter to students (Carter & Doyle, 1987). Sometimes teachers' thoughts about the importance of certain aspects of a topic may influence their teaching decision. These aspects of teaching become more important for science topics related to everyday life and those that are particularly complicated. Climate change is one such topic. Despite appreciating the importance of teaching about climate change, teachers' personal choice to prioritize topics related to climate change, their level of understanding the science of climate change, and their beliefs about climate change could impact their teaching practice about climate change (Plutzer et al, 2016; Feirebend, Jokmin, & Eilks, 2011; Boon, 2012; & Dawson, 2012). For instance, Feirebend, Jokmin, and Eilks (2011) reported that secondary school chemistry teachers appreciated the importance of teaching about climate change, yet they also feel that teaching about climate change may take away from time available to teach chemistry content.

The Ministry of Climate Change in Pakistan issued a climate change policy in 2012. This policy recommends climate change education be included at all grade levels in Pakistani education institutions. Moreover, the National Curriculum of Pakistan (2006) has sections on environmental sciences in chemistry for grades 10 and 12. These

sections contain topics related to global warming and climate change. Yet, it is not clear to what extent these topics are taught or whether teachers experience any barriers to the teaching of science topics related to climate change and how well teachers understand the climate change science. Thus, this study is focused on understanding on how grade 10 and 12 chemistry teachers implement instruction related to climate change as well as how this implementation is influenced by their knowledge about the science of climate change and their beliefs about the teaching of climate change.

### **Literature Review**

This study was planned based on the existing literature about the teaching of climate change. To get an idea about the issue around the world, we reviewed relevant studies from different parts of the world that explicitly address teachers' knowledge, beliefs, and teaching practice related to climate change.

### **Teachers' Knowledge About Climate Change**

Teachers' content knowledge is an important part of their repertoire. Their scientific knowledge about the subject has been shown to impact classroom practice and students' learning (Shulman, 1987; Haney, Czerniak, & Lumpe, 1996). Because of having better content knowledge and understanding in their areas of specialization, teachers do a better job teaching a topic from their area of specialization than topics outside this area (Gess-Newsome & Lederman, 1995, p. 318). Therefore, it is important to explore the knowledge and understanding of teachers about climate change.

Several studies have found that teachers' knowledge about climate change is not well aligned with the scientific viewpoint (Boon, 2010; Dawson, 2012; Herman et al, 2017; Wise, 2012). While studying climate change knowledge of secondary school teachers from Puerto Rico and Florida, Herman et al (2017) reported that most of the teachers have inadequate scientific understanding about climate change. The researchers found that only 6 % of teachers could correctly define climate change. In a similar study, Boon (2010) reported that preservice teachers and secondary students in Australia showed similar lower level of understanding about climate change. It was true for the teachers who had taken environment and science focus courses at various levels in their studies. Similarly, Dawson (2012) and Wise (2012) reported that many primary and secondary teachers possess inadequate scientific knowledge about climate change.

While there is a dearth of literature about climate change teaching and learning in Pakistan, studies from the geographic region such as India and China indicate that teachers and students are enthusiastic to take action to improve their environment but possess inadequate knowledge about climate change (Malinda et al., 2017; Sah & Bellad, 2015; Wong 2012; Zeeshan et al., 2021). Sah and Bellad (2015) found that the school students in south India have inadequate knowledge about causes and effects of climate change. Malinda et al (2015) found that more than 50% of the in service and preservice science teachers in Indonesia have incorrect perceptions about climate change and global warming. Zeeshan et al., (2021) explored the level of awareness and willingness to act about climate

change among school students in Jammu and Kashmir. The researchers found that the majority of students showed moderate level of awareness about climate change, 60% were highly proactive towards advocacy and 88% were willing to get involved in action to about their environment. Similarly, the secondary students in Hong Kong were found to have moderate level of understanding about climate change high majority of students were willing to participate in activities to improve environment (Wong, 2012).

In addition to the content knowledge, teachers' beliefs about teaching and prioritizing a topic may also impact their decision about instruction on a topic in class.

