Climate Change Education in K-12: Teacher Preparation, Understanding, Needs and Concerns

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Introduction

K-12 Earth and space science teachers are on the front lines of climate change education in the classroom. Because of the scope of the scientific discipline which they teach, much of the science behind climate change falls squarely within the courses they offer. From the perspective of an educator, there are significant advantages for including climate change in the curriculum, including the opportunity to teach about the unifying concepts and processes of science[1], to access and apply interdisciplinary science (and math) knowledge in meaningful applications, and societal relevance. There are also significant pressures associated with teaching about climate change which impact Earth and space science educators (and other educators teaching about this topic) which are further compounded by the crisis in Earth and space science education today across the country.

This paper explores current practices in K-12 climate change education today, including teacher preparation, professional development, and understanding of climate change, in addition to reflections on their use of resources, the barriers and challenges they face when teaching about this subject, as well as student and teacher misconceptions[2]. The paper ends with recommendations for the characteristics of K-12 climate change classroom educational resources and the professional development needs of classroom teachers.

Climate Change Education in K-12 Today – When, Where, and By Whom?

Because of the interdisciplinary nature of the subject of climate change, its scope reaches broadly across disciplines, from science to economics to ethics to history and beyond. Yet the basic science of climate change falls squarely within the scope of Earth and space science courses, which are typically offered at the middle and high school grade levels. Figure 1 shows the teaching levels of K-12 teacher survey respondents teaching about climate change in K-12. The majority of K-12 climate change education is occurring in high school (~62%) and middle school (~36%). Climate change content is taught in a variety of courses, including (in order of frequency) courses on Earth science and Environmental science, as well as being included as a topic in courses on Biology, Chemistry, Physics, Physical Science, Ecology, and other courses.

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[1] *National Science Education Standards*, 1996, National Academy of Sciences.

[2] The paper draws upon the results of informal surveys conducted by the National Earth Science Teachers Association over the past year, including a survey of the needs and concerns of Earth and space science educators (Johnson, 2011), between 22 April and 15 August, 2011 (915 respondents), and an ongoing survey of K-12 educators on climate change education (begun in August 2011 and continuing through September), from which preliminary results are highlighted here.

Earth science courses and the educators that teach them are experiencing additional pressures today, which negatively impact their ability to deliver climate change education.

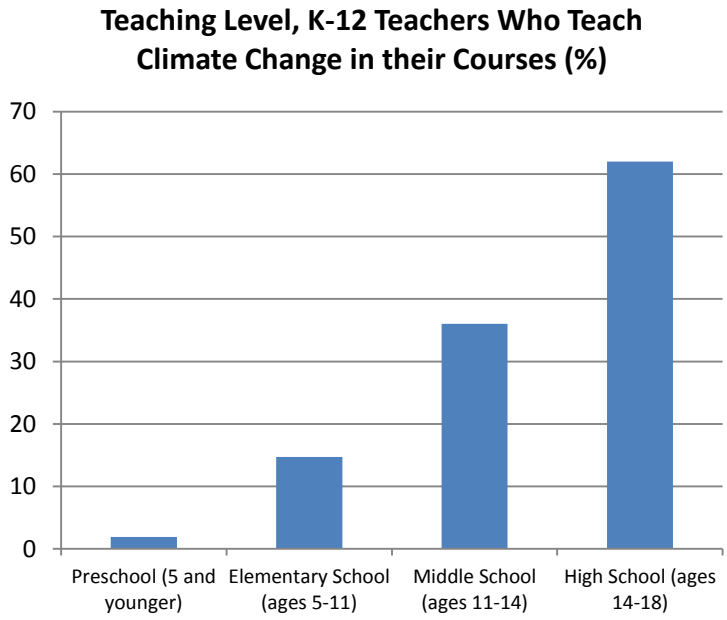

Figure 1 - Teaching level of K- 12 climate change education survey respondents (386 to date) who report that they are K-12 teachers and teach about climate change.

Increasingly, in many school districts, the treatment of Earth and space science courses is changing – mainly for the worse. According to NESTA's survey of the needs and concerns of Earth and space science educators earlier this year (Johnson 2011), respondents report that Earth and space science is being dropped from the high school curriculum entirely (17% of respondents), moved from a required high school course to an elective (16%), or moved to the middle school level from high school (19%)[3]. A significant number of respondents report that the content of Earth and space science courses is being broken up and integrated into other science courses. This trend, in part, a result of extreme financial pressure on public education today, is compounded by perceptions at the university level that high school Earth and space science is not sufficiently rigorous to qualify as a "Lab Course" accepted for university entrance requirements. Advanced Earth and space science courses, which qualify for credit at the university level, are rare across the country, and as a result, high achieving students are tracked away from Earth and space science and into courses where advanced credit is an option. As a result, in a time of severely limited school funding, schools are forced to drop courses (and faculty), and this impact appears to be disproportionally falling on Earth and space science courses and educators, where the bulk of climate change education currently takes place.

K-12 climate change educators are typical of other Earth and space science educators in their age distribution. Nearly 39% of these educators are between the ages of 51 and 60 years of age, while ~18% are between the ages of 31 and 40. While preliminary survey results show that there are fewer male K-12 climate change educators than female (~44% males compared to

[3] 5.6% of respondents report that it is being added as a required high school course, and 7.5% report that it is being added as a high level capstone course in high school (11th or 12th grade). This question received 319 responses in the survey.

~56% females), female K-12 climate change educators are concentrated at lower educational levels relative to their male counterparts, as shown in Figure 2. Our preliminary survey results show that the percentage of male high school climate change educators is ~25% higher than that of female high school climate change educators.

