Curriculum gaps for adult climate literacy

Olivia Cooper1 | Annika Keeley2 | Adina Merenlender3

1Smith College, Northampton, Massachusetts
2Delta Stewardship Council, Sacramento, California
3Environmental Science, Policy, and Management, UC Berkeley, Berkeley, California

Abstract
Conservation scientists need to advance climate literacy so that people understand how climate affects all of life, acquire the skills to communicate about climate change, and become aware of ways to increase local resiliency. We examined syllabus content for 74 general climate change courses taught at the undergraduate college-level to investigate the scope and extent to which these climate change courses include key topics to advance climate literacy. By analyzing the textual data, we discovered most courses had a strong focus on biogeophysical science and only 8.8 and 9.4% of the terms that occurred in this sample were connected to climate change solutions and communication, respectively. The fine category “Organisms,” which includes terms for specific animals such as “jellyfish” and “urchin” and related terms like “species”, was only observed in 26% of the syllabi; and the term “biodiversity” was mentioned seven times, “extinction” four times, and “animal” was mentioned two times across all 74 syllabi. This reveals a potential gap in addressing the impacts of climate change on biodiversity, and the role of some species in regulating climate. We recommend educators include a broader array of inter-disciplinary topics, place-based information, communication strategies, and mitigation and adaptation solutions to bridge the gap between climate science, literacy, and action.

KEYWORDS
climate change, climate education, climate literacy, interdisciplinary, syllabi, word analysis

1 INTRODUCTION
Despite the progress made by scientists in measuring and forecasting climate change and its impacts to ecosystems, along with well-documented threats to global infrastructure and human health, the rate of greenhouse gas emissions is on the rise (Scheffers et al., 2016). Efforts by the world’s nation states to come to global agreements, from the 1992 Rio Declaration on Environment and Development to the recent Paris agreement on emission targets, are proving to not be enough to address this global crisis. At the same time, local efforts to mitigate climate change are widespread (Bushnell, Peterman, & Wolfram, 2008) including the Global Covenant of Mayors in 2016 who has set local emissions targets and monitors progress toward meeting these targets (Bertoldi, Kona, Rivas, & Dallemand, 2018). Local entities are also actively trying to adapt to future change as exemplified by 147 local adaptation strategies recently reviewed in Europe (Aguiar et al., 2018).

Bickford, Posa, Qie, Campos-Arceiz, and Kudavidanage (2012) state that “conservation biologists need to be more proactive, provocative, and purposeful in increasing environmental literacy,” and we argue that climate literacy is an important component of this call to action. We need climate-
literate adults to interpret climate change in the local context, take action, and demand environmentally friendly policies and green supply chains (Vaughter, 2016). Here, we refer to being climate-literate as understanding that all life is shaped by climate and the role earth’s systems play, having the skills to communicate climate change science in a manner that is locally relevant, and being aware of ways to address the social and physical ramifications of a warming climate. This definition complements “The Essential Principles of Climate Science” (2009) that assume a climate-literate person understands earth systems governing climate, knows how to access credible scientific source information, communicates meaningfully, and makes informed decisions.

These definitions include required knowledge about climate change science and an understanding of effective climate communication, as well as how to take action. These skills are interrelated. For example, without an understanding of what determines climate, most adults do not feel comfortable communicating about the science of climate change or tackling the challenges their own communities are facing. To assist informal institutions with effective climate communication, Spitzer (2014) emphasizes the importance of peer networks that foster agency and engagement in meaningful climate communication. Being exposed to climate solutions that inspire hope, efficacy, and real concern has also been posited to increase civic engagement (Anderson, 2016).

It is clear that climate change education is essential to advancing climate literacy. Only by advancing climate literacy can we ultimately secure the collective actions required to mitigate the drivers of climate change and improve natural and human community resiliency. Yet, sociologist David Hess investigated the core curricula at the top 100 U.S. 4-year universities and colleges and found the probability of a student taking a climate change related course to be low (0.17 on average) (Hess & Collins, 2018).

