Long-term E-cApacity builDing (LEAD)

A New Approach for Climate Science Research

This discussion paper has been prepared by Mesquita M d S, Veldore V, Yarker M B, and Lamadrid A, TERI, for the 17th Conference of Parties to the United Nations Framework Convention on Climate Change, 28 November–9 December 2011, Durban, South Africa

teri

The Energy and Resources Institute

www.teriin.org

Long-term E-cApacity builDing (LEAD): A New Approach for Climate Science Research

Mesquita M d S[1,2], Veldore V[3], Yarker M B[4], and Lamadrid A[5]

Abstract

Climate change, though global in nature, may affect regional scales in different ways. Thus, preparing for climate change impacts requires a cascaded assessment of climate information at different spatial and temporal scales. Climate studies require state-of-the-art computing facilities, updated scientific knowledge, and a firm understanding of climate modeling, which poses a challenge to many developing countries. The limited computational infrastructure, together with limited access to current scientific information, hinders the development of climate modeling practices in these countries. Several projects have tried to address this issue by providing capacity building to different institutions. In many situations, it has become a challenge to perform the training due to several reasons: a) infrastructure and technical requirements; b) expensive travel costs for distant training facilities; c) political constraints; d) hierarchical barriers; and e) lack of follow up. Due to these reasons, many such projects become expensive, limited, and unable to fulfill the essence of capacity building. An alternative approach is proposed here as a new framework to perform capacity building in developing countries, named LEAD—"Long-term E-cApacity builDing"—for climate sciences. This approach involves an extended timeline and continuous support through online training, tailored to specific target groups. The ultimate goal of LEAD is to provide an explicit link between science concepts and climate models in a way that conceptual change is achieved. This article provides a theoretical argument that LEAD could be an effective capacity building approach in developing countries.

The ultimate goal of LEAD is to provide an explicit link between science concepts and climate models in a way that conceptual change is achieved.

Introduction

The perception of climate change and climate prediction has increased from the late 1990s in both developed and developing countries; however, access to the robust scientific information and its improvements has progressed at a slow pace for various reasons. The concepts of climate change need to be grasped in greater detail by community stakeholders and policy-makers alike for better preparedness.

---

[1] Uni Bjerknes Centre, Bergen, Norway
[2] Bjerknes Centre for Climate Research, Bergen, Norway
[3] The Energy and Resources Institute, Delhi, India
[4] University of Iowa, USA; Center for Global and Regional Environmental Research, Iowa, USA
[5] Center for International Climate and Environmental Research, Oslo, Norway

Global Climate Models (GCMs) are appropriate tools to understand large-scale features of the climate system. However, due to their coarse horizontal resolution, they do not resolve extreme precipitation and regional climatic processes essential for impact studies (Giorgi *et al*. 2009). In order to understand the changes in regional climate, to global climate changes and their impact on different sectors, it is necessary to downscale global-model data using Regional Climate Models (RCMs). Downscaling is a complex task, since it requires infrastructure: fast, multi-core computers, plenty of disk storage space, computing support, and most importantly—expertise in weather or climate modeling.

The fast pace of advances in computing and regional climate modeling research makes it a daunting task to keep up with, especially for developing countries with deficiencies in infrastructure capacity. They often lag behind and depend on international funding resources to attend expensive capacity building courses. Most often, these short-term courses fail to achieve their intended purpose because of the lack of feedback and support after the training ends.

Climate modeling challenges in the developing world

Many nations feel the pressure of adapting to a changing climate. Adaptation planning requires climate projections at high-resolution—i.e. at a scale relevant to impact studies. This type of climate modeling is currently in high demand, but it is expensive due to the required computational facilities and expert knowledge needed. This poses a challenge to many countries where infrastructure is uneven or where access to current state-of-the-art numerical modeling practices are non-existent. In short, a robust education system is needed to train new modelers at the graduate-level, as well as professionals within target institutions. This system must also aid learners in the development of skills needed for climate modeling; which not only includes theoretical knowledge, but also computational skills in order to work with Unix platforms, write software programmes, and use supercomputers.