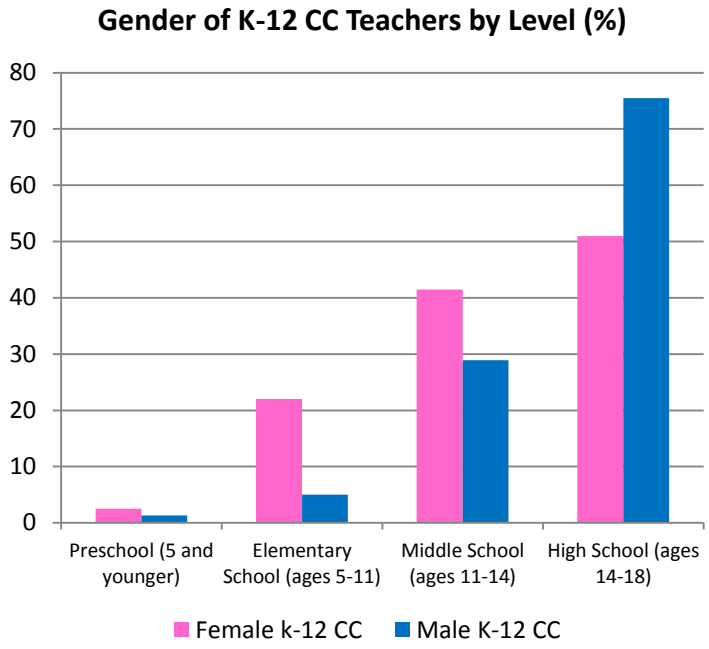

Figure 2 - Gender of K-12 climate change educators. Note that some educators teach at multiple levels, so that percentages can add to more than 100% (386 respondents).

The preparation and professional development experiences of K-12 climate change educators also varies, with a somewhat smaller percentage of female educators reporting taking college courses that included climate change content (~30%) than their male counterparts (~43%). On the other hand, a larger percentage of female climate change educators (~73%) report having participated in in-service professional development on climate change through courses (either in person or online), through workshops, or web seminars than their male counterparts (~66%).

In terms of general science background, Figure 3 shows the number of Earth and space science related courses respondents report taking at the college/university level, including in-service professional development courses. A larger percentage of male K-12 climate change educators report having an undergraduate or graduate degree in an Earth and space science related field than do their female counterparts, by more than a factor of two. Approximately 26% of female climate change educators report having had one to three Earth and space science related science courses, compared to ~16% for their male counterparts.

Climate Change Understandings of K-12 Climate Change Educators

The preliminary survey of K-12 climate change educators currently underway is collecting information on the understandings of respondents on a selection of questions about climate change (in addition to other questions), to assess their understandings about climate change. These questions were drawn, with permission, from the surveys developed by Leiserowitz et al. (2011).

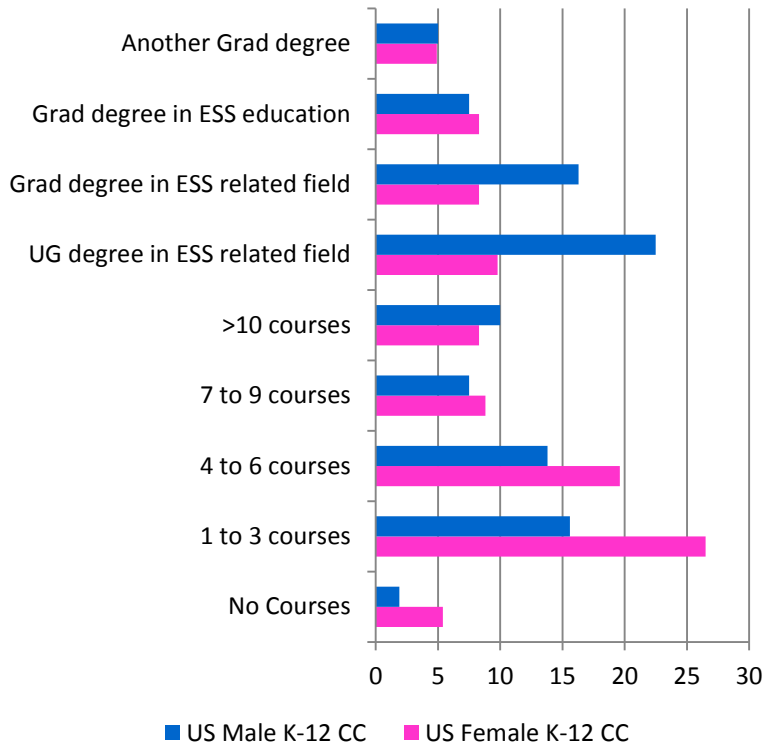

Figure 3 - % response by gender to the question "Please indicate the amount of preparation you have had in Earth and space science related courses at the college/university level, including in-service professional development courses". 385 respondents.

Table 1 provides preliminary results on responses to some of the questions posed regarding climate change understandings, for all K-12 US climate change educator respondents, as well as filtered by gender, college preparation and professional development, region of the country, and type of area in which the teacher teaches. In addition to the preliminary survey results, the results of the study by Leiserowitz et al. (2011) for adults are shown for comparison purposes.

