Envisioning Science Teacher Preparation for Twenty-First-Century Classrooms for Diversity: Some Tensions

Norman Thomson and Deborah J. Tippins

The Arrival of the Anthropocene: Where Is Biodiversity Going?

Over the past several decades, our knowledge and concerns for climate change, especially in the context of twentieth- to twenty first-century global warming, is shaping the consciousness of scientists and global communities. Global warming is especially worrying for those peoples who inhabit low-lying oceanic coastal islands and for those who are immediately ocean resource dependent – but in a broader sense extending to all nations because (1) most nations have extensively populated coastal communities and (2) physical changes in the oceans can have a profound effect on weather and climate (National Research Council [NRC] 2010a). Presently, 40 % of the world's 6.5 billion people live within 100 km of a coastline and it is estimated that 2.75 billion people will be under threat from sea level rise by 2050; in other words, they will be forced to migrate from their islands or inland as coasts change their shorelines or all together disappear. Concurrently, the continental landmasses' climates will have greater variance in disruptive weather events including periods and areas with more extreme drought, rainfall patterns, temperatures, and other weather-related variables. And, as the nature of the oceans' water changes, a series of sequential and unanticipated events, biotic and abiotic, will most likely take place on land (NRC 2011a). Ehrlich and Holdren (1971) developed a model relating how population size (P), affluence or resource consumption per person (A), and the beneficial and harmful environmental

N. Thomson (✉) • D.J. Tippins
Department of Mathematics and Science Education, University of Georgia, Athens, GA, USA
e-mail: nthomson@uga.edu

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effects of technologies (T) [all inputs], help to determine the environmental impact (I) [output] of human activities. In their model equation:

$$\text{Impact (I)} = \text{Population (P)} \times \text{Affluence (A)} \times \text{Technology (T)}$$

What was missing from their discussion of the equation was consideration for a consequential feedback loop of how the Impact response will affect the inputs, for example, global warming. Of special concern then is that the current "business model" that demands unsustainable growth and development is leading toward a disastrous change in climate; scientists argue that on a finite planet, a model of sustainability is the only option that may save humans from extinction.

Most peoples are likely aware that climate and species have changed in the past through learning about dinosaurs and ice ages as a part of earth history, informally through pictures and movies and formally in early schooling. However, not all people are fully aware of the implications of contemporary climate change and, because it is the consequence of anthropogenic activities, that there are opportunities for its mitigation (International Panel on Climate Change [IPCC] 2011). Intensive research studies into contemporary climate change began in 1988 when the World Meteorological Organization and the United Nations Environmental Programme commissioned the formation of an International Panel on Climate Change (IPCC) with the purpose of evaluating the state of climate science, based on peer-reviewed published scientific literature, with the goal of formulating policies for action. One outcome of the panel's investigations has been a consensus of scientific opinion that "human activities … are modifying the concentration of atmospheric constituents … that absorb or scatter radiant energy … most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations" (McCarthy and Canziani 2001, p. 21). These greenhouse gases are carbon dioxide (56 %), methane (16 %), tropospheric ozone (12 %), halocarbons (11 %), and nitrous oxide (5 %). Yet, despite the increasing and overwhelming knowledge that Earth's climate is changing, there remains a mixture of defining what actions should be taken as recently exemplified in the Global 2011 IPCC conference in South Africa. Unfortunately, the inaction concerning this global problem is being sidelined by a few countries whose own short-ranged economic and political interests disregard the majority of other nations (Kerr 2007). For science teacher educators, whose task is to prepare the next generation of science teachers, real-world issues that tend to be controversial, can be addressed at the intersection of science and cultures.

What Is Known About Current Climate Change?

The NRC (2011b) reports that (1) climate change is occurring, is caused largely by human activities, and poses significant risks for – and in many cases, is already affecting – a broad range of human and natural systems, and (2) the global community needs a comprehensive and integrative change in the science enterprise, one that not only contributes to our fundamental understanding of climate change but also informs and expands the world's climate choices. Some scientists consider that we may now be entering a new geological epoch, the Anthropocene (Crutzen and Stoermer 2000), mainly as a consequence of human activities resulting in an unprecedented and catastrophic environmental impact. Human activities such as "co-opting resources, fragmenting habitats, introducing non-native species, spreading pathogens, killing species directly, immersing indigenous peoples into developmental programs modeled on economic consumerism and infinite growth, changing global climate affecting food production are collectively seen as factors that are leading us towards a sixth mass extinction" (p. 51) both in rate and magnitude of species loss (Barnosky et al. 2011). Naomi Oreskes (2004), in her review of 928 refereed science articles, determined that there is a 100 % consensus among qualified scientists that current global warming is not caused by natural climate variation. And, documentation for the dynamics of the Earth's trophic downgrading (Estes et al. 2011) and rapid range shifts of species (Chen et al. 2011) in response to warming is clearly established.

In a World Bank (2010) survey of over 15,000 people in 16 countries, over 60 % thought climate change is already doing harm to people in their country; but in six countries, including Russia and the United States, only a minority thought climate change is having an effect now. Majorities in all countries thought that there would be widespread adverse effects if climate change were unchecked. All participants were asked whether they believe their country does or does not have a responsibility to take steps to deal with climate change. In all 16 countries, majorities said their country does have a responsibility. Most majorities were very large and ranged from 90 % or more in France, China, Indonesia, Vietnam, Senegal, Bangladesh, and Kenya to 80 % in the United States, Japan, Mexico, Turkey, Iran, Egypt, India, and Brazil. In Russia, a more modest but clear majority of 58 % said the country had a responsibility to deal with climate change.