It has been observed that many participants who recently completed capacity building courses still view climate and weather models as a metaphorical “black box”, where data goes in and results comes out. Additionally, there is evidence that these participants still lack a basic understanding of the climate system. Both of these issues limit the ability of some scientists to go beyond running a model based on rote memorization of the process. As a result, they are unable to solve problems regarding run-time errors, thus, becoming dependent on expert modelers. In addition to that, they are not able to assess model limitations in order to make further checks to determine whether or not their model simulation is reasonable (Warner 2011). Since they view their model as a metaphorical “black box”, it is impossible for them to explore alternative scenarios in order to improve the simulation.

Many nations feel the pressure of adapting to a changing climate. Adaptation planning requires climate projections at high-resolution—i.e. at a scale relevant to impact studies.

Capacity building barriers

In many situations, it has become a challenge to perform capacity building training due to several reasons:

a) *Infrastructure and technical requirements*: Climate modeling cannot be achieved without the use of powerful computing capabilities. The demand for high spatial resolution in recent years also means that there is a demand for higher computing resources and storage space. These are expensive, and they require experts for installation and maintenance.

b) *Expensive travel costs for distant training facilities*: Many of the existing training courses can cost up to thousands of dollars. In addition to that, whenever plane travel is involved for participants and instructors, the amount of greenhouse emissions from such travels is too high[1]. The question is whether it is worth all of the expense if the training programme is too short to give the students the chance to really learn and become independent.

c) *Political constraints*: Many nations have restrictions to whom they allow inside their countries. There are also restrictions on the number of people that can travel to a training programme. Added to that is the need for entry visas— this can be time consuming and many may not get the chance to attend a training programme.

d) *Hierarchical barriers*: This can limit the attendance of many potential participants. Only a few are sometimes selected to attend such courses.

e) *Lack of follow up*: After a short-term programme, many go back to their countries and do not have anyone to help them if they encounter problems while running a model. This can be a challenge especially if they view the model as a metaphorical "black box", which can lead to frustration. Even for the experienced modelers, running into computational difficulties can be detrimental to productivity. This demotivating factor can make some to simply quit using the model, which means the expenses incurred on the short-term programme are lost.

> Capacity building training has become a challenge due to infrastructure and technical requirements, expensive travel costs, political constraints, hierarchical barriers, and lack of follow up.

For the reasons listed above, many of these projects become expensive, limited, and unable to fulfill the essence of capacity building. The following sections will address the theoretical background, the social implications and the target groups for LEAD.

Theoretical background

The use of science models is common practice throughout the scientific community; however, models are predominately perceived by the general public as a representation of a system (Halloun 2004) by way of weather and climate forecasting. Since computer models are the best method we have to forecast the future of our climate, the weather, and all complex scientific phenomenon (de la Rubia and Yip 2008), scientific models and

---

[1] If one considers that for every 1.6 km, an airplane uses 0.45 kg of CO_2 per passenger (see http://www.stewartmarion.com/carbon-footprint/html/carbon-footprint-plane.html), then a student flying from Bangkok to attend a course in New Delhi would spend 1,631 kg of CO_2 on a round-trip (average distance between these cities is 2,900 km each way). This does not take into account the car/bus trips to and from the airports and course venue.

modeling should be a topic covered as part of a comprehensive science curriculum (Grosslight *et al.* 1991, Harrison and Treagust 2000, Justi and Gilbert 2002, Michaels *et al.* 2008, NCISLAMS 2000, NRC 1996, Schwarz *et al.* 2009).

In the field of science education, there is no clear consensus on the definition of a science model (Halloun 2004). However, scientists are constantly constructing and using models as an analogy to real world systems as a part of the scientific process (Michaels *et al.* 2008). By this observation, a science model can be anything from a visual representation to a scientific theory. Recent research by Harrison and Treagust (2000) organized a typology of science models in order from least to most complex. From their typology, visual representations (such as scale models) are the simplest and most commonly used in science classrooms. The next level of complexity includes chemical and mathematical formula, which represent more complex, natural relationships and serve as a way to communicate phenomenon that are not directly observable (Windschitl *et al.* 2008). Finally, the most complex types of models are those that depict multiple concepts simultaneously. These range from simple maps, diagrams, and graphs, to the more complicated concept-process models and simulations (Harrison and Treagust 2000). Based on this typology of models, climate and forecast simulations are among the most complex and difficult for learners to understand. As a result, it is important that we are mindful of how we introduce learners to the concept of modeling.