Comparison of preliminary K-12 climate change teacher survey results with the previously mentioned study provides interesting insights into teacher understandings. K-12 climate change educators on average appear to do considerably better than adults in general in answering these questions correctly (with "correctly" defined based on scientific evidence cited in the Appendix of that study). For instance, 88% of K-12 climate change educators understand that global warming is a reality, compared with 63% of adults in the Leiserowitz et al. (2011) study. Similarly, 71% of K-12 climate change educators understand that most scientists think that global warming is taking place, compared to 39% of adults in the previous study. 65% of climate change educators correctly identify that "exponential" is the best descriptor of the rate of change of CO2 in the atmosphere over the past 500 years (when selecting from "no change", "linear increase", "linear decrease", "exponential increase", and "exponential decrease"), compared to 40% of adults in the previous study. 48% correctly identified that most of the glaciers on Earth are melting, compared to 21% of adults in the previous study. Although fewer K-12 climate change educators correctly attribute global warming mainly to human activities (26% compared to 50% of adults in the previous study), 45% of these educators attribute the cause to a combination of human and natural causes, compared to 6% of adults in the previous study. Together, 71% of K-12 climate change

educators attribute global warming either to mainly human activities or human activities and natural causes – 15% more than adults in the previous study.

There also appear to be differences in responses of K-12 climate change teachers based on gender, geographic region, and the type of area in which the school is located in some of the preliminary survey results. The highest level of understanding that global warming is happening is found among Western[4] (93%), female (91%), urban (92%), and K-12 climate change educators with college preparation and/or in-service professional development (90%). The lowest level for this understanding is found among teachers who have had no college preparation or professional development (78%) and male climate change teachers (82%). Similarly, K-12 climate change educators from the Northeast (33%) and urban teachers (31%) correctly attribute global warming primarily to human activities. A larger percentage of male and Southern teachers tend attribute global warming to natural changes in the environment or state the view that it is not happening at all (29% for both of these categories for males and 25% for Southern teachers, compared to 11% for female teachers and 13% for Western teachers). Similar differences in responses are apparent for the teacher understandings of the rate of change of CO2 increase in the atmosphere over the past 500 years.

The climate change teacher survey results shown here are clearly preliminary and additional data is needed. Nonetheless the results to date suggest trends which could, if verified in a larger sample, have significant implications for K-12 climate change education efforts. The survey will continue through September 2011, and results will be made available in November 2011 on the NESTA website at http://www.nestanet.org.

Teaching about Climate Change – Topics Covered, Barriers and Challenges Faced by K-12 Climate Change Educators

In order to get a feeling for the concerns of K-12 climate change educators about teaching climate change, and the challenges they face, the survey poses numerous questions about what climate change topics they teach, their comfort and preparation level in teaching these topics, the extent of external pressures they feel in teaching about climate change, and acceptance of climate change education by school administration and the community. I refer to a few of the preliminary results here, with more complete results available in November 2011.

[4] For the purposes of this study, "Western" teachers teach in the states of Hawaii, Alaska, California, Washington, and Oregon, as well as the territory of Guam, "Southern" teachers teach in the states of Florida, Georgia, South Carolina, North Carolina, Mississippi, Alabama, Arkansas, Tennessee, West Virginia, Texas, and Louisiana, as well as the territory of Puerto Rico, and "Northeastern" teachers teach in the states of New York, Massachusetts, Connecticut, Pennsylvania, Delaware, New Jersey, New Hampshire, Vermont, Maine, and Rhode Island. Survey respondents self-identify the type of area they teach in as either urban, suburban, rural, or "other".

Figure 4 shows the distribution of self-assessments from the survey of how comfortable teachers perceive themselves to be to teach about various climate change topics. Overall, more than 50% of teachers express that they are slightly or extremely comfortable teaching about all of the topics noted. Teachers express the greatest amount of discomfort (extremely or slightly uncomfortable) at about the 20% level when teaching about climate change skepticism, political and socio-economic aspects of climate change, and values, ethics, and moral obligations. Results for teacher self-assessments of their preparation to teach in these areas do not appear to be significantly different than the results for comfort, indicating that comfort and preparation are highly correlated.