On average across 16 countries, 87 % said their country has a responsibility and a majority thinks their national government is not doing enough. And, this perspective was reiterated in the 2011 United Nations' climate conference held in Durban, South Africa. Karl Hood, Grenada's foreign minister and chairman of the 43-nation Alliance of Small Island States (AOSIS) whose members are in the frontline of climate change, said the talks were going around in circles. "We are dealing with peripheral issues and not the real climate ones which is a big problem, like focusing on adaptation instead of mitigation," he said. "I feel Durban might end up being the undertaker of UN climate talks." The dragging talks frustrated delegates from small islands and African states, who joined a protest by green groups outside as they tried to enter the main negotiating room. Maldives' climate negotiator Mohamed Aslam lamented, "You need to save us, the islands can't sink. We have a right to live, you can't decide our destiny. We will have to be saved" he said (Chestney and Herskovitz 2011).

In contrast to the global consensus of climate scientists, the US public remains less convinced, and some are even vocally polarized and recalcitrant. And, although the United States is but one country with a minority of the world's people, many nations look toward the United States both as a major causal agent and for leadership in climate change mitigation (NRC 2011a). One argument as to why climate change remains a US publicly charged issue, in part, is because of a well-constructed "climate cover-up" perpetrated by major corporations, lobbyists, politicians, and a small group of influential "junk scientists" (Hoggan 2009) that continues the well-established tactics developed and learned through the cover-ups and litigation experienced in the tobacco industries while they invested 50 years denying any linkage of smoking to cancers and a multitude other health problems. In their attempts to thwart linkages between the natural and additive/addictive constituents with active carcinogens, the "merchants of doubt" (Oreskes and Conway 2010) introduced and flaunted the "uncertainty of science in an uncertain world" (Pollack 2003). This is contrary to the interpretation for the nature of science that scientists and science educators view as science literacy (Flick and Lederman 2004) in which "tentativeness with skepticism" is one of the hallmarks of science as a way of knowing. In addition, the cover-up consortium purposively ignores and manipulates scientific data, utilizes the media (including creating misleading web-based sites) and misrepresents and fabricates the qualifications of their spokespersons as another means of misleading the public among other deceitful malfeasant practices (Oreskes and Conway 2010).

Some characterizations of global warming finding their way into the media have their origins in quotes by individuals who seemingly do not have a grasp of basic science. For example, one recent aspirant candidate for the United Stares' Presidency (Rep. Michelle Bachmann, Minnesota) stated in the US House of Representatives on Earth Day: Rep. Michele Bachmann spent part of Earth Day arguing against a carbon "cap and tax" because carbon dioxide is a "natural by-product of nature." It is "portrayed as harmful, but there isn't even one study that can be produced that shows that carbon dioxide is a harmful gas... It is a harmless gas... And yet we're being told that we have to reduce this natural substance and reduce the American standard of living to create an arbitrary reduction in something that is naturally occurring in the earth" (Schmelzer, *Minnesota Independent*, April 2009). In part, the issues of global warming are basically economic. In the development of industrial-based societies, their foundations lie on a false assumption that on a planet of finite resources, an infinite requirement is exponential population growth and consumption (Morelo-Frosch et al. 2009).

The World Bank has been conducting numerous surveys to determine international awareness of climate change and global warming (World Bank 2010). In the United States, regardless of the several hypothesized causes associated with global warming, US adults remain divided on whether to take action or not. A recent national telephone survey of American adults reports that 69 % of the participants indicated that it is at least somewhat likely that some scientists have falsified research data in order to support their own theories and beliefs. Nevertheless, an overwhelming majority (72 %) believe that the United States is not doing enough to develop alternative sources of energy. While 40 % of the participants believe Americans should take immediate action to stop global warming, 42 % suggest waiting a few years. Out of three scenarios, 30 % of Americans say a period of dangerous global warming is likely to occur, while just four percent (4 %) say a dangerous ice age is more likely. Half of adults (50 %) say something in between is most likely to happen and 16 % are not sure what the consequences might be. Internationally, World Bank (2010) findings have changed little from surveys conducted over the past decade. For example, in the United States, 67 % of adults have been following news stories on global warming at least somewhat closely, while 32 % have not. In comparative public surveys, 44 % of the participants in the United States and Russia, and even fewer in China (30 %), consider global warming to be a very serious problem, whereas 68 % in France, 65 % in Japan, 61 % in Spain, and 60 % in Germany say that it is a serious problem (World Bank 2010). Accounting for the similarities and variance between countries seems to be multifaceted.

What Is Known About Past Climate Change?

Although all of today's extant organisms share an origin into antiquity in billions of years (Rogers 2012), humans are a relatively recent evolutionary arrival joining Earth's natural systems within, at most sensu latu 6–7 million years ago (*Sahelanthropus tchadensis*) and some could well argue only the last 1–2 million years (*Homo egaster/erectus*) as an assigned starting point (Cartmill and Simth 2009). And, although as members of our bipedal ancestors evolved in response to climate change for some reason, about 1.8 million years ago, some of our ancestral groups left Africa (Klein 2009). Why do people migrate? It seems most plausible that migration is a means of searching for and finding resources necessary for sustaining life when a local depletion has occurred (Kingston 2007). As our past ancestors meandered into new environments, nature acted as a selective filter among fortuitous adaptations that eventually emerged as cultures. Within these various peoples, distinctive cultures emerged with words, languages, and thoughts unique to the particular environments. And, it seems that it is only within the last 50,000 years that these characteristics of humans permitted them to successfully spread around the globe with a destructive and unsustainable impact on the entire global environment (Lieberman 2011).

Thus, as recent arrivals on Earth it seems that in many ways we humans have not ingratiated ourselves and are choosing to live "apart" from nature rather than recognizing how we exist as an "interconnected part" fully and integrally entwined within every ecosystem we inhabit. In being able to make choices, humans (*Homo sapiens*) are privileged in the sense that we are not only aware of the present, but through our collective cultures, languages, and experiences, we are able to share unique knowledge of our present experiences and contextually reflect upon our pasts, and perhaps more importantly dwell on the future. Furthermore, through technology, language, and culture, we are able to instantaneously share experiences with the other 6^+ billion people on our "island planet" that we inhabit. But, as previously described, our planet's biological diversities and cultural legacies are at risk of disappearing – extinction is really – forever.