The most complex types of models are those that depict multiple concepts simultaneously. These range from simple maps, diagrams, and graphs to the more complicated concept-process models and simulations.

According to this research, mathematical and chemical formulas are less complex than computer simulations. According to a statement adopted by the American Meteorological Society, the basic components of an undergraduate degree in atmospheric science includes coursework in physics, chemistry, and mathematics, which are prerequisites to support coursework in atmospheric physics, atmospheric chemistry, and atmospheric dynamics. Computer use and software programming skills are listed as a required proficiency (AMS 2010). Understanding science concepts and having computer proficiency are necessary steps towards understanding the more complex computer simulations; however, they are not sufficient steps. There must be an explicit link between students' current understanding of the atmosphere to the concept of a climate model, in that they are representations of our understanding of the natural world's interaction with climate; therefore, they are complex, uncertain, and always evolving. In science education, we refer to this link as *conceptual change* (Posner *et al.* 1982).

Conceptual change is a process of learning where the student has to change the way he or she thinks about a concept in light of alternative conceptions (Posner *et al.* 1982). In climate modeling, this requires that learners recognize that atmospheric science is not limited to the formulas and theories exactly as they experienced them in university coursework; rather formula and science theory are *components of computer simulations*. For a naïve scientist, simulations may be viewed as a metaphorical "black box", where a question is inserted into one end and an answer comes out the other with no conception of what happens inside the box. To inform future climate modelers about the process inside the box, they must

The goal of LEAD is to expose learners to concepts of and practice with RCMs in order to achieve best results in terms of learning through the process of conceptual change.

undergo conceptual change. To support learners in conceptual change, it is necessary to guide them towards an understanding that mathematical formula are not just tools to do science, rather they are a form of science model. As a result, the authors have chosen to define science models as *representations that explain and predict natural phenomenon* (Schwarz *et al.* 2009) because it is the best definition that describes how scientists use all types of models: from formulas, to simulations, to theories. LEAD is designed to teach scientists how to use computer RCMs using the process of conceptual change.

Although the process of guiding students towards conceptual change seems straight-forward, it is actually a difficult process that requires ever-evolving strategies and lots of time (Posner *et al.* 1982, Martin and Hand 2009). In a longitudinal study by Martin and Hand (2009), elementary school teachers met with instructors on a regular basis for multiple years for professional development designed to support conceptual change. Results indicate that it can take approximately 18 months for conceptual change to occur. Therefore, it is not sufficient to expose naïve scientists to the concept of computer modeling during short-term workshops; rather an extensive programme with regular support from instructors is required (Penuel *et al.* 2009). The goal of LEAD is to expose learners to concepts of and practice with RCMs in order to achieve best results in terms of learning through the process of conceptual change.

Curriculum

The fundamental goal of LEAD is to explicitly link conceptual understanding of how the atmosphere works with the concept of a climate model. To accomplish this, LEAD will develop a series of modules, each specifically focused on a set of skills and/or concepts that progress in a way that supports the conceptual link between science content, technology use, and the concept of climate models. For example, it seems natural to encourage learners to use the models as soon as possible so they have lots of time to practice using the models with instructor support. However, if learners are unfamiliar with Unix, their focus is often on syntax and navigation rather than understanding the model they are using. Therefore, LEAD will provide Unix training and the concept of modeling as two separate modules. This way, the participants gain understanding of science models in an environment that is free of the constraints of technology.

Additionally, LEAD will focus on participant networking and community building. A research study showed that an online blended e-learning environment can support conceptual change of a community of learners that co-construct ideas and actively reflect and reconstruct conceptions. More importantly, they show that if conceptual change is achieved, conceptual understanding is long-term and stable; in other words, information is not forgotten over time (Tao and Gunstone 1999).

A common worry when implementing an online course regarding science content is whether everyone will have the opportunity to be involved and learn equally. If a collaborative, reflective learning environment is established, research indicates that learning differences between groups of people (such as men and women) are minimized (Prinsen *et al.* 2007, Barrett and Lally 1999, Hsi and Hoadley 1997). Also, in case of blended e-learning, interactions between participants and instructors maximizes the learning opportunities, provides participants with a variety of ways to gather information, and provides immediate feedback for instructors to track learning. One very important aspect of e-learning includes video conferencing, which provides the participants with constant guidance, feedback, and live interactions with the instructors throughout the course.