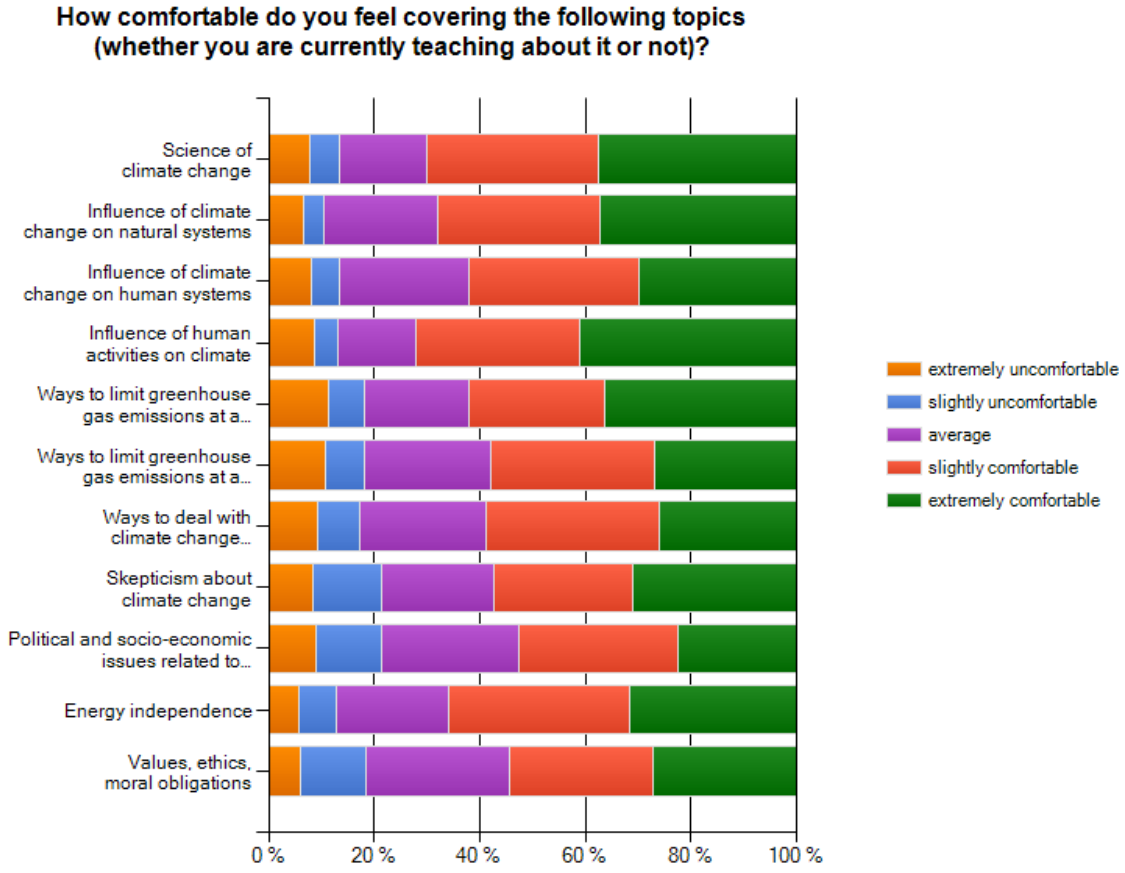

Figure 4 - Distribution of responses to the question "How comfortable do you feel covering the following topics?" directed to US K-12 climate change educators. Topic order was randomized. 358 respondents.

Figure 5 shows the results of responses to a question asking for teachers to indicate which of the topics indicated they teach, with topic order randomized and the ability to mark as many topics as apply. While responses to the majority of topics are relatively similar by gender, within a few percentage points (for example, ~75% of respondents report teaching “the science of climate change”), responses to a couple of questions appear to be more significantly

different by gender, including “Ways to limit greenhouse gas emissions at the personal or consumer level” (~70% female, ~47% male), and “Skepticism about climate change and global warming (~70% male and 51% female).

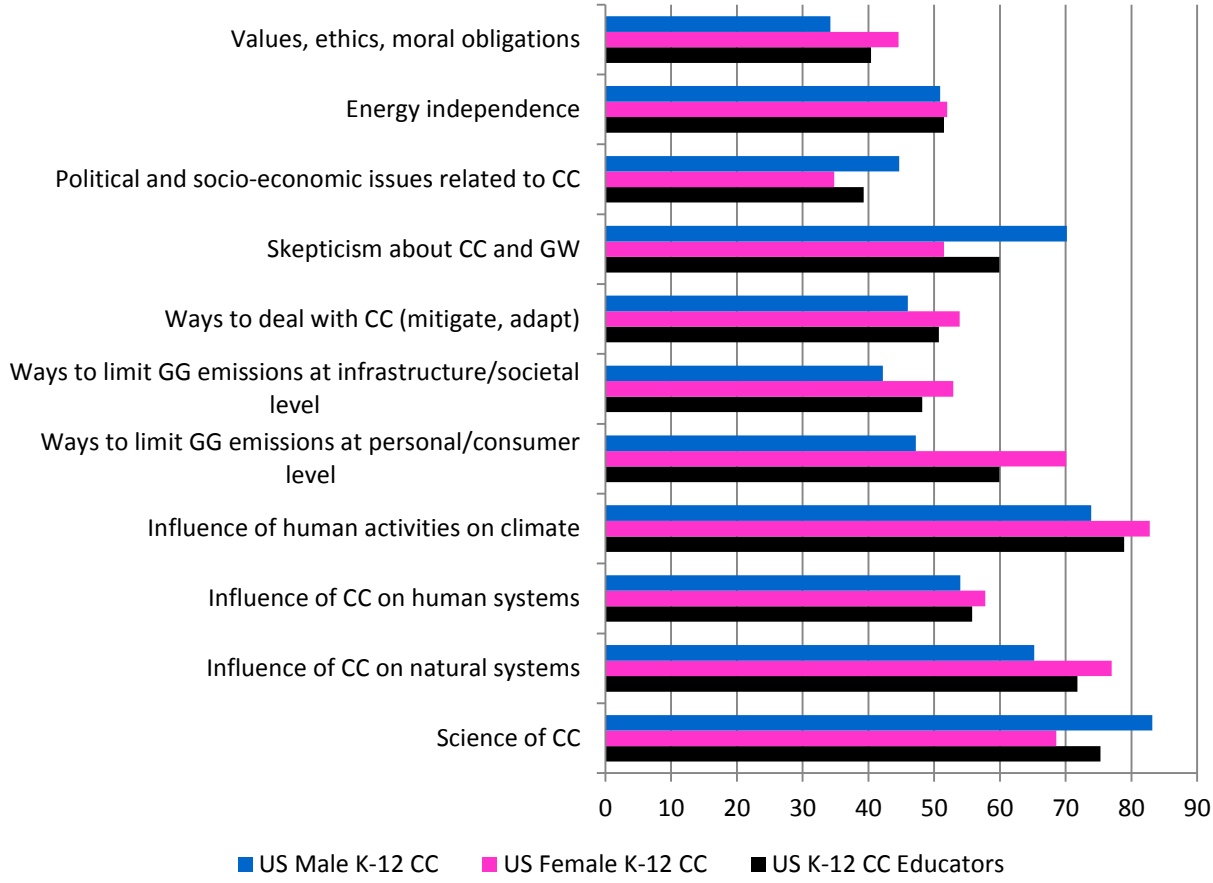

Figure 5 - Responses from US K-12 climate change teachers to the question "Which of the following major topics do you cover when teaching the subject? Mark all that apply." Topic order was randomized in the survey. 372 respondents.