Where Are the World's Cultures Going? Diversity at Risk!

It is estimated that if nothing is done, 90 % of the planet's 6,000+ languages spoken today will disappear by the end of this twenty-first century. With the disappearance of unwritten and undocumented languages, along with others less used, humanity will not only lose cultural wealth but also important ancestral ecological knowledge of localities embedded in the indigenous languages will disappear. While it is widely acknowledged that the degradation of the natural environment, in particular traditional habitats, entails a loss of cultural and linguistic diversity, new studies suggest that language loss, in its turn, has a negative impact on biodiversity conservation. There is a fundamental link between language and traditional knowledge (TK) related to biodiversity. Local and indigenous communities have elaborated complex classification systems for the natural world, reflecting a deep understanding of their local environments. This environmental knowledge is embedded in indigenous names, practices, oral traditions and taxonomies, and can be lost when a community shifts to another language (Moseley 2011).

Ethnobotanists and ethnobiologists recognize the importance of localized subsistence, cultural attitudes and values, which have left us with some of the only remaining pristine areas on Earth. And, it is within these rich reservoirs that humans are provided some of the only hope that they might have to develop successful initiatives related to endangered species recovery and restoration activities. Every language reflects a unique worldview with its own value systems, philosophy, and particular cultural features. The extinction of a language results in the irrecoverable loss of unique cultural knowledge embodied in it for centuries, including historical, spiritual, and ecological knowledge that may be essential for the survival of not only its speakers, but also countless others. And, the impact of language colonization leads to a homogenization or extinction of not-knowing local environments.

One international project that demonstrates the need to maintain cultural heritage can be seen in food production in Africa. Africa has long been viewed as a continent unable to provide food for itself especially with constant instances of famine and starvation. Ironically, most external aid is used to promote the introduction and production of energy-demanding crops with exogenous origins, which create new forms of dependency (including corporate patented and protected genes) making them unsustainable food sources. This is just a new input into the cycles of children starving.

The National Research Council has conducted a series of studies into what has and is being lost throughout sub-Saharan Africa with respect to indigenous food sources: grains (NRC 1996), vegetables (NRC 2006), and fruits (NRC 2008). Why is this considered to be important? It is because we seemed to have evolved with grasses as a main food source. And currently, the world's six billion peoples' sustenance depends upon only three grasses: wheat, maize, and rice as sources of carbohydrate. It is anticipated that genetic potentials of these crops will not be able to accommodate for change in climate. As with languages, there is a plethora of identified lost African crops for which the elders lament. In international surveys of over

1,000 Africans the local peoples have identified and documented favorite grains, fruits, nuts, vegetables, legumes, and other food plants in significant numbers. Local people have identified crops that are not in commercial use and being ignored in development as including over 1,000 grains; over 3,000 roots, stems, leaves, bulbs, and fruits; and thousands of fruits they know and use, but are being displaced by introduced exportable fruits. These surveys have not even begun to explore the medicinal plants. Associated with climate change and seasonal rains seed germination, plant growth, flowering, and fruit production have become less predicable and dependable even for the indigenous foods resulting in marginal harvests (NRC 2005).

Why Do Languages Matter and Should We Care?

Indigenous communities make up one third of the world's 900 million extremely poor people whose existence is dependent upon a regional ecology. So where do we find our global heritage in the diversity of languages (Fig. 1)? Listed as a

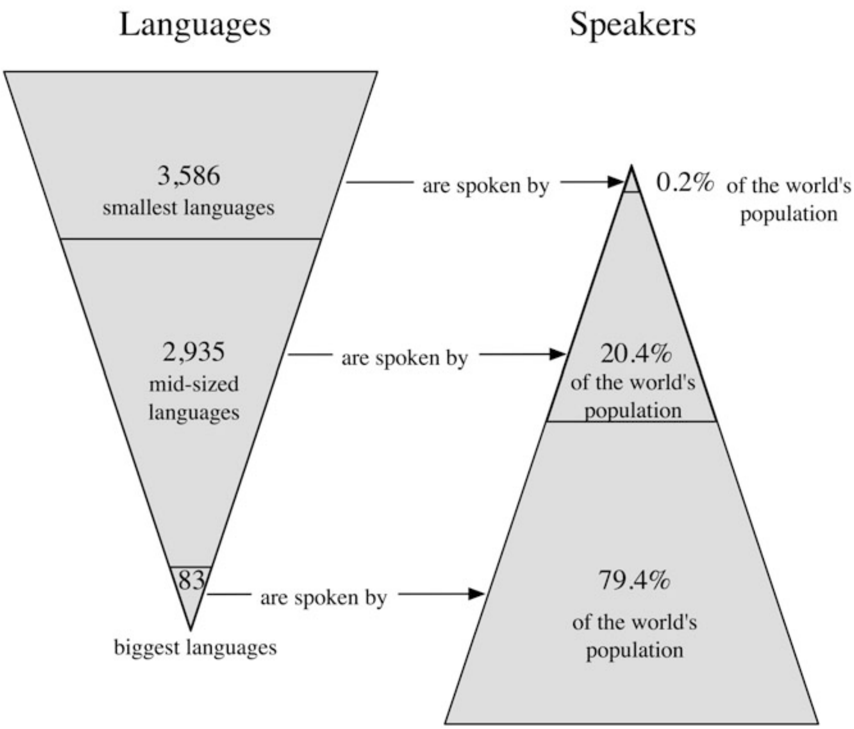

Fig. 1 The world's 6,000 languages and speakers represented as inverted *triangles*. Over half of the languages are spoken by a very few people placing many at risk (Harrison 2011)

Degree of Endangerment	Intergenerational Language Transmission
safe	A language is spoken by all generations; intergenerational transmission is uninterrupted
vulnerable	Most children speak the language, but it may be restricted to certain domains (e.g., home).
definitely endangered	Children no longer learn the language as mother tongue in the home
severely endangered	A language is spoken by grandparents and older generations; while the parent generation may understand it, they do not speak it to children or among themselves
critically endangered	The youngest speakers are grandparents and older, and they speak the language partially and infrequently
extinct	There are no speakers left.