### **Teachers' Beliefs About Teaching Climate Change**

Teachers' beliefs have a direct impact on their classroom practice (Richard & Lockhart, 1994). As climate change is a topic related to everyday life, people may have different beliefs associated with causes, impacts, and reasons to teach about climate change. Climate change is also a scientific as well as political issue, so teachers may have different beliefs about the validity of science and the appropriateness of teaching about climate change. Because students learning is associated with teachers' understanding, interest, attitudes, and classroom practice (Ramsey & Howe, 1969) and McNeal Et al., (2017) reported that teachers who are personally motivated to teach climate change take it as a responsibility to equip students to be scientifically literate and teach students based on scientific findings. Therefore, it is important to consider teacher beliefs about teaching of climate change.

At times, teachers may consider a topic as an important, but they believe that someone else should teach it. For example, McGinnis et al. (2016) found that educators from higher education, K-12 and informal settings held varying views about their responsibilities on imparting climate change education. The researchers recruited a limited number of educators during a summer training program in the USA. It was found that educators believed that climate change is an extremely important topic for citizens to understand. However, the educators at each level felt that teaching climate change to students was not their responsibility; rather, educators at other levels should teach climate change.

Curriculum focus about a topic is another important factor that could potentially impact teacher inclination to teach a topic. Thus, it is important that teachers understand the justification for teaching about the topic as well as its place in the curriculum (Monk & Osborne, 1996). Teachers' beliefs about the importance of including climate change education in different disciplines and levels may also affect their classroom practice. Feirebend et al (2011) conducted a study -in Germany- to investigate secondary school chemistry teachers' views about the proper place of climate change education in chemistry, and the way to make climate change education interdisciplinary. It was found that the chemistry teachers believed that this topic would impact students' lives in the future and has the potential to impact society. There was no consensus among teachers about where in the curriculum -lower or upper secondary level- climate change education should be placed within K-12 education. Despite appreciating its importance, the participants felt that climate change teaching may compromise the time and effort available to teach

chemistry content. Furthermore, the participants did not think that climate change teaching could help teach the chemistry content.

### **Climate Change Education in Pakistan**

While teachers' content knowledge and beliefs may be associated with their classroom practice, the relationship between teachers' knowledge and classroom practices is complex (Newsom & Lederman, 1995). What teachers believe should be taught could be substantially different than what they teach in the classroom (Fang, 1996; Munby, 1982). For example, some teachers believe that climate change is an important issue but still prioritize other topics during classroom practice (Dawson, 2012). In Pakistani context, to the best of our knowledge, Begum's (2012) study is the only empirical study that explores some parts of climate change from Pakistani secondary teachers' secondary teachers. Begum (2012) investigated school science teacher's belief about teaching environmental issues, including climate change, in class and its relationship to classroom practice. The researcher found that the teacher believed in teaching environmental issues in the classroom and that the students should be engaged in activities and projects related to environment education however, their enacted classroom practice was contrary to the belief. It was further found that the teachers' content knowledge, pedagogical knowledge and lack of support from the school administration were the factors keeping them from teaching environmental education.

Although not explicit, Pakistani education system particularly K-12 includes some climate change education. Pakistani Government is making efforts to mitigate the climate change effects and support climate change education in K-12 education. The government of Pakistan has established a cabinet level ministry named Ministry of Climate Change in Pakistan. The role of this ministry is to take necessary steps to mitigate the impacts of climate change in Pakistan. The Ministry of Climate Change issued the National Climate Change Policy in 2012. The policy provides a framework to address Pakistan's current and future issues related to climate change. It has identified important climate change threats to Pakistan, including frequent extreme weather events, erratic monsoon rains, the projected recession of glaciers, as well as enhanced heat and watershed conditions (Climate Change Policy, 2012). Along with many other measures, the policy states that the Government of Pakistan will take action to promote awareness and climate change education at all levels in the education system.

### **Research Problem and Research Questions**

The literature suggests that teachers and students from various parts of the world have varying levels of scientific understanding and a variety of beliefs about teaching climate change. The K-12 Curriculum in Pakistan (2006) includes topics on global warming and climate change in grades 10 and 12 of chemistry in the section of environmental sciences, yet there is lack of research on teaching of climate change in Pakistan to understand how this curriculum is interpreted and implemented regarding teaching of climate change. The purpose of this study is to describe what Pakistani chemistry teachers understand about climate change and what they believe about teaching it in Pakistani schools because such beliefs and practice may significantly impact students concept building and subsequently it may affect climate change literacy among citizens.