Question 24 of the survey poses a number of different statements, and asks respondents to identify which, if any, describe the challenges they face in teaching about climate change (with statement order randomized and the option for multiple responses provided). Teachers also had the option to provide open comments to this question. Figure 6 shows the preliminary results for this question for all US K-12 climate change teachers, as well as results filtered by gender. 38% of teachers identify the difficulty in addressing student misconceptions as a major problem. More than 25% of teachers report that students, parents, administrators, or other community members have argued with them either that climate change is not happening, or that it is not the result of human activities. Several statements generated significantly different responses between males and females – for instance, ~16% of male respondents indicated that

they feel they should teach “both sides” of climate change, and are told to only teach that it is happening, while ~8% of females agreed with this statement. 16% of male respondents

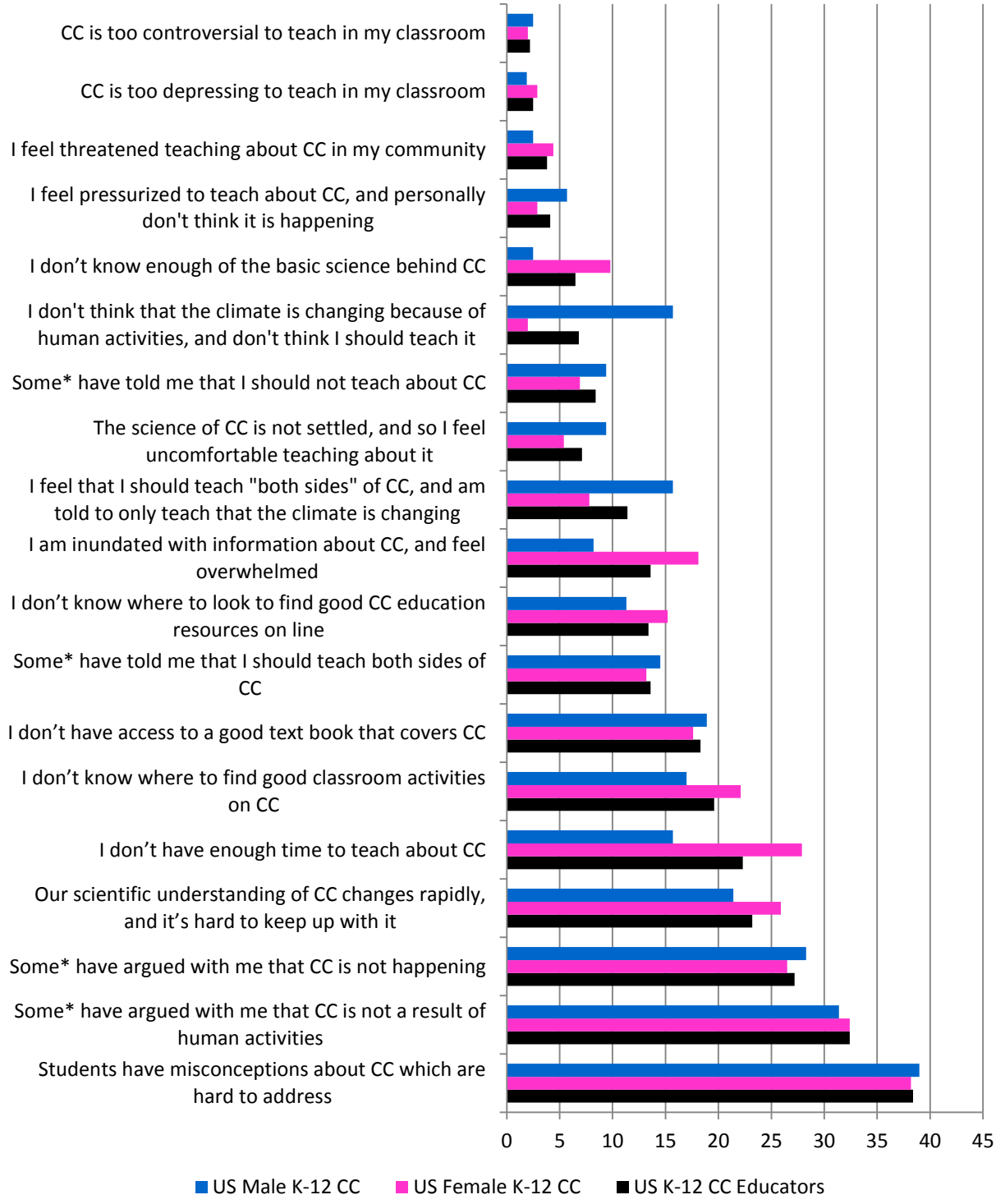

Figure 6 - Responses to the question "Please indicate which of the following, if any, describe the challenges you face in teaching about climate change (mark all that apply)". Statement order is randomized on the survey. 370 respondents.

indicated that they don't think climate is changing because of human activities, and don't think they should teach it, compared with 2% of female climate change teachers. Relatively few teachers expressed difficulty with finding good climate change education resources online (~15% or less), with slightly more reporting difficulty finding good classroom activities on climate change (~20%). Approximately 10% of female respondents indicated that they do not know enough of the basic science behind climate change, compared to 2.5% of male respondents. Small minorities (5% or less) expressed that climate change was too depressing or controversial to teach in their classrooms, or that they felt threatened teaching about climate change in their communities.