Fig. 2 The world's languages are classified as to their status for intergenerational transmission (Moseley 2011)

percentage/estimated number of languages: Europe = 3 % /209; Americas = 15 % /949; Africa = 31 % /1,995; PACIFIC* = 21 % /1,341[*New Guinea has over 1,200 languages = 20 % of the world's languages]; and ASIA = 31 %/2,034. Traditional cultural and biodiversity losses share important threats, such as urbanization and exposure to globalized commercialization. Community participation in research has yielded data on the identification and distributions of new and previously described species. Indigenous cultural knowledge and know-how have informed and assisted in conservation research and practice. Indigenous peoples are contributing to and enforcing conservation policies (Cohen 2010, p. 30).

A culture and its language disappears when its speakers disappear or when they shift to speaking another language – most often, a larger language used by a more powerful group. Languages are threatened by external forces such as military, economic, religious, cultural, or educational subjugation, or by internal forces such as a community's negative attitude toward its own language. Today, increased migration and rapid urbanization often bring along the loss of traditional ways of life and a strong pressure to speak a dominant language that is – or is perceived to be – necessary for full civic participation and economic advancement. It is impossible to estimate the total number of languages that have disappeared over human history. Linguists have calculated the numbers of extinct languages for certain regions, such as, for instance, Europe and Asia Minor (75 languages) or the United States (115 languages) lost in the last five centuries, of some 280 spoken at the time of Columbus (Moseley 2011).

The most important thing that can be done to keep a language (i.e., local knowledge) from disappearing is to create favorable conditions for its speakers to speak the language and teach it to their children (Fig. 2). This often requires national policies that recognize and protect minority languages, education systems that promote mother-tongue instruction, and creative collaboration between community members and linguists to develop a writing system and introduce formal instruction in the language. Since the most crucial factor is the attitude of the speaker community toward its own language, it is essential to create a social and political environment that encourages multilingualism and respect for minority languages so that speaking such a language is an asset rather than a liability. Some languages now have so few speakers that they cannot be maintained, but linguists can, if the community so wishes, record as much of the language as possible so it does not disappear without a trace of its existence.

What Are the Language Options for Nations with Respect to Maintaining Diversity Versus Extinctions?

There are several choices that nations may make with respect to the languages they use, and the options are made in the context of the past, present circumstances, and the nation's future. A nation may:

- Remain uncommitted on the question of a language policy and allow things to change without interference.
- Use an ex-colonial language as the official (and national language) as it is perceived to be neutral at the expense of losing cultural heritages (British, French, Portuguese, etc.).
- Adopt the majority language, where such a language is predominant.
- Allocate to some of the major languages certain public roles at the regional or district level.
- Give nominal public roles or none to the smaller languages (which, e.g., most African countries have chosen).

As globalization, climate change, and languages of countries differentially affect peoples, internationally, science educators are facing daunting challenges. How do we make informed decisions about how to best prepare our science teachers for their own futures? As science educators, we are trying to find answers to this question in our own pre-service science teacher courses.

So, What Visions Do We Think Science Educators Need for the Twenty-First Century?

Science educators have an integral role in bringing "unity through diversity" in preparing the next generation of teachers who will be in classrooms preparing students who, in turn, will be their own decision-makers extending well into the twenty-second century. With respect to climate change we think that perhaps the most important role in preparing science teachers then, is not "what to think", but "how to think" as decision makers. The dimensions of "how to think" in a global context, in which our evolutionary past is integrally linked with changes in climate and, especially with reference to current global warming, brings together what we see as four important integrated phenomena: the geological record, climate change, human evolution, and culture and language. Today, as previously described, it is proposed that humans are in the process of forming a new geological epoch, the Anthropocene, that will bring transformative challenges and tensions in science teacher preparation that we suggest are essential for science educators to include in science teacher preparation for the twenty-first century. And, though our current data referents in our study are drawn mainly from the United States, from our own international experiences, and in working with many international science education colleagues throughout the world, we know they share our concerns.

Climate change is becoming a major topic at the forefront of secondary biology, earth and environmental science courses. Its study is of particular significance in light of the fact that most scientists' recognize that a basic knowledge of evolution is essential to understanding the processes that occur in the context of global climate change – speciation and extinction (NRC 2010b). Concurrently, science educators continue to give attention to polls, which suggest that more than 50 % of Americans reject evolution as a viable theory, supporting instead the teaching of creation/intelligent design science in public schools (Berkman and Plutzer 2010). And, non-evolutionary views seem to parallel the promulgation of religious fundamentalism globally. Researchers indicate that many students graduate from college without a basic understanding of evolution (NRC 2010b). This is of particular concern because most scientists (Cartmill and Simth 2009) contend that a basic knowledge of evolution is essential to understanding processes that occur in the context of what we have learned from paleoenvironmental data (NRC 2010b). In the past few years, through the efforts of the Intergovernmental Panel on Climate Change (IPCC), the issue of global climate change has shaped the consciousness of almost every citizen and is a topic of ever-increasing importance at the forefront of the curriculum of secondary biology (Wagler 2011) and earth and environmental science courses (Gautier et al. 2006).