Since the National Curriculum of Pakistan contains topics relevant to climate change in chemistry at grades 10 and 12, it is appropriate to base this study on chemistry teachers at these levels. The research questions for this study are as follows:

- 1) What do Pakistani grade 10 and 12 teachers believe about teaching climate change?
  - 1a) To what extent do teachers think climate change is a topic that should be taught in schools?
  - 1b) In what grade levels and disciplines do teachers think climate change should be taught in schools?
- 2) What are Pakistani grade 10 and 12 teachers' practices related to teaching climate change?
  - 2a) To what extent do teachers teach about climate change in their classrooms? What are their reasons for this level of teaching about climate change?
  - 2b) What, if any, obstacles do teachers face in teaching about climate change?
- 3) What do Pakistani grade 10 and 12 teachers know about climate change?
  - 3a) How well do teachers understand the science of climate change?
  - 3b) How well do teachers understand the causes and impacts of climate change?

## **Methods**

This study follows a cross sectional descriptive qualitative research approach. A qualitative study provides deeper insight into a real-world problem (Moser & Korstjens, 2017). The present study aims to get in-depth understanding about teachers' knowledge, beliefs and practices of climate change; therefore, qualitative approach suits this study. Since very little is known about this issue in the region this study was conducted in, this study will provide a detailed description of the participants' knowledge and views about climate change instruction.

### **Participants**

Public and private schools in Pakistan follow a unified curriculum for chemistry at grades 9-12. At the end of grades 9, 10, 11 and 12, students appear for the external board exams which are based on the curriculum taught during those years. Well-educated and trained teachers teach at these grade levels. A total of 13 participants were recruited from four districts of Punjab province in Pakistan. Convenience sampling was used to recruit all participants. Of the participants, ten were males and three were females. Since, the curriculum from the Punjab Government requires chemistry teachers of grades 10 and 12 to teach about climate change, they were chosen for this study. The participants were in-service teachers having the experience of teaching chemistry from five to fifteen years. All the participants speak and understand Urdu and Punjabi languages.

### **Instrument**

A semi-structured interview protocol (Appendix A) was used as the instrument for data collection. The questions about teachers' beliefs and practices about teaching climate change were designed based on the study by Feirebend et al (2011). The study investigated German secondary school chemistry teachers' perceptions about the teaching of climate change in chemistry education. Findings suggested that teachers had differing views about placement of climate change in the chemistry curriculum and that they give different amounts of time for teaching climate change, ranging from specific periods for climate change to discussing this issue with other topics. Because the motivation

and findings of this study are aligned with our research questions, we based our questions on teachers' beliefs and practices on the instrument. Moreover, we were interested to know about teachers' understanding about climate change. We developed our questions on teachers' understanding of the definition of climate change, reporting causes and consequences of climate change based on the study by Herman et al (2017).

The face and content validity of the interview protocol was established by two climatologists and two science educators. The science educators checked and gave feedback on questions about teachers' beliefs and practices. The climatologists reviewed questions about scientific understanding of climate change. The questions were finalized after making relevant edits based on the feedback. The instrument was then translated into Urdu. The validity of the translation was checked by the first author and two college level language teachers who understand the English and Urdu languages. The translated instrument was further amended and validated by conducting interviews of two Pakistani grade 10 and 12 chemistry teachers and making sure that the participants understand the questions in the same way as they were intended. Those teachers were not recruited in the final interviews. The research instrument and the study design were approved by the Human Subject Institutional Review Board.

### **Research Design**

The study intends to explore chemistry teachers' beliefs, scientific understanding and teaching practices related to climate change. Therefore, a qualitative study design was followed to get teachers' in-depth responses about teaching of and understanding about climate change. The motivation for this study came from two previous studies about secondary school teachers' perspectives on the teaching of climate change. One study is chemistry teachers' views on teaching climate change by Feirebend et al (2011). The researchers in this study used semi-structured interviews to evaluate service chemistry teachers' views about the teaching of climate change. Another study by Herman et al (2017) was used because this study investigated secondary school teachers' knowledge and teaching of climate change.