In another survey question touching on external influences in the classroom, 38% of K-12 climate change teachers report being influenced in some way (directly or indirectly) to teach "both sides" of climate change (highest in rural areas at ~44%, followed by males at 43% and in the South at ~41%). While few teachers report being required to teach "both sides" by their school, school district, or state (highest in the South at 7%), 49% of climate change teachers overall report teaching both sides, even though they are not required to, because they think there is validity to both sides. This perspective is highest for rural climate change teachers (55%) and for males and Southern teachers (52% for both), but is relatively consistent among different cohorts. For example, 47% of teachers from the Northeast and 46% of female teachers also share this view, along with 51% of teachers who have had some university courses or in-service professional development on climate change. In contrast, 45% of respondents overall report not being required to teach "both sides", and not doing so.

Figure 7 shows the distribution of responses from responding US K-12 climate change teachers (368 respondents) to the question "What has been the trend of attitudes about teaching the science of climate change in your school, college, or university?" The majority of respondents identified an increase in positive attitudes, while 27% noted no change in attitude, and ~15% noted an increase in negative attitudes about teaching the science of climate change.

In the previous NESTA study on the needs and concerns of Earth and space science teachers (Johnson, 2011), two questions touched on the question of climate change education indirectly, and are relevant here. One question (275 respondents) asked respondents to indicate if they "had difficulty or pressure from students, parents, administrators, or other community members to not teach about the following topics" (with the ability to select as many as they wanted, and to add other topics in a comment field). The top five topics which teachers identified difficulty with were evolution (68% of respondents), the age of the Earth/geologic time (47%), climate change (42%), solar system formation (22%), and planetary formation (13%). Happily, magnetism (2%), electricity and the water cycle (both at 3%) were the least controversial of the 18 topics listed!

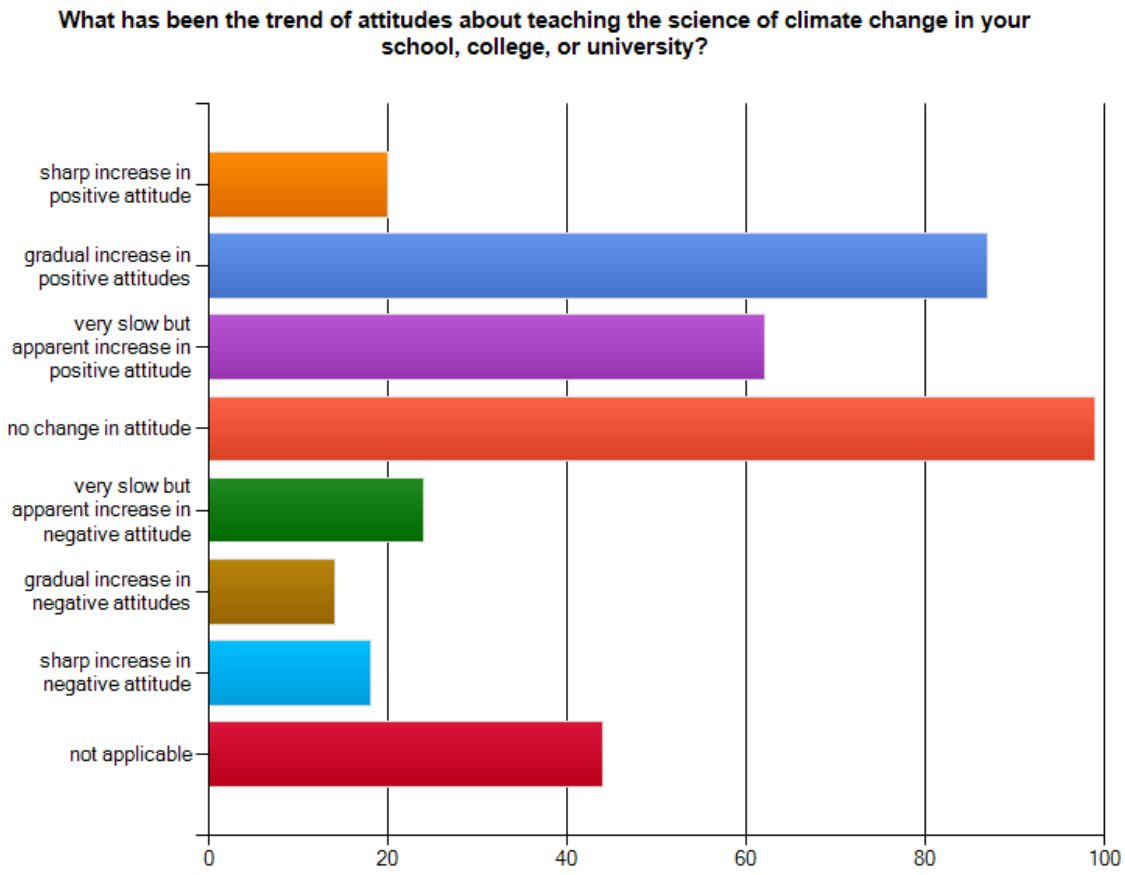

Figure 7 - Responses to the question "What has been the trend of attitudes about teaching the science of climate change in your school, college, or university? 368 respondents.

Survey respondents then had the opportunity to share their experiences, regarding difficulty arising from non-scientific influences in an open-response format, generating 164 responses. While the majority of these responses focus on difficulties teaching about evolution in religious communities, several touch on climate change. These comments typically refer to the difficulty of teaching about climate science in an area where climate science is viewed to be a political rather than a scientific issue. Several teachers report individuals challenging them about teaching this science, including threatening behaviour, and occasionally guidance from school administrators to not teach about climate change.