The Standards for Science Teacher Preparation (NSTA 2010) emphasize the fundamental role of students' informed decisions about contemporary societal issues in developing scientific literacy and citizenship in a democratic society. In the context of understanding the relationship between evolution and global climate change, processes such as interpreting data, constructing hypotheses, evaluating alternatives, weighing evidence, interpreting texts, and evaluating the potential of scientific claims are all seen as essential components of meaningful learning and the construction of scientific arguments. An important part of the science teaching and learning process that has not been studied is the use of argumentation as a strategy for using evidence and observations of the real world to explain and understand climate's influence on evolution (NRC 2010b). There is an urgent need to prepare science teachers in ways that enable them to help their twenty-first-century students develop genuine understandings of global climate change as a factor in evolution.

What Do Our Current Twenty-First-Century Teachers Understand About Climate's Influence on Human Evolution?

Because of our concern for the introduction of climate's influence on human evolution to students in secondary science, we decided to conduct a study of our current pre-service teachers' (1) knowledge of, and, (2) what they might choose to teach as part of an assigned project in a school-based teaching practicum. Our study took place in a one-semester secondary science teacher preparation course that includes a field teaching practicum experience, and is required of all future secondary science teachers at a major university in the southeast United States. The students were introduced to human evolution and climate change through a 2-week curriculum unit (Thomson and Bealls 2008) that includes the use of replica cast skulls of extant vertebrates and fossil hominins (Bone Clones 2013), hands-on activities, power points, and background readings and the species are analyzed in the contextual interpretations of ecology and climate (Bobe et al. 2007). The students were asked to develop a two-lesson unit using the hominin casts (Fig. 3). The eight students chose to work as pairs with the earth science majors forming one group and the six biology majors the other three groups. The earth science majors developed and implemented a unit that focused on the oldest fossils (1). *Sahelanthropus*, *Ardipithecus*, and *Australopithecus spp.*, 3.0–6.5 Mya; and the biology groups focused on units that would cover (2) *Australopithecus spp., Paranthropus spp., Kenyanthropus*, 1.5–2.5 Mya; (3) *Australopithecus spp.*, *Paranthropus spp.*, *Homo spp.*, *Kenyanthropus*, 1.2–3.2 Mya; and (4) *Homo spp.*, 0.0–2.0 Mya, respectively. They were encouraged to use an argumentation approach (observation/evidence to inference/claim) in their lesson design to promote active student participation (Erduran and Jimenez-Aleizandre 2008). They were allowed to modify and create their own lessons as they wished, but were asked to link human evolution to climate change in some way. The students used 1 week to develop their lessons and implemented in successive days, "Skull Groups I – IV" in two secondary classrooms.

The researchers included two science educators, a paleoanthropologist whose research focus is paleoclimate, and, three graduate students who participated in data-collection. Primary participants in the study were eight pre-service teachers (three males, five females) enrolled in the Science Teaching Curriculum course with majors in biology or geology. Secondary participants in the study were high-school students enrolled in two sections of tenth-grade biology classes in one school and an anatomy and physiology class in a second. A case study design utilizing interpretive research methodology (Patton 2002) was used in our study. Case study research (Hays 2004) involves the study of an issue or phenomenon explored through one or more cases within a bounded system. More specifically, the researchers explore the bounded system through detailed, in-depth data collection involving multiple sources of information (Creswell 2007). Patton (2002) stated that the purpose of a case study is "to gather comprehensive, systematic, and in-depth information about each case of interest" (p. 447) and that a case study illustrates

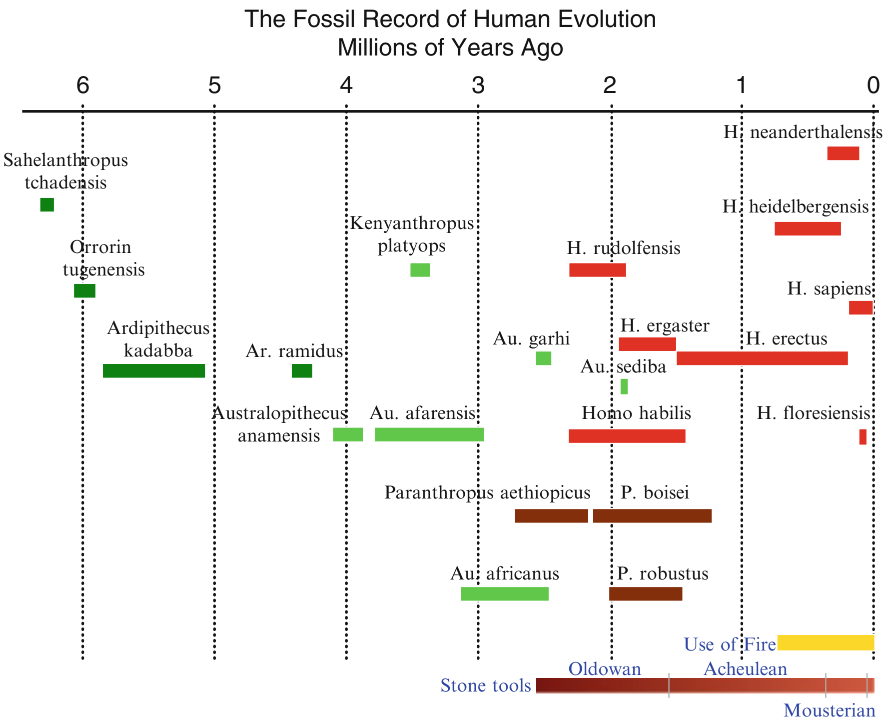

Fig. 3 A timeline of fossil hominins used in the development and implementation of the units designed by the pre-service teachers

"the value of detailed, descriptive data in deepening our understanding of individual variation" (p. 16). Data collection techniques consistent with interpretive research were used in this study. More specifically, the researchers used in-depth, semi-structured interviews, classroom observations, and the collection of artifacts and documents of the students.