There is strong evidence that people have formed misconceptions about climate change (McCaffrey & Buhr, 2008), such as confusion between the ozone hole and greenhouse effect (Cordero, Todd, & Abellera, 2008), renewable and non-renewable energy sources, and weather and climate, as well as the link to pollution (Boylan, 2008). Some have blamed the media and corporate interests for the public’s confusion about climate change. A review of formal climate change education reveals widespread misconceptions about the topic and a dearth of climate-related information across science education curricula, which is being corrected in some states and prevented in others (McCaffrey & Buhr, 2008).

Even the increase in efforts to incorporate climate change content into education curricula, and informal avenues of communication over the past 10 years have not resolved the climate literacy problem. This is in part because climate change involves complex systems and is operating at a global scale and across long timeframes which can make it difficult to conceptualize the drivers and impacts, or to imagine solutions. Also, climate science crosses many disciplines and hence requires a multi-disciplinary approach which draws on physics, chemistry, geography, ecology, history, and the arts, making it difficult for an instructor to teach the subject on their own (Anderson, 2012). These diverse topics and complexity of scales make developing an effective climate change education course challenging.

Educational interventions designed to advance climate change knowledge and agency are most effective when focused on local, tangible, and actionable interventions (Anderson, 2012), because this encourages environmental stewardship through feelings of connection and attachment to place (Ardoin, 2014). Observations of local phenomena that connect to individuals’ sense of place are far more likely to motivate local action than distant impacts such as the decline of polar bears or flooding of far off islands (Spitzer, 2014). It is clear that a place-based curriculum can lead to measurable change in individual and collective action (Haywood, Parrish, & Dolliver, 2016).

Beyond dispelling misunderstandings and drawing on multiple disciplines to foster communication and social action, more attention needs to be paid to how we engage adults in learning and doing something about climate change. There is ongoing discussion among educators and researchers about the most effective, appropriate method of communicating and teaching climate change. With respect to pedagogy, (Cordero et al., 2008) emphasizes the need for active learning methods and inquiry- or problem-based exercises (Fahey, 2012) that can help students make a personal connection to energy use and climate change; and the need to go beyond the biogeoophysical sciences to build personal and social connections.

Here, we conduct a content analysis of publicly available climate change course syllabi to investigate what is being taught at the college level, assess gaps, and propose new directions to engage adults in the topic. Syllabi content analysis has been widely used to explore issues covered in higher education courses and to assess which competencies are covered, including examples with fewer than 20 syllabi (Cashwell & Young, 2004; Hong & Hodge, 2009; Maschi, Rees, Leibowitz, & Bryan, 2019). This research represents the first content analysis for syllabi on this topic. Our overarching research objective is to examine the scope, extent, and interdisciplinarity of topics covered in college-level climate change courses. More specifically, we investigate the following questions. How well do the course syllabi examined cover climate change impacts to biodiversity and the role of earth’s marine and terrestrial ecosystems in driving the climate change trajectory? Given the importance of communication in the definition of climate literacy, is it included in college courses? Also, to what extent is information...
place-based and are mitigation and adaptation solutions being shared?

2 | METHODS

All syllabi included in the analysis were publicly accessible online for download. We included introductory courses about climate change if taught in-person to adults at accredited higher education institutions at an undergraduate level, and excluded distance learning courses offered solely online. We included course syllabi if they either had “climate change” in the course title, or a similar phrase such as “climate science,” demonstrating that they clearly were concerning climate change. We only included general education climate change courses, not those that only covered one specific aspect of the topic, such as government and climate change or that required prior college-level courses on the topic to enroll. We did this to focus on general climate literacy and avoid including courses with entirely different objectives. Additionally, we limited syllabi publication dates to January 2012 to April 4, 2019, to focus on more recent courses that may reflect current approaches to teaching climate change science. We only analyzed one syllabus per course.

We pursued different avenues to find syllabi online. We obtained a list published by Professor David Hess at Vanderbilt University of climate science courses in the core curriculum for each of the 50 most prestigious research universities and 50 most prestigious liberal arts colleges, according to the US News and World Report 2016 rankings. From this list, we searched the course names and corresponding college name using Google. If a syllabus was publicly available and met the above criteria, it was included. Using this strategy, we obtained 20 syllabi. To find additional syllabi, we conducted a Google search for “climate change syllabus” in January 2018. The first 157 results were related to the topic of interest, others down the line were no longer related to climate change courses per se. We screened these results and found 35 syllabi. In April 2019, we conducted another Google search and investigated the first 200 results; beyond this, the results were no longer related to climate change courses. This search resulted in an additional 19 syllabi that had been posted online after January 2018.