Resources and Professional Development Preferences

The climate change education survey also asks a number of questions about the educational resources teachers use in teaching about climate change, as well as their professional development preferences. Figure 8 shows the distribution resulting from responses to the question “Please indicate if you have used resources from any of the following organizations or

programs to teach about climate change science (mark all that apply)", with program and organization names listed in randomized order on the survey. The results show that teachers

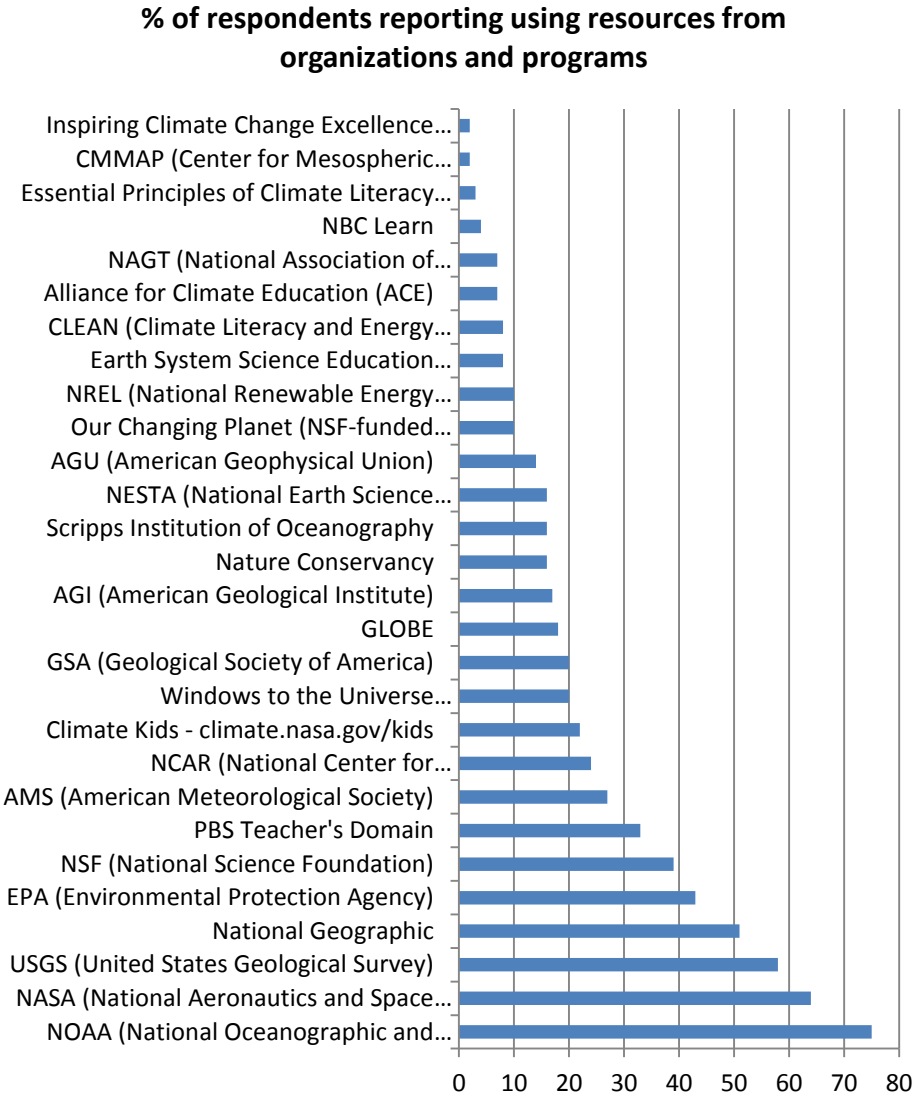

Figure 8 - Per cent of respondents reporting using resources from various organizations and programs. Respondents could mark multiple items, and item order was randomized in the survey. 364 respondents.

rely more heavily on resources provided through programs offered by federal agencies, as well as external programs which have a long track record.

Respondents report that the best ways for them to find out about existing quality educational materials is through searching for them online (chosen 1st or 2nd choice in 59% of responses), through professional development opportunities (chosen 1st or 2nd choice in 50% of responses), and through the professional societies to which they belong (chosen 1st or 2nd choice in 41% of

responses). The least effective approach identified is resources provided by their school or district curriculum supervisor.

Respondents expressed a preference for learning more about climate change in the following experiences, in order of preference: in-person workshops offered near them (50%), participating in a climate change research experience with a scientist from a nearby research facility or university (44%), in-person workshops at existing professional development venues (36%) or at their state science teachers conference (32%), or through self-directed online learning (31%). The least popular approaches identified were self-paced learning modules (17%), web seminars (18%), and science cafes (20%).

Discussion and Recommendations

The preliminary results presented here from our ongoing study of K-12 climate change education provide interesting insights into how climate change education is treated across the country. The results show that, overall, K-12 climate change educators are better informed than adults in the general population (according to Lieserowitz et al. 2011).

Preliminary results also show interesting differences in understandings based on gender[5], region of the country, and area in which the school is located which will need to be analysed further on a larger data set, once the survey is completed. Furthermore, these survey results must be qualified based on the fact that this is an informal study – respondents are not selected based on a statistically representative sample, but instead, are invited to respond through listserves, newsletters, and other information sharing venues. Results found when the survey is completed should be followed up by a formal study, using statistically representative sampling techniques. Nonetheless, I think the results point to some climate change education issues which are worth considering.

Survey results show that college preparation in climate change science and/or in-service professional development on climate change science has a positive impact on teacher's ability to reflect climate change understandings in agreement with scientific evidence for climate change. Clearly, this seems to work, and we should do more of it. Interestingly, though, a stronger background in Earth and space science does not, in itself, appear to result in this same ability, based on the results highlighted above.

Our results suggest that, at the high school level, climate change is taught predominantly by male teachers (~25% more than female teachers). In view of the other results reported above,

[5] The gender-based differences in climate change understandings preliminarily identified here are consistent with those identified by McCright (2010), in his study of the effects of gender on climate change knowledge and concern in the American public.

this population may be a priority to reach with accurate climate change science in-service professional development.