We each used the following questions as our semi-structured interview framework:

1. What are the big ideas that science teachers need to be aware of in order to understand evolution?
   (a) What do you think science teachers need to understand about the relationship between ________ and evolution? [(i) Deep-time, (ii) Speciation and Extinction, (iii) Fossilization & Dating (absolute and relative), (iv) Phylogenetics, (v) Nature of science.
   (b) Describe the relative importance of these concepts for science teachers' understanding of evolution? Why did you make those choices?
   (c) What distinctions, if any, do you think science teachers should understand about the relationship between evolution and human evolution?

2. What are the big ideas that science teachers need to be aware of in order to understand climate change?
   (a) What do you think science teachers need to understand about the relationship between ________ and climate change? (i) Deep-time, (ii) Cyclical change / Orbital Forcing (cyclical change or Milankovic Cycles), (iii) Acyclical change (volcanism, plate tectonics, asteroids, etc.), (iv) Fossilization and dating, (v) Speciation and extinction, (vi) Nature of science.
   (b) Describe the relative importance of these concepts for science teachers' understanding of climate change? Why did you make those choices?
   (c) What distinctions do you make between historical climate change and modern climate change?
3. What do you think science teachers need to understand about the relationship between evolution and climate change?

The student pairs were interviewed on three occasions: (1) individually prior to initiating their lesson design, (2) as a pair during their lesson planning, (3) individually following their lesson implementation, and (4) on one final occasion, collectively as an entire group five weeks after their lesson implementations. Members of the research team met on a regular basis to plan and discuss what they were learning, as part of ongoing data collection and analysis. The research team used grounded theory and selective and axial coding to construct specific narratives and identify themes. Although we have copies of the students' curriculum materials, we feel that the students' comments made in the interviews best demonstrates what we have learned in this study.

What Did We Learn About Our Pre-service Teachers' (1) Knowledge and (2) Their Implementation of Climate Change and Human Evolution in the Design of Students' Lessons?

Four themes with specific relevance to the preparation of twenty-first-century science teachers who need to be prepared to teach evolution in the context of climate change are presented:

1. The pre-service teachers in their science content preparation courses are not experiencing interdisciplinary learning. Accordingly, the pre-service biology and geology majors are developing only partial and fragmented understandings of the evolutionary basis of climate change. Geology majors, for example, have a strong understanding of deep time but little knowledge of speciation, extinction and phylogenetics, and the consequences of climate change. Conversely, biology majors struggled to relate deep time, fossilization and dating, both absolute and relative, to climate change. This finding has strong implications, suggesting the need for the development of interdisciplinary science content courses for

our twenty-first-century teachers. This was particularly the case for the biology majors, who are not required to take a geology course. The geology majors do take one biology course, but the pre-service teachers indicated that because it was taught in isolation from their geology courses they were not able to see "the big picture:" A geology major feels that the biology students have not really developed a sense of deep time and fossilization even though they have all had a course in evolutionary biology:

> I think for understanding evolution deep time is the most important concept. If they don't understand deep time they're not going to be able to place when these evolutionary changes were happening. So I think deep time is a good stepping-stone to opening their mind to the fact that a billion years ago change was happening. Fossilization and dating I've worked with more because I'm in Earth science. But I would place it last only because I don't think other people perceive its importance. For example, in our group no one else talks about that kind of stuff. And they joke with us. When we start talking about rocks and geologic time scale they don't know what we're talking about. The biology people never had to take our geology classes and I don't think they understand how much science is involved in those classes. We Earth science majors have to take chemistry and physics, but they never have to take geology. It's interesting that there's not that interdisciplinary focus. I took astronomy and that was the first course when I really realized that I needed to grasp deep time. (Geology major, Interview #3)

However, one of the biology majors stated that it is not a problem of understanding, but the difficulty in representing the scale of deep time and strategies for teaching scalar concepts (time, matter, and space):

> Just to add on to what everyone has said, so teachers need to know how the students conceptualize deep time, evolution is such a broad topic, it seems like such a hard pitch out there, we don't see or experience it on a day-to-day basis, so we have to look back on it, so you have to look back and see what has occurred, and to get students to realize the time scales that we are referring to, so ... (Biology major, Interview #4)

2. In the process of designing and teaching lessons, the pre-service teachers struggled to create activities and experiences that reflect the most recent scientific understandings of the evolutionary consequences of climate change. They found most textbook resources useless, as these books were not able to keep pace with the exponential growth of science. For example, paleontology was not included in any of their textbook resources. At the same time, they had difficulty evaluating the credibility of Internet resources. As a consequence, the lessons they designed were more based on and limited by what they knew from their course work. In addition, this was the first time they had actually worked with 3-D hominin skull replicas, in contrast to seeing human evolution depicted only as pictures in their textbooks. Consequently, they spent much more time learning for their own professional growth and emphasized this topic in their lessons rather than moving onto understanding climate change and its link to human evolution. As a result, we feel that without more hands-on experiences addressing contemporary issues for the science-public interface not generally addressed at university level course work, the science pre-service teachers will be reluctant to address these issues in their future classrooms. On the other hand, they also viewed how rapidly science

generates new data, hypotheses, and methods as the reason why science teaching requires life-long learning:

> Even when we taught the anthropology, the human skulls, I said "Wow"!, I had not even encountered that, and I was a biology major! I was really shocked that there was a whole other area that I didn't know about, it is fascinating to me about how much I did not know. (Biology major, Interview #4)