In order to examine how well different topics were represented across all the syllabi, we examined the frequency of relevant terms listed in each syllabus and compared the number of syllabi that covered each term as well as the times the terms were detected. These terms were extracted from the syllabi and classified using the following methods. All syllabi were cleaned to eliminate words that are unrelated to the relevant course content information under investigation, such as class meeting times, instructors’ names, and words like “assignment” and “midterm”. Just the primary course descriptions and lecture- or topic titles and descriptions for each syllabus were included in the analysis, not the readings or auxiliary information. Readings were removed because not all courses included additional reference materials whereas all courses did have topics and course descriptions. This approach made the final syllabi text similar in nature and more comparable.

A text analyzer tool, Voyant (voyant-tools.org), was used to extract word count per term from the cleaned text. The data were manually scanned for scientific terms, location names, association or policy names, and other technical terms that were deemed to have one specific, relevant meaning. After identifying the relevant, more technical terms (such as “atmosphere” and “capitalism”), and removing general language vocabulary (e.g., “talk,” “and”), we consolidated very similar or identical technical terms, such as singular and plural forms of the same term into a single term. Words were also analyzed on an individual basis, leading to multi-word terms, such as greenhouse gases, to be split. To minimize this issue, when we suspected a split term, we searched for it in the original document to find the full term to assign the term to the correct category. The resulting technical terms were coded manually and sorted into four coarse categories (Biogeophysical Science, Social Science, Solutions, and Communication), and 47 fine categories (Table 1). We quantified the frequency of terms that fell into coarse and fine categories used across all syllabi and for each syllabus. We used this information to conduct a hierarchical cluster analysis with a Manhattan distance matrix and the weighted method to group the syllabi (R Core Team, 2014). We ran this analysis for all syllabi using both the terms detected in each syllabus, and the number of times each fine category appeared.

3 | RESULTS

We found 74 publicly available syllabi that met the criteria for general climate courses being offered through higher educational institutions in the United States and Canada, constituting 82% of the 90 courses discovered online. Most courses were taught at universities, and five were offered to adults at informal science institutions. The 74 cleaned syllabi included 3,178 terms from which 534 technical terms were identified and sorted into the four coarse and 47 fine categories (Table 1). All syllabi (74/74) included at least one Biogeophysical Science term, nearly all included a Social Science (73/74) and a Solutions (70/74) term, and around three-quarters (57/74) included a Communications term. Out of a total of 534 terms used in all of the syllabi, over half (52.4%) fall into the Biogeophysical Science category, while
TABLE 1  Fine category and terms for each with number of times each term was detected for the each of the following 4 course categories