The participants were recruited via phone calls after getting their contact information from respective school offices. The schools included both private and public that were conveniently chosen from three districts of Pakistan. Twenty teachers were contacted and a total of thirteen agreed to participate. After getting their consent, participants were interviewed in person at public places of their convenience. The average duration of an interview was about 20 minutes. The interviews were audiotaped and later transcribed in Urdu. These transcripts were translated into English for analysis. For the translation, the first author and two college level language teachers (for Urdu and English) from Pakistan independently translated each transcript and then engaged in discussion to create the agreed-upon translation of each script. The transcribed and translated data was validated by discussing the transcripts with 3 of the study participants who agreed with relevant datasets.

Each research sub question was treated separately for analysis. For the first two questions, the In-Vivo coding method was employed. In this method codes are taken directly from what participants say and are placed in

quotation marks (Saldana, 2021, p. 7). One transcript was coded by the first author and two experienced researchers. The interrater reliability was 83% and consensus was developed for the codes where coders disagreed. After developing a coding scheme, two researchers coded the rest of the transcripts. For each sub question, codes were combined into categories and after multiple discussions between coders common themes were developed to answer each question.

For question 3, we used the following as our definition of climate change paraphrased from IPCC synthesis report (2007a, b) “the change in the average weather or the variability of its components over an extended period of time (for example a decade or longer) or both”. Three people analyzed the transcripts and reported the responses in terms of participants’ ability to describe the climate change as long-term weather changes. Two researchers noted the causes and consequences in each transcript in terms of correct, incorrect, and partially correct answers. After noting the causes and consequences in each transcript, coders compared their codes and developed a consensus through mutual discussion and consulting the transcripts. The codes were placed in informed, partially informed and naïve categories. This method of reporting definition, causes and consequences was adopted from Herman et al (2017).

## Results and Discussion

The purpose of this study is to examine Pakistani teachers’ knowledge, beliefs, and teaching practice of climate change. This investigation was pursued through three major research questions. Our findings for each question are discussed below.

**Research Question 1:** What do Pakistani grade 10 and 12 teachers believe about teaching climate change?

1a) To what extent do teachers think that climate change is a topic that should be taught in schools?

All the participants showed strong agreement about the need to teach climate change in Pakistani schools. All participants felt that it is important to teach climate change at schools because they felt that our climate is undergoing abrupt changes due to global warming, human activities, and chemical reactions in the environment. Further, they think that teaching of climate change is important because the rise in temperature is impacting our lives and nation. It is important to give awareness and educate our students about climate change so that they play their role to control it. For example, Emanuel said “*Climate change should be taught in schools because we are living in a period of global warming. Temperature of earth is rising day by day. This topic should be taught from grade 9 rather we should start teaching climate change from grade 6 and 7 because global warming is impacting our rural and urban areas.*” Similarly, Iqra said “*It is very important to teach students about climate change because our climate is undergoing many changes. In old days, our climate was not this much extreme. People often say that its God’s punishment, but I say that its environmental change. This change is because of chemical reactions in the environment, global warming and human activities. Therefore, it is very important to teach students about it.*”

1b) In what grade levels and disciplines do teachers think climate change should be taught in schools?

No consensus was found among participants about what grade level climate change instruction should be started. Seven participants think that climate change should be included in general science curriculum at the primary/elementary level. According to Anil “*It should start from primary level because students develop their*

*habits from this level. The study of climate change will impact students' minds once habit is developed. Climate change is an implementable thing which students will implement in their lives. Its study should have effect on our lives".* Whereas six felt that it should start from grade 9 and 10 because students become mature enough to understand this issue. For example, Alex said *"I think we must include them in chemistry and biology. I don't know much about biology but there is very less content on climate change in chemistry. It should be much more in chemistry. And I think we should start from grade 9, and 10 because at this level students become mature enough to understand it"*. Five of them explicitly said that climate change should be the part of chemistry and biology curriculum. For example, Iqra said *"I think it should be taught in biology and chemistry. Chemistry must contain the chemical effects while biology should include biological effects which impact humans"*. Eight participants gave varying views about the disciplines they feel climate change should be taught in. For example, general science at elementary level, general knowledge (combination of social studies and general at grades K-2) and science in the primary classes.