> Well, I think that as a teacher you are constantly learning, I think that is what separates a good teacher from just any teacher ... you have to be really passionate about what you are trying to do, that is what you are going to have do. Well, that is what scientists are doing anyway. In fact, that is what we want to teach our students, that you are going to continually, continually learn ... you know, they shouldn't stop with what is in the classroom, they need to learn what is outside their classroom as well, that learning is a wondrous thing, I don't want to put the content aside, but it is that wonder -when we prepare to teach something we need to go out and discover what we don't know ... you do not what to stop that wondering, that curiosity, that the students don't want to learn just facts to regurgitate. (Biology major, Interview #4)

> You do not want to get up in front of a group of students when you are supposed to be teaching and end up looking like a complete idiot like you don't know what you are talking about yourself! When you are teaching them and you don't know it – so, I spent a lot of time researching the different skulls that we have ... (Geology major, Interview #4)

3. With respect to the use of argumentation in the lesson design and teaching process, the results were mixed. The pre-service teachers were able to infuse some aspects of argumentation (weighing evidence, evaluating scientific claims) into their lessons with little difficulty. They experienced more difficulty in designing experiences that enabled students to interpret texts and construct viable explanations, important aspects of argumentation. Although the pre-service teachers planned their lessons working in pairs, they indicated that some large group planning sessions would have been helpful in making interdisciplinary connections:

> Yeah and it is not just about knowing the content, that just took hours alone, it wasn't just spending hours learning what we needed to know, but then spending time thinking about how we were going to teach it. Delivery was very important for us and we did not what to do in a traditional kind of, you know just a bunch of details would be boring. We wanted to capture the students' attention, that was a key element for us, and to let them develop an understanding. (Biology major, Interview #4)

> When we got together we were able to actually collaborate, for example my partner and I sort of approached it from an ecological perspective. And, from what I have learned at college, I know that when I came to college and took ecology it finally brought things together. It wasn't just organisms or organelles, so I think when you are teaching about evolution the important factor is to tie in all together. Well, we kind of constructed our own little ecology course. And made links to each other – even our lessons – we tried to connect them together. (Biology major, Interview #4)

4. The pre-service teachers entered the tenth grade classroom expecting to encounter some resistance to instructional lessons focused on evolution and climate change. Much to their surprise, they did not encounter the type of resistance that they expected. While there could be several explanations for this, including the

background of the host teachers, the tenth grade students were more amenable to learning about evolution and climate change than the media seems to portray to the "general public", especially in the context of the way in which the public is reported polarized on these topics. It is through teaching integrated subjects that our teachers seem to begin seeing the big picture for the nature of interdisciplinary science.

> Well, we need to do it in our classrooms because they are going to be part of the general public. So, we need them to look at science and it is going to affect their lives. And, as a teacher the stuff we did in our other courses we need to teach them how to really look at issues and realize our impact on earth. And, then, how are we going to adapt to those changes. For example, global warming over time, we may not notice it everyday, but our skin may become more prone to cancer. You know any of your physiological features can change. And, we won't notice it until science brings it to our attention and then we will say "oh!" The atmosphere has changed, and now, so have we. I guess we need to keep the students aware on a daily basis and how things can affect their everyday lives. And, how they can make a difference and I think that will seep out into the public. Maybe not to the masses but at least even if only a few students, you never know where they may take it. (Biology major, Interview #4)

So, What Do We See as Some of the Tensions of Science Teacher Preparation for Diversity in Twenty-First-Century Classrooms?

In the preparation of science teachers for the twenty-first century, it seems to be essential that to be part of a global science education community that is concerned with the consequences of climate change, we include components of past and current climate change as a part of our curriculum. Paleoanthropology is reconstructing past environments, investigating the appearance and extinction of hominin species to provide some insight into biological responses to past changing environments in relation to other fauna and flora. Climate change is leading species' extinction and though we did not include it in this study, we wanted to draw awareness to language and cultural extinctions in our chapter. Languages and cultural diversity are integral to addressing issues of climate change and biological extinction. We have found out that our twentieth-century model for teacher preparation may no longer best meet the needs of our twenty-first-century science teachers. Not only is there diversity in learners, but also there is a need for a new diversity and combinations of integrated interdisciplinary science courses for effective science teacher preparation. We are constantly faced with issues of which courses are required to become an effective science teacher in one's discipline, but the number of courses for graduation and certification is generally fixed; what can be changed is the content of courses. Such a change might take place through multiple instructors in a modular course that includes a sequence of topics.

Science teachers need to be prepared to teach contemporary issues in which science knowledge is preceding opportunities for its inclusion into university science textbooks, current university science course structure and content, and the current science courses we think pre-service teachers need. We also need to change what and how we prepare our science teachers to think more holistically – beyond their individual science discipline – as our pre-service teachers brought to our attention: There needs to be more thoughtful integration of science learning for secondary science students through co-planning with teachers. Although our study is a glimpse into what our pre-service science teachers currently know about climate and evolution, we would like to suggest that twenty-first-century science educators have a critical role in ensuring that our future science teachers are prepared to teach important issues concerning climate change, human evolution, species and language/cultural extinctions, and possible consequences – but, more optimistically, offer solutions to our future generations.

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References

Barnosky, A., Matzke, N., Tomiya, S., Wogan, G., et al. (2011). Has the Earth's sixth mass extinction already arrived? *Nature, 471*, 51–57.

Berkman, M., & Plutzer, E. (2010). *Evolution, creationism, and the battle to control America's classrooms*. New York: Cambridge University Press.

Bobe, R., Alemseged, Z., & Behrensmeyer, A. (2007). *Hominin environments in the East African Pliocene*. Dordrecht: Springer.

Bone Clones, Inc. Osteological Reproductions. (2013). Canoga Park, CA. Available: http://www.boneclones.com/

Cartmill, M., & Simth, F. (2009). *The human lineage*. Hoboken: Wiley.

Chen, I.-C., Hill, J., Ohlemuller, R., & Roy, D. (2011). Rapid range shifts of species associated with high level of climate warming. *Science, 333*, 1024–1026.