LEAD will utilize a Moodle (Moodle.org 2011) course management module system, which is one-of-a-kind for climate modeling courses. Using this technology will provide constant participant support by providing lectures, video conferences, video recordings, text chats, presentations, guidelines, assignments, and so on to motivate participants and enhance the overall experience of the course.

Climate model capacity building: climate 'middlemen' for the future

What if, as suggested above, the students being trained come from communities where conflict, social and economic strife, dysfunctional government, poverty and poor computational capacity, coupled with a sub-standard education system are an everyday reality? Unfortunately, these are the conditions plaguing a large part of the world today. As if this was not enough, the poorest places happen to be the most vulnerable to increasing climate variability and extremes, and, therefore, are the most in need of modeling capacity.

The growing climate impacts and the rapid development of climate downscaling methods are twin forces creating a rising demand for climate modelers, especially in vulnerable regions. As downscaling improves, offering the possibility of better forecasting and preparation for climate extremes, more people personally invested in the adaptation of localities all across the world are needed to conduct regional modeling assessments for climate change adaptation (CCA) and disaster risk reduction (DRR). LEAD answers this growing call to train the next generation of climate modelers in developing countries, who will be ever more important for building community resilience through CCA and DRR efforts.

Climate modeling capacity must be seen as embedded within a broader socio-cultural context since the primary aim for modeling is to benefit society. Therefore, the 'naïve modeler' must also have sufficient knowledge about where and how their knowledge will be of greatest benefit.

While LEAD's capacity building aims are of utmost importance, the complex social realities of the modern, globalized world demand much more from the "naïve modeler" than just revealing the contents of the "black box". More than ever, climate science (and climate modeling specifically) is taking centre stage in the production of knowledge about climate change and its impacts on the earth and humanity. While LEAD seeks to educate the next generation of regional climate modelers, we cannot simply assume that training more modelers alone will result in better disaster preparedness and increased climate resilience. Climate modeling capacity must be seen as embedded within a broader socio-cultural context since the primary aim for modeling is to benefit society. Therefore, the "naïve modeler" must also have sufficient knowledge about where and how their knowledge will be of greatest benefit. For instance, in the case of Tibetan pastoralists, even if future temperature and precipitation patterns are downscaled for a particular location on the Tibet–Qinghai Plateau, the information may not be relevant to the Phala nomads, who are only interested in the impacts these changes will have for their pastureland. But, even if future climate change information is translated into a meaningful road sign pointing toward greener pastures, the Chinese government's privatization and fencing-off of traditional grazing lands are political blockades to the survival of the pastoralists' livelihood (see Næss *forthcoming*).

The path from climate information to climate knowledge is neither direct nor unfettered. Thus, the chain in the production of this knowledge is complex, and its demands are unique at every point on the map, depending on local needs and nuances.

In the case of disasters in the Upper Indus Basin, Azhar-Hewitt and Hewitt (*forthcoming*) describe how traditional risk-averse practices are eroded due to modernizing forces, and how some larger disasters reveal a disconnect between research and official responses. Thus, even downscaled modeling translated into hydrometeorological impact maps may prove useless to women in Baltistan left to fend for their livelihoods alone since their husbands migrated as labourers to large cities. This case illustrates the socially-constructed nature of vulnerability and inherent difficulties of applying modeling results on the ground. In such a place where climate change "is always subordinate to or overshadowed by socio-economic developments", the authors instead advocate the tuning of the "professional ear"—for scientists to learn to "listen and translate what people report into actions that best serve their needs and to which they can contribute intelligently" (Azhar-Hewitt and Hewitt *forthcoming*).

In light of the above cases, one realizes that the path from climate information to climate knowledge is neither direct nor unfettered. Thus, the chain in the production of this knowledge is complex, and its demands are unique at every point on the map, depending on local needs and nuances. It is, therefore, important to consider these needs and nuances when a programme, such as LEAD dares to ask: climate modeling for *whom*? An equally daring question may also be "*where?*" depending on whose power this may be in conflict with. These ethical questions must be asked in order for trained climate modelers to fit in where they are needed in their respective countries, in order for them to be effective messengers of climate information, while being sensitive to local needs. This hints at the etching out of a new role for "climate middlemen", beyond traditional modelers, who are as fluent in the workings of the "black box" as they are in communicating climate knowledge at different levels in society, from top government ministries to local NGOs.