| Fine category                  | Terms (N = number of times detected across all syllabi) |
|--------------------------------|--------------------------------------------------------|
| (a) Biogeophysical             |                                                        |
| Astronomy                      | Astronomical 1 Ecliptic 1 Equinox 1 Mars 1 Mercury 1 Moon 1 Transparent 1 Tide 2 Universe 2 |
| Orbit 10                       |                                                        |
| Season 11                      |                                                        |
| Space 13                       |                                                        |
| Atmosphere                     | Hydrodometors 1 Isobars 1 Tropospheric 1 Turbulence 1 Vorticity 1 Aeroallergens 2 Cyclogenesis 2 Keeling 2 Particles 2 |
| Particulate 2                  |                                                        |
| Vapor 2                        |                                                        |
| Condensation 3                 |                                                        |
| Cfc 4                          |                                                        |
| Stratosphere 4                 |                                                        |
| Geostrophic 6                  |                                                        |
| Aerosol 12                     |                                                        |
| Ozone 17                       |                                                        |
| Air 26                         |                                                        |
| Cloud 29                       |                                                        |
| Atmosphere 161                 |                                                        |
| Carbon                         | Radiocarbon 3 Dioxide 11 co2 18 Carbon 114             |
| Chemistry                      | Anoxia 1 Helium 1 Liquids 1 Tritium 1 210pb 2 Hydrogen 2 Molecular 2 Oxygen 2 Nitrogen 4 |
| Isope 7                        |                                                        |
| Chemi 27                       |                                                        |
| Hydrocarbons 1                 |                                                        |
| Biogeochem 5                   |                                                        |
| Climate/models                 | Climatologist 1 Gcms 1 Runaway 1 Milankovich 2 Scale 40 Variability 41 Model 101 Clim 1366 Hydroclimatology 1 |
| Energy                         | Joule 1 kichoff 1 Refrigerant 1 Conduct 8 Energ 214   |
| Epichs                         | Cenozoic 1 Dinosaur 1 Holocene 1 Pleistocene 1 Paleoclimate 32 |
| Feedback/forcings              | Force 23 Forcing 28 Feedback 46 Cycl 65              |
| Fire                           | Wildfires 2 Burn 7                                    |
| Geography                      | Amazon 1 Antarctic 1 East 1 Everest 1 Extratropical 1 Hemisphere 1 Inland 1 Temperate 1 Continents 2 |
| Gulf 2                         |                                                        |
| Midlatitdue 2                  |                                                        |
| Sahara 2                       |                                                        |
| North 4                        |                                                        |
| Southern 5                     |                                                        |
| Volcano 6                      |                                                        |
| Tropic 7                       |                                                        |
| Coast 12                       |                                                        |
| Geothermal 1                   |                                                        |
| Jungle 1                       |                                                        |
| Terrestrial 11                 |                                                        |
| Greenhouse gases               | Methane 1 Ghs 2 Saturation 2 ch 4 3 Gas 84 Greenhouse 11 |
| Ice and glaciers               | Deglaciation 1 Lgm 1 Interglacial 2 Polar 3 Snowball 3 Melt 4 Cryosphere 6 Glacial 10 Ice 31 |
| Ocean                          | Nao 1 Pacific 1 Ph 1 Physical 38 Ocean 120 Buoyancy 2 Philosophy 2 Salinity 2 Stomel 2 |
| Photon 3                       | Thermohaline 3 Atlantic 4 Wave 5 Aquatic 6 Current 7 Sediment 7 Marine 13 Absorb 16 |
| niño 19                        | Physics 24 Acid 26 Sea 36                             |
TABLE 1 (Continued)

| Fine category | Terms (N = number of times detected across all syllabi) |
|---------------|------------------------------------------------------|
| **Organisms** | Genus 1, Species 8, Animal 2, Vegetation 3          |
| **Physics**   | Electromagnetic 1, Optics 1, Kinetic 5              |
| **Science methods** | Dendrochronology 1, Statistical 1                |
| **Science**   | Electromagnetic 1, Halos 1, Inertia 2              |
| **Economics** | Allocation 1, Capitalism 1, Inequality 1           |
| **Health**    | Malaria 1, Infection 2, Disease 4                  |
| **Industry**  | Clothing 1, Company 1, Concrete 3                 |
| **Political science** | Diplomatic 2, Intergovernmental 3              |
| **Social science** | Tax 3, Poor 4, Market 6                         |