Chestney, N., & Herskovitz, J. (2011). Climate talks split on drafts, EU warns of collapse. (December 8), Reuters. Available On-line: http://www.reuters.com/article/2011/12/09/us-climate-idUSTRE7B41NH20111209

Cohen, J. (2010). In the shadow of Jane Goodall. *Science, 238*, 30–35.

Creswell, J. W. (2007). *Qualitative inquiry and research design: Choosing among five approaches*. Thousand Oaks: Sage Publications, Inc.

Crutzen, P., & Stoermer, E. (2000). *The Anthropocene* (IGPB Newsletter 41). Stockholm: Royal Swedish Academy of Sciences.

Ehrlich, P. R., & Holdren, J. P. (1971). Impact of population growth. *Science, 171*, 1212–1217.

Erduran, S., & Jimenez-Aleizandre, M. (2008). *Argumentation in science education: Perspectives from classroom-based research*. Dordrecht: Springer.

Estes, J., Terbough, J., Brashares, J., & Power, M. (2011). Trophic downgrading of planet Earth. *Science, 333*, 301–306.

Flick, L., & Lederman, N. G. (Eds.). (2004). *Scientific inquiry and nature of science: Implications for teaching, learning, and teacher education*. Dordrecht: Kluwer Academic.

Gautier, C., Deutsch, K., & Rebich, S. (2006). Misconceptions about the greenhouse effect. *Journal of Geoscience Education, 54*(3), 386–395.

Harrison, D. (2011). *Global language hotspots*. Available http://www.swarthmore.edu/SocSci/langhotspots/globaltrends.html

Hays, P. A. (2004). Case study research. In K. DeMarrais & S. Lappan (Eds.), *Foundations for research: Methods of inquiry in education and the social sciences* (pp. 217–234). Mahwah: Lawrence Erlbaum Publishers.

Hoggan, J. (2009). *Climate cover-up: The crusade to deny global warming*. Berkeley: Graystone Publishers.

IPCC (International Panel on Climate Change). (2011). *Special report on renewable energy sources and climate change mitigation*. Available http://srren.ipcc-wg3.de/

Kerr, R. A. (2007). Climate change: Global warming is changing the world. *Science, 316*(5822), 188–190.

Kingston, J. (2007). Shifting adaptive landscapes: Progress and challenges in reconstructing early hominid environments. *Yearbook of Physical Anthropology*, *50*, 20–58.

Klein, R. (2009). *The human career: Human biological and cultural origins*. Chicago: The University of Chicago Press.

Lieberman, D. (2011). *The evolution of the human head*. Cambridge, MA: Belknap.

McCarthy, J., & Canziani, O. (Eds.). (2001). *Impacts, adaptation, and vulnerability: Contribution of Working Group II to the third assessment report of the Intergovernmental Panel on Climate Change*. Available http://www.ipcc.ch/publications_and_data/ar4/wg2/en/contents.html

Morelo-Frosch, R., Pastor, M., & Shonkoff, S. B. (2009). *The climate gap*. Los Angeles: USC Center for Sustainable Cities, University of Southern California.

Moseley, C. (Ed.). (2011). *Atlas of the World's Languages in Danger* (3rd ed.). Paris: UNESCO Publishing. Online version: http://www.unesco.org/culture/en/endangeredlanguages/atlas

National Research Council (NRC). (1996). *Lost crops of Africa: Vol. I, Grains*. Washington, DC: National Academies Press.

National Research Council (NRC). (2005). *The geological record of ecological dynamics: Understanding the biotic effects of future environmental change*. Washington, DC: National Academies Press.

National Research Council (NRC). (2006). *Lost crops of Africa: Vol. II, Vegetables*. Washington, DC: National Academies Press.

National Research Council (NRC). (2008). *Lost crops of Africa: Vol. III, Fruits*. Washington, DC: National Academies Press.

National Research Council (NRC). (2010a). *Advancing the science of climate change*. Washington, DC: National Academies Press.

National Research Council (NRC). (2010b). *Understanding climate's influence on human evolution*. Washington, DC: National Academies Press.

National Research Council (NRC). (2011a). *Warming world: Impacts by degree*. Washington, DC: National Academies Press.

National Research Council (NRC). (2011b). *Advancing the science of climate change*. Washington, DC: National Academies Press.

National Science Teachers Association (NSTA). (2010). *Standards for science teacher preparation*. Arlington, VA: NSTA.

Oreskes, N. (2004). Beyond the ivory tower: The scientific consensus on climate change. *Science, 306*(5702), 1686.

Oreskes, N., & Conway, E. (2010). *Merchants of doubt: How a handful of scientists obscured the truth on issues from tobacco smoke to global warming*. New York: Bloomsbury Press.

Patton, M. (2002). *Qualitative research & evaluation methods*. Thousand Oaks: Sage Publications.

Pollack, H. (2003). *Uncertain science … uncertain world*. Cambridge: Cambridge University Press.

Rogers, S. (2012). *Integrated molecular evolution*. Boca Raton: CRC Press.

Schmelzer, P. (2009, April 24). On climate science, Bachmann accused of 'making things up' on the House floor. *Minnesota Independent*. Retrieved July 5, 2010. Available On-line: http://minnesotaindependent.com/33294/on-climate-science-bachmann-accused-of-making-things-up-on-the-house-floor

Thomson, n., & Beall, S. (2008). An inquiry safari: What can we learn from skulls? *Evolution: Education and Outreach, 1*, 196–203.

Wagler, R. (2011). The anthropocene: An emerging curriculum theme for science educators. *The American Biology Teacher, 73*(2), 78–83.

World Bank. (2010). *Public attitudes toward climate change: Findings from a multi-country poll*. Available http://econ.worldbank.org/