**Research Question 2:** What are Pakistani grade 10 and 12 teachers' practices related to teaching of climate change?

2a) To what extent do teachers teach about climate change in their classrooms? What are their reasons for this level of teaching about climate change?

Ten participants responded *yes* when asked whether they teach climate change in class. Three initially said *no* but being reminded about the content in the required syllabus, they changed their answer. All thirteen respondents expressed varying reasons/concerns about their practice of teaching climate change. For example, some participants said they do not teach more climate change because there is insufficient content and there are very few exam items about climate change in the final exams.

All of them said they teach climate change because it is a syllabus requirement. Ten participants said that there is insufficient content on climate change in the syllabus. As Alex said *"Basically, we are required to focus on our syllabus. And there is not much content about it in our syllabus. There is a chapter which has topic like air pollution, its types, and ways to control it. In chapter there is a little content on climate change. We teach only the content given in our syllabus"*. Nine participants said that they do not teach climate change as a separate lesson but discuss it with relevant topics because the curriculum contains climate change content (like greenhouse effect, global warming, carbon cycles) that is mixed with other science topics. As Nayar said *"We include it (climate change) with general science topics like greenhouse effect, global warming and carbon cycle. Students learn a little about these issues, however if there is a specific chapter on climate change, they will better understand climate change, its causes and effects"*. According to Kashif *"We teach only topics which are part of our syllabus. Since our syllabus has topics on climate change we teach it. I teach it with syllabus. There is no specific lesson for climate change."*

2b) What, if any, obstacles do teachers face in teaching about climate change?



All the participants said that they face no obstacles like opposition from administration, parents or students) in teaching climate change. Four participants indicated just the opposite, that they are encouraged to teach about climate change because its relevant to students' lives and students take keen interest in learning about it. For example, Sham said *"No, we don't face such obstacles. I teach it in the form of a story, then students take keen interest and other people support me. We don't face any problems. Students learn that flooding is not happening at once but there has been some long-term mishandling in the environment which has caused it. Children learn it and others like and support me."*

**Research Question 3:** What do Pakistani grade 10 and 12 teachers know about climate change?

3a) How well do teachers understand the science of climate change?

When asked "What do you think is the best scientific definition of climate change" only two participants described climate change in terms of long-term weather changes. For example, Asif said *"Climate change means weather changes in a particular region. With respect to entire country, we say overall environmental changes we observe are climate changes. We talk about the long-term changes here"*. Most participants (n=11) described climate changes as short-term weather changes or any environmental changes because of human activities. According to Kashif *"Climate change is any change in our environment because of our activities. We bring such changes by breaking mountains, by deforestation, by explosions, and by increasing our population. Cutting of forests will result in flooding. Deforestation will increase the amount of carbon dioxide in the atmosphere which will trap sun radiations."* Akram said *"If we see any changes in our usual environment, we say it is climate change. I mean if we see any changes in the environment we see on daily basis; I would take it as climate change."*

3b) How well do teachers understand the causes and impacts of climate change?

The participants gave nine major causes for climate change. Each participant gave 2-5 causes. These causes included deforestation, use of fossil fuels, urbanization, industrialization, overpopulation, emission of CFCs, land and air pollution, use of nuclear weapons, and volcanic eruption. Deforestation, use of fossil fuels, urbanization, urbanization and volcanic eruption were considered as correct and the use of CFCs, land and air pollution, and use of war weapons were taken as incorrect. Based on their responses, participants were divided into informed, partially informed and naive categories (Table1). Those who's responses were aligned with scientific understanding were placed in informed, those who mixed scientifically aligned and not aligned responses were placed into partially informed and those who gave only non-scientifically aligned answers were placed in naive categories. Only three participants gave scientifically aligned responses on major causes of climate change. They described deforestation and use of fossil fuels as major causes of climate change. As Asif said *"Deforestation and automobiles are the major causes. There are some natural cycles in our atmosphere. The rise in temperature is because of release of carbon dioxide which is produced by automobiles. Carbon dioxide is used by trees which we reduce by deforestation"*.