Note: (Continues)
| Justice and activism | Indigenous 1 | Humanitarian 1 | Resistance 1 | Activis$ 2 | Revolution 2 | Movement 5 | Right$ 9 | Resilien$ 14 | Just$ 20 |
|----------------------|-------------|---------------|-------------|------------|-------------|------------|--------|-------------|---------|
| Legislation          | Legislation 1 | Litigation 1 | Ratified 1 | Legal 3 | Propos$ 12 | Law$ 15 |        |             |         |
| Local                | Angeles 1 | Chicago 1 | Denver 1 | Europe 1 | Greenland 1 | Gunnison 1 | Mauna 1 | Montana 1 | Oregon 1 |
| Virginia 1          | Canadian 2 | Orleans 2 | American$ 2 | Asia 3 | Hadley 3 | la 3 |        |             |         |
| Midwest 4         | Africa 6 | Lake$ 7 | Ca 15 | Local 20 | Land$ 22 | Region$ 26 |        |             |         |
| Policy              | Copenhagen 1 | Janeiro 1 | Montreal 1 | Napcc 1 | Permit 1 | 2° 2 | 4° 2 | ab32 2 | Regulate$ 2 |
| Rio 2               | cop21 4 | Paris 7 | Agreement$ 9 | Protocol$ 12 | Kyoto 16 | IPCC$ 17 | Policy$ 108 |        |         |
| Politics            | Constituents 1 | Federal 1 | Geospatial 1 | Municipal 1 | Polls 1 | Geopolitic$ 2 | Nasa 2 | Vote$ 2 | Democra$ 3 |
| u.s 5               | Govem$ 21 | Nation$ 35 | Public 47 | Politic$ 54 |        |             |         |         |             |
| Society             | Firefighters 1 | Medieval 1 | Residents 1 | Socio$ 1 | Family 2 | Library$ 2 | Person 2 | Religion 2 | Civiliz$ 3 |
| Lifestyle$ 5        | Citizen$ 6 | Popular 6 | Urban 7 | Infrastructure 8 | Population$ 8 | Cities 9 | Cultur$ 13 | Literate$ 16 |        |
| Countr$ 18          | Communit$ 22 | People$ 23 | Anthropo$ 32 | Social 43 | Societ$ 48 | Human$ 151 |        |             |         |
| Trauma              | Harvey 1 | Relocation 1 | Crisis$ 2 | Destruct$ 2 | Stress$ 4 | Threat$ 7 | Disaster$ 8 | Vulnab$ 52 |        |
| War and military    | Military 1 | Violence 1 | War 1 | Weapons 1 |        |             |         |         |             |

(c) Solutions

| Adaptation | Adapt$ 106 | Ecomodernism 1 | Engineering 14 | Geoengineering 8 | Innovat$ 8 | Synergies 2 | Synthesize 2 |        |         |
|------------|------------|----------------|----------------|-----------------|------------|-------------|--------------|--------|---------|
| Emissions  | Emission$ 50 | Emit$ 2 | Footprint$ 9 | Forecast$ 12 | Fossil 32 | Pollut$ 4 |        |         |         |
| Energy sector | Battery$ 4 | Biofuels 2 | Circuits 1 | Coal 3 | Electric$ 27 | Fuel$ 32 | Hydro 7 | Hydrocarbons 1 | Hydroclimatology 1 |
| Hydrodynamics | Hydroelectricity 1 | Nuclear 13 | Oil 1 | Pipelines 1 | Solar 43 | Turbines 3 | Watt 1 |        |         |
| Future generations | 21st 28 | Century$ 28 | Children 3 | Future$ 123 | Intergenerational 2 | Youth 1 |        |         |         |
| Mitigation | Abate$ 6 | Decarboniz$ 9 | Mitigat$ 98 | Reduc$ 14 | Sequestration 4 | Solution$ 51 |        |         |         |
| Sustainability | Alternative$ 15 | Organic 1 | Renewable$ 10 | Stewardship 1 | Sustainab$ 31 |        |         |         |         |
| Transportation | Aviation 2 | Transport$ 10 | Vehicles 2 |        |             |            |         |         |         |
29.4% fell into Social Sciences, 8.8% into Communication, and 9.4% into Solutions (Figure 1).

The most common fine subject categories were Climate Models appearing 1,553 times, Society (430), Global/International (357), Ocean (340), and Weather (287). The percent of syllabi with terms in each fine category are shown in Figure 1. The number of terms that fall into each fine category differ, for example, “precipitation” has one term, while “weather” has 27 terms. However, the percent of syllabi that contain each fine category does not appear to be influenced by the total number of terms per category because there was no observable relationship between number of terms in a category and the number of times that category occurred ($R^2 = 0.21$). In other words, the categories that occurred more times across the syllabi were not necessarily categories that included more terms.

A visual representation of the data is portrayed by a word cloud (Figure 2), with words that appear more frequently in the syllabi represented by larger words in the cloud. Clearly, “climate” dominates the syllabi content, and is included a total of 1,366 times in the sample of syllabi, along with “energy” at a count total of 214; followed by “global,” “earth,” “science,” “atmosphere,” and other similar terms. The top 20 terms by count are primarily Biogeophysical Science terms like “earth,” “atmosphere,” “greenhouse,” and “ocean,” Social Science and Solutions terms also make an appearance in the top 20 terms, including terms like “human,” “policy,” and “mitigate”. No Communications terms are in the top 20 terms.