It is striking how many teachers (nearly 50%) cite the view that they should teach "both sides" of climate change to their students. Some teachers go farther than this, and say that students should be able to "choose what to believe", based on hearing both sides. This state of affairs, in 2011, is a considerable distance from where we were, just a few years ago (Johnson et al., 2009). While I wonder if teachers would apply this approach to other areas of their curriculum, these and other comments point to a valid concern that those of us that provide climate change preparation and professional development for educators should address.

As we know, there is abundant observational evidence that climate is changing rapidly, and that human activities are a key driver of that change. When we couple this evidence with model simulation outcomes for different scenarios in the face of continuingly increasing atmospheric CO2, it's not surprising that individuals and groups working on developing climate change education resources may sometimes find themselves moving beyond the basic science, assuming the reality of climate change is a "given", and into implications of the science for society, alternatives, and even advocate for solutions.

Nonetheless, I think this additional step is a step too far, at least at the introductory level, in the Earth and space science classroom. Survey responses clearly show that, for many teachers, climate change is a controversial topic in their classroom. Each year, classrooms are filled with a new set of students, some of whom may not have had any opportunity to look at the evidence of climate change, and instead rely upon what they have heard at home and from other sources. Much of the information they bring to the classroom may bring into question not only the scientific evidence for climate change, but also the motivations of those involved in climate change associated research and education. In this real life environment, teachers need access to a range of robust educational resources and classroom activities that suit the needs of diverse students.

Climate change educational resources prepared by our community should include a substantial set of resources (particularly at the introductory level) that are clearly evidence-based and data driven, providing abundant opportunities for students to work with actual data, question the data, and dig deeper. With these inquiry-based resources, and the science process and math skills developed in their courses working with their teachers, students should be able to draw science-based conclusions about climate change – the data can, and should, speak for itself. Indeed, student's ability to document their reasoning with evidence and draw science-based conclusions from the evidence provides an excellent opportunity for assessment. Science education is all about asking questions, and answering them with the scientific knowledge, process skills, and analytical toolkit they develop in their studies.

Because of the controversy associated with climate change, resources for teachers should provide multiple levels of support and guidance for teachers who may be working with students seeking additional evidence and probing the data deeply. Furthermore, professional development for teachers should provide effective strategies for dealing with controversy and conflict in the classroom, as well as with community members. And because the scientific evidence around climate change continues to grow, while arguments about the evidence evolve, we must find a way to provide accurate, up-to-date information on climate change (and the actual data behind the evidence) to teachers, so they don't find themselves facing challenges for which they are not prepared. The professional development required for teachers to support the effective use of such resources in the real classroom will necessarily be more extensive, and likely require continuing engagement with a community of educators working to support each other in this effort.

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Table 1 - Understandings of selected questions regarding global warming from US K-12 climate change educators, and filtered by gender, college preparation and professional development, region of the country, and type of area in which the teacher teaches. The column entitled "Adults" shows results from the study of Leiserowitz et al (2011), for comparison with the preliminary survey results shown here. Values shown are results in % of respondents for each question.

Question	Responses shown in %	All CC Teachers	Adults (Leiserowitz et al., 2011)	Male CC Teachers	Female CC Teachers	No Prep or PD	Prep or PD	Southern CC Teachers	Northeastern CC Teachers	Western CC Teachers	Rural CC Teachers	Suburban CC Teachers	Urban CC Teachers
	# respondents	369	1513	161	204	69	296	75	79	76	74	189	89
Do you think that global warming is happening?	Yes	88	63	82	91	78	90	84	85	93	84	87	92
	No	8	19	13	5	15	7	13	10	3	10	8	8
	Don't know	4	19	4	4	6	3	3	5	4	6	5	0
Assuming global warming is happening, do you think it is…	Caused mostly by human activities	26	50	26	26	14	29	18	33	24	29	24	31
	Caused by both human activities and natural changes	45	6	35	56	56	44	52	41	55	48	44	48
	Caused mostly by natural changes in the environment	17	35	26	10	14	18	21	13	13	17	19	17
	None of the above because global warming isn't happening	2	7	3	1	8	1	4	3	0	3	1	1
	Don't know	1	1	1	1	2	1	1	1	1	0	2	0
Which comes closer to your own view?	Most scientists think global warming is happening	71	39	68	73	61	74	63	80	72	70	70	72
	There is a lot of disagreement among scientists	24	38	24	23	29	22	28	17	24	27	22	25

	about whether or not global warming is happening												
	Most scientists think global warming is not happening	2	6	5	1	5	2	3	1	0	0	2	2
	Don't know	3	17	3	3	5	2	6	1	4	3	0	0
Which statement best describes the rate of change of CO2 in the atmosphere over the past 500 years?	Linear increase	22	41	31	15	25	22	25	20	23	27	23	18
	Exponential increase	65	40	55	74	52	68	55	75	69	63	65	67
	Don't know	11		11	10	23	7	18	4	9	9	11	11
Which of the following statements is correct?	All of the glaciers on Earth are melting away	13	11	10	16	7	14	14	14	11	15	11	14
	Most of the glaciers on Earth are melting away	48	21	46	49	52	46	32	51	54	42	48	54
	Some of the glaciers on Earth are melting away	37	48	41	34	36	38	49	34	34	40	40	29

This paper was commissioned for the Workshop on Climate Change Education in Elementary School through the first Two Years of College. The workshop was convened by the Board on Science Education on August 31 – September 1, 2011 in Washington, DC, with support from the Committee On Human Dimensions Of Global Change and the Division Of Earth And Life Studies.