Nine participants described causes which were a mixture of informed and naive answers. They mainly included deforestation, industrialization and burning of fossil fuels with air and land pollution and use of CFCs. Kashif said *“Human activities are the main cause. We have brought many changes on earth which are now impacting us. Such activities include pollution, deforestation, urbanization, burning of oils, and atom bombs. Ozone is an allotropic form of oxygen in the stratosphere which protects us ultraviolet rays of sun. Human activities are impacting ozone layer as well. This layer is largely impacted by CFCs produced by air-conditioning and refrigeration. CFCs break the layer of ozone which would allow harmful radiations to enter our atmosphere and will have harmful effects on human health”*. Likewise, the responses about the consequences of climate change were placed into informed, partially informed and naive. Overall, the participants reported 11 consequences of climate change those being flooding, extreme weather conditions, unpredictable weather, irregular rainfall, droughts, melting of glaciers/ice caps, rise in earth temperature, rise of sea level, air and land pollution, health issues like heart attack and breathing problems, and depletion of ozone layer. Each participant reported 3-5 consequences of climate change. Flooding, extreme weather conditions, unpredictable weather, irregular rainfall, droughts, melting of glaciers/ice caps, rise in earth temperature, rise of sea level were taken as informed whereas heart attack and breathing problems, air and land pollution, and depletion of ozone layer were taken as naive consequences. Responses containing informed and naive consequences were placed in the partially informed category.

Table 1

*Teachers’ Responses about Causes and Consequences of Climate Change*

|              |           | Causes   |                    |       | TOTAL |
|--------------|-----------|----------|--------------------|-------|-------|
|              |           | Informed | Partially informed | Naïve |       |
| Consequences | Informed  | 3        | 3                  | 0     | 6     |
|              | Partially | 1        | 2                  | 1     | 4     |
|              | Informed  |          |                    |       |       |
|              | Naïve     | 1        | 2                  | 0     | 3     |
|              | TOTAL     | 5        | 7                  | 1     | 13    |

As shown in Table 1 only three respondents could scientifically describe causes and consequences of climate change. Seven participants gave partially informed causes of climate change. For example, when asked ‘what do think are the main causes of climate change?’ Kashif said *“Human activities are the main cause. We have brought many changes on earth which are now impacting us. Such activities include pollution, deforestation, urbanization, burning of oils, and atom bombs. Ozone is an allotropic form of oxygen in the stratosphere which protects us ultraviolet rays of sun. Human activities are impacting ozone layer as well. This layer is largely impacted by CFCs produced by air-conditioning and refrigeration. CFCs break the layer of ozone which would allow harmful radiations to enter our atmosphere and will have harmful effects on human health.”* Six participants scientifically described the consequences of climate change. For example, Asif said *“With climate change, weather will become severe, there will be less patterns in weather, winter will change into summer, ice will melt in the northern areas, and it will cause flooding.”*

Four participants mixed the informed and naive consequences of climate change. As Sehar said *“There will be larger quantity of greenhouse gases, the temperature of earth will rise, ice caps will melt and there will be less rainfall. People will suffer from different diseases including heart attack, headache, skin cancer which is mainly caused by ozone depletion. In the olden days there were such diseases like heart attack but today the main reason of heart attacks is climate change. Human drink uncleaned water. All this is because of climate change”*. Three participants gave naive consequences including ozone layer depletion, health issues, formation of smog, and air/land pollution. As Sheron said *“As we can see get ozone layer is getting depleted and more ultraviolet rays are entering our atmosphere. These ultraviolet rays are carcinogenic. They cause cancer. And all the volatile and pollutant compounds in our environment enter our bodies and they disturb our internal systems which result in many diseases”*.

We conclude that teachers believe that climate change should be taught because it is an important global issue and related to students’ lives. They claim to teach climate change and follow the curriculum and they report facing no opposition from parents, students or administration regarding the teaching of climate change. Insufficient climate change content in the national curriculum and associated final exams were reported as important obstacles obstructing the teaching of climate change. Further, we found that many teachers lack knowledge about the science of climate change that is required for its effective teaching.