Examining terms that were rarely observed and comparing their count to the average term count of 14.57 provides insight as to which specific terms and groups of terms were poorly represented in the syllabi. While biogeophysical sciences are generally well-covered, some physical science terms that span the fine categories “Sun/radiation,” “Physics,” and “Astronomy” were only mentioned once across all syllabi. These included “luminosity,” “scattering,” and “wavelength.” While terms classified in the “Environment” fine category, such as nature and ecosystems were widely included (found in 77% of syllabi), those under the fine category “Organisms,” which includes both specific animals like “jellyfish” and “urchin,” and related terms like “species,” were observed in far fewer of the course syllabi (26%). More specifically, the term “biodiversity” was mentioned seven times, “extinction” four times, and “animal” was mentioned two times across all 74 syllabi.

Local contexts and place-based terms such as “California,” “Midwest,” and “Chicago” were included in around two-thirds (63%) of the syllabi. In contrast, terms referring to the consequences of climate change experienced by humans that can cause hardship tended to be underrepresented in the syllabi. Among the terms related to impacts to humans mentioned only once are “contaminated,” “famines,”
“inequality,” “malaria,” “undernutrition,” “war,” “relocation,” and “violence,” which span the fine categories “Health,” “Food and agriculture,” “Trauma,” “Economics,” and “War and military.” Additionally, under the umbrella of the coarse category “Communication,” terms regarding emotion and communication were rarely present in the syllabi. “Empower,” “rhetoric,” “persuasive,” “journalism,” “television,” and “radio” were each included once in the syllabi.

The clusters that resulted from the hierarchical cluster analysis based on the fine categories (Figure 3) are similar to the groupings that resulted from using all of the terms but easier to interpret. The resulting clusters reveal three major clusters of courses with a similar topical focus and one outlier.

One cluster (cluster 1 in Figure 3) included 17 courses with an emphasis on social science and solutions. Terms coded as Social Science and Solutions appeared in these syllabi notably more frequently than the average count. More specifically, these syllabi contain words related to adaptation, mitigation, economics, emissions, energy and the energy sector, future generations, global and international context, justice and activism, local effects, policy, politics, and society.

The second cluster (cluster 2 in Figure 3) had an earth systems and global focus with words related to energy, feedbacks and forcings, ice and glaciers, oceanography, thermodynamics, weather, and global/international context appearing more frequently than the mean. Within this cluster is one group of 34 syllabi (cluster 2a in Figure 3) that, in addition to a relative biogeophysical focus, did not feature any finer focus, and had a fairly even distribution of terms across the fine categories. On the other hand, a second group of seven syllabi (cluster 2b in Figure 3) had a greater emphasis on the mechanisms of global warming and climate change; specifically, physics, radiation, greenhouse gases, geology, and atmosphere.

The third cluster (cluster 3 in Figure 3) also featured terms coded in the biogeophysical fine categories, but differed slightly from cluster 2 in its focus on life and biogeophysical sciences. Terms included more often than average in these syllabi tended to be related to biology,
chemistry, feedbacks, geology, oceanography, and thermodynamics.

One syllabus is grouped by itself (see branch labeled 4 in Figure 3), differing from the others by its distribution of content. While courses in the three clusters predominantly feature biogeophysical or social sciences, this course spends only 1 week covering these aspects in a unit titled “Climate Change: Causes, Contributors, Consequences.” The remaining 12 weeks are spent instead on individual energy sources in the context of climate change, such as fossil fuels, nuclear power, and solar power.

4 | DISCUSSION

By analyzing syllabi textual data, we were able to compare intended course topics across a large number of climate change courses to improve our understanding of how college instructors view climate literacy. For example, while nearly all of the syllabi have at least one term in the social sciences and solutions coarse categories, and three-quarters have at least one term in the communications category, terms classified as biogeophysical science occurred far more often across all syllabi compared to the other categories. We are particularly concerned that given that the impacts of climate change on organisms and ecosystems are expected to be severe, terms related to biodiversity were rarely detected.