Target-group-oriented LEAD

As is illustrated by the above cases, it is essential to consider the target group of climate model capacity building. Two main groups can be identified: a) Academic-oriented professionals: these are people who would benefit from post-graduate courses to improve their skills with the goal of a certificate, which would allow them to have better job prospects, or support their career planning; b) professionals who already work with weather or climate-related issues, but need to update their knowledge or to receive specific training on a certain global or regional model. These professionals do not need a certificate, since it would not change their working prospects (Figure 1). Figure 1, shows the overarching framework of LEAD, which tries to link the society with the information not only on basic science, but also including the technology and state-of-art information to provide to the society.

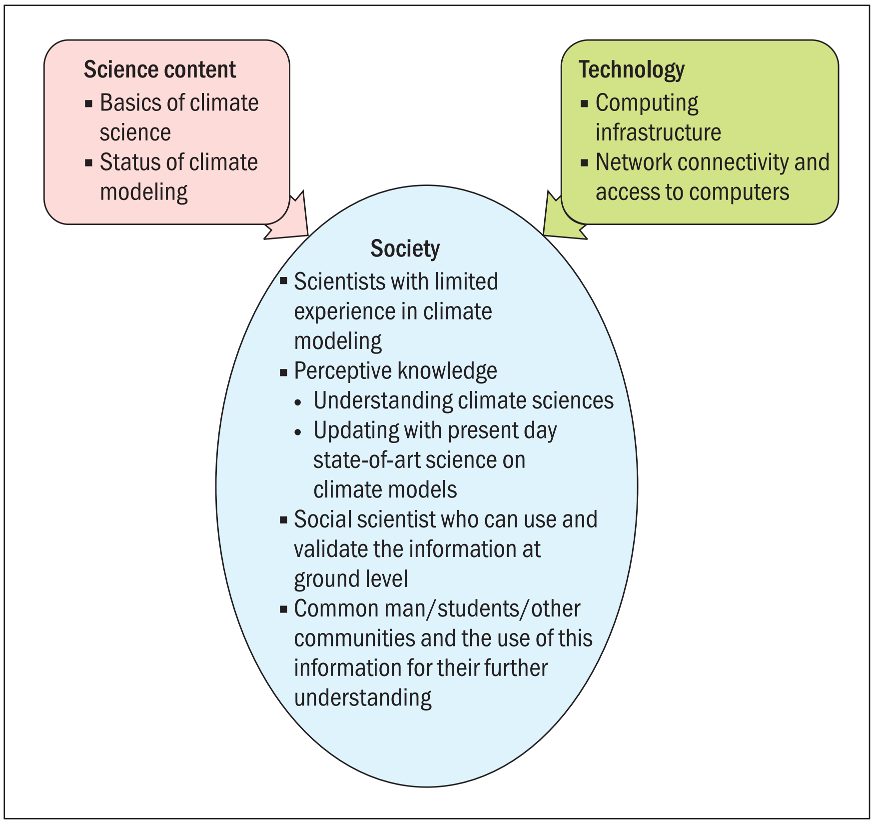

Figure1 Conceptual framework of LEAD: aiming to develop an understanding of science and technology and providing them to the society. We would like to start our pilot effort in providing the information to first target group who would already have basics in climate sciences and would then extend to the second target group.

The first target group would benefit directly from LEAD. However, the second group still lies within the traditional capacity-building type; which implies shortcomings as mentioned in this paper. This type of approach lacks both the technical and learning support after the training ends. One way LEAD could be applied here is in the follow-up process. After a training session is completed, social media could be used to provide a network the participants feel they can rely on. Online-based discussion sessions, can also be created to provide feedback and support to the participants. There has been a tendency, as a result of some capacity building courses, for the students themselves to setup a social-media group to continue the discussions after the course has ended.