Our findings about teachers’ lack of knowledge about climate change aligns with prior studies (Boon, 2010; Dawson, 2010; Herman et al, 2017; Wise, 2012). As found by Wise (2012) and Herman et al (2017) many teachers perceive that climate change is related to ozone layer depletion. Our study found that teachers report pollution in general as a cause and consequence of climate change. These findings are compatible with Papadimitriou (2004). This could be associated with the fact that topics of climate change and air/land pollution are placed in the same section of the chemistry curriculum in Pakistan. It was surprising to find that teachers do not see climate change as controversial topic, these findings may be attributed to the fact that participants are science teachers who have advanced degrees in chemistry and might be aware of the scientific consensus on the topic or they might have purposely chosen to adhere with the scientific consensus.

### **Conclusion and Limitations**

Most teachers possess only partially correct understanding about causes and consequences of climate change; only 3 out of 13 teachers were found to have correct understandings. This suggests that teachers lack the scientific knowledge of climate change needed to successfully teach about it, raising concerns about the effectiveness of their classroom practice. It is important to find ways to improve teachers’ knowledge about climate change. We recommend that teacher preparation programs include research-based climate change content and modules. For in-service teachers, there is a need of professional development with an explicit focus on research-based climate change science to improve teachers’ scientific understanding about climate change.

The research was based on self-reported data which may not be the true representation of actual classroom practices. Observation of actual teaching practice would give better results on teaching practice of climate change. The teachers investigated here were a small convenient sample and may not be the representative of all grades 10 and 12 chemistry teachers of Pakistan.

The findings of this study hold implications for science curriculum and teacher training programs. The chemistry teachers' views suggest a need for the inclusion of more climate change content in secondary school chemistry and including it in the biology curriculum at grades 9 through 12. National assessment should match the curriculum and also emphasize the climate change content. The teachers' lack of scientific understanding of climate change science calls for improvement of teachers' knowledge about climate change. We recommend that teacher preparation programs include research-based climate change content and modules. For in-service teachers, there is a need for professional development with an explicit focus on research-based climate change science to improve teachers' scientific understanding about climate change content. This will help teachers improve their teaching climate change.

This study provides directions for the future research with a larger and more representative sample from Pakistan to examine secondary school teachers' knowledge and beliefs about climate change in Pakistan. A larger sample size with mixed method design will provide a deeper perspective that can be generalized. The lower level of scientific knowledge of teachers raises concerns about the environmental science courses that chemistry students take in their graduate studies. Teacher preparation programs also need to be researched to find the level of attention to climate change teaching.

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## Appendix A

### Interview Protocol

I am interested in your thoughts about teaching climate change in the secondary education. There are no right or wrong answers to my questions. Please ask if you don't understand any question and provide as detailed answer as you could.

1. Do you think climate change should be taught in schools?

Follow-up: If so, what aspects of climate change must be taught? At what grade level and in what courses?

If not, why do you think so?

2. Do you teach climate change in your classroom?

If not, why not?

If yes, how is climate change incorporated in your course?

Do you focus on climate change in certain lessons or associate with other topics?

3. Could you please describe any obstacles that impact you teaching climate change?

4. What do you think is the best scientific definition of climate change?

Follow-up question: What are some of the ways you think climate change is likely to affect the natural environment in next decades?

If nothing: Do you think there will likely be a change in the temperature of the earth?

If nothing: Do you think there will likely be a change in the pattern of the rainfall on earth?

5. What do you think of as the main causes of climate change?

If they mention greenhouse gases:

Follow-up: What re greenhouse gases?

Follow-up: How do greenhouse gases cause the earth surface to warm?

Follow-up: Where are these greenhouse gases coming from?

If they do not mention greenhouse gases:

Follow-up: Do you think that greenhouse gases have any role in climate change?

6. What do you think will be some global consequences of climate change?

7. Do you think the issue of climate change is controversial?

If yes, what is the controversy?

If no, why do you think it is not controversial?

8. Do you believe that climate change is happening?

If yes, why do you think so?

If no, why do you think so?

9. Do you believe that climate change is impacted by human activities?

If yes: What are such activities?

Do you think that humans can reduce the impact of climate change?

If no: If humans do not cause climate change, then what are the causes of climate change?

10. How do you think climate change will impact the nation?

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