Communication terms, such as “discuss” and “media” were also rarely included in the syllabi examined. We did find terms such as “policy,” “humanity,” “mitigation,” and other words relating to social sciences and solutions in most course syllabi. However, the word “population” rarely appeared which may be due to the complex political considerations underlying population discussions. Overall, the essential concepts presented in the definition of climate literacy (i.e., knowledge of earth systems governing climate, how to communicate the topic, how to act on it) do not directly correspond to what is generally outlined in the climate change syllabi we analyzed.

The scope of terms in the syllabi and cluster analysis illustrates a focus on biogeophysical terms and points to the increased need to address the interdisciplinary nature of climate literacy. It is insufficient to understand only the geology, biology, chemistry, and physics of climate change,
although these areas are essential. It is also necessary to learn political, societal, economic, and psychological aspects of climate change, as well as strategies for action, adaptation, and mitigation, and rhetorical strategies for communicating one’s climate literacy to various audiences.

We know that focusing on solutions that people can contribute to by highlighting success stories increases motivation, efficacy, and persistence in utilizing new knowledge pertaining to climate change (O’Neill & Nicholson-Cole, 2009). Interestingly, one main group in the hierarchical cluster analysis was comprised of 17 courses focused more on solutions. Place-based solutions connected to locally relevant information fosters a sense of place—a key intervention to motivate action on climate change (Spitzer, 2014). The lack of focus on place-based solutions in the syllabi may be in part because these courses are offered at colleges where the focus may be on global aspects of climate change rather than local. However, based on effective climate communication, we argue that relevance to local context will be more relatable and foster dialog among the students, and is a key strategy to increase climate science literacy.

It is important to note that the analyzed syllabi originated from a variety of colleges and universities mostly in the United States and hence represent a geographic as well as an English language bias. Using automated word analysis reduced the subjectivity of the content analyses compared to the alternative of coding each document for its general content. However, classification of the terms into fine-scale subject categories was determined by the authors, thereby introducing some subjectivity into the category results. For example, we decided to list the terms “global/international” in the social science and not the solutions category.

Not all syllabi were equally detailed or lengthy in describing the content so the syllabi that appeared in the largest cluster (cluster 2a in Figure 3) may represent a balanced approach to the fine topic categories; alternatively, it could reflect fewer terms being included overall, limiting the ability of this analysis to identify these courses as having a particular topical focus. Also, prior to analysis, we removed words from the syllabi that were not content-related such as “various,” which may have resulted in some words related to the subject matter being inadvertently removed.

Finally, our approach cannot account for false absences where a topic may have been covered in class lectures, discussions, or within assigned readings, without being included in the syllabus. False positives may occur in that the course may not have delivered all the intended content. However, this is less of a concern as we focus many of our conclusions on missing content, and false positives have more to do with how well a course was implemented rather than what is intended to be taught. To help overcome these issues, we focus our findings on large differences in the occurrence of the various terms used. A complementary approach to measuring course content would be to interview instructors and observe a sample of climate courses in person. Both approaches would make valuable future research on climate change course content. While attending multiple courses is clearly beyond the scope of this first survey, examining how well the content delivered in the course was reflected by the language presented in the syllabus would be a good way to ground-truth our findings.

Bridging the gap between scientific information and civic engagement on climate change is a challenging problem. Our findings reveal that higher education courses on climate change may be missing key aspects of climate literacy. These gaps include a dearth of place-based solutions, little attention to climate change communication, and few references to biodiversity. Improvements could be made by making climate change courses more interdisciplinary and ensuring biodiversity and natural ecosystems are addressed. Also, including place-based information, and mitigation and adaptation solutions will make it easier for students to digest complex systems, deepen their level of inquiry, and practice communication skills.

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CONFLICT OF INTEREST
The authors declare that they have no conflict of interest.

AUTHORS CONTRIBUTIONS
A.M.M and O.C. conceived of the idea and methods used for this research. O.C. and A.K. carried out data analyses. A.M. and O.C. wrote the manuscript with review by A.K.

DATA ACCESSIBILITY
All data analyzed for this research is included in the Table 1. The original syllabi are available through each institution’s web site.

ETHICS STATEMENT
The methods are covered under UC Berkeley Institutional Review Board UC Berkeley 2018–01-10,641.
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