Conclusion

Conceptual change is an important step towards a successful capacity building programme because it is a process of learning that supports the student to change the way he or she thinks about climate and weather models in light of his or her current science and mathematical knowledge, which requires continuous support and long-term programmes. In addition to that, capacity building needs to create a network for the participants to belong to. The present capacity building programmes often fail to provide conceptual change because of their short duration and the lack of support after the programme concludes. Also, previous studies suggests that in order to understand a concept and apply, it is needed to have minimum 18 months of training in the field of interest. Thus, the concept, which we propose here called LEAD, is a new initiative that would use a unique blended e-learning course module for researchers who are interested to work in the field of climate modeling, giving them the concepts of climate science, graphical tools to understand the climate datasets, and also basic learnings in Unix, which could help the participants to take forward the climate modeling activity on their own at the end of the course. The course would use different approaches to retain the interest of the participants throughout the 18 months proposed in the present article. Additionally, blended e-learning is a tool currently used by other organizations to support online coursework; for example, TERI has a platform already in place for use with developing countries (ESD Online 2011), which LEAD can modify for our specific purposes.

The goal is to move participants beyond the naïve concept of the 'black box', towards a perspective that models are an instrument that they have full control of, which will indicate that conceptual change has been achieved.

Current capacity building programmes are also expensive. Funding agency programmes spend hundreds of thousands of dollars each year to provide travel for instructors and students to attend short-term programmes. Normally, only a few can benefit. The same amount of funding could be spent for funding many more professionals if a capacity building framework, such as LEAD, was used. The benefit would also be larger, since participants would have a more holistic understanding of the climate system. The goal is to move participants beyond the naïve concept of the "black box", towards a perspective that models are an instrument that they have full control of, which will indicate that conceptual change has been achieved.

Acknowledgements

We would like to thank Dr Rajendra Pachauri, Dr Arabinda Mishra, and Dr Eystein Jansen for the discussions on the LEAD framework. We also thank Craig Yarker for the comments provided. We further thank Dr Senaka Basnayake, Mr Susantha Jayasinghe, and Mr NMSI Arambepola, at the Asian Disaster and Development Center, for the interviews and inputs provided. We would also like to thank Ambassador Dasgupta, for reviewing our article and providing insights to improve the same.

Appendix

Lessons learned in capacity building in South Asian countries

Box 1 Interview with the Asian Disaster Preparedness Center

A few Asian countries have tried online-based learning. For example, the Asian Disaster Preparedness Center (ADPC, Bangkok, Thailand) provided a few courses through video lectures a few years ago. We conducted an interview with ADPC, since they have been one of the leading centres in capacity building in southeast Asia. Their previous online courses were about six-months in duration and have mostly been about community-based disaster reduction. ADPC had several participants interested in those online courses.

The main challenges were related to the support provided to the participants because the international faculty was volunteer-based. The limitation with volunteer faculty is that there could have been minimal commitment from the instructors for necessary follow up. The lessons learned from ADPC for a successful online programme are that there needs to be a committed team to provide both technical and instructional support.

According to the recent experiences in capacity building workshops conducted by ADPC, they agree that a period of 12–18 months would be a good length for an online programme. Any period more than this might be too long and miss the intended focus. One of the other suggestions by the ADPC group is to have different modules and assess each module separately, since the module system might provide more insight to the course and can lead to a post-graduate level course structure.

The post-graduate level is also essential because it opens doors for job opportunities. This would be a motivational factor for many to attend an online education programme. Another motivational factor would be to include elements other than climate modeling into the programme. For example, the first 12 months could be related to understanding climate modeling and running a model, then the students could choose to specialize in one area of interest (such as dynamical downscaling, disaster management, water resources, health, and so on) for the next six months. This would also attract many practitioners, and it would also add more flavour to the course. In addition, the course would be more applicable to specific climate-change issues faced by a variety of countries, for example, Bangladesh.

Box 2 Science and Policy of Climate Change: a learning initiative

In 2011, an eight-week training on Science and Policy of Climate Change was organized by the Energy and Resources Institute (TERI), in collaboration with Global Development Learning Network (GDLN) and Institute of Global Environmental Strategies, with support from World Bank Tokyo Development Learning Centre. The training programme includes an interdisciplinary approach, which uses the latest information and communication technology (ICT) tools and techniques. The concepts were included as modules where the first module focuses on the science concepts behind climate change as well as information about the state-of-the-art climate system models and impact assessment models. They also develop an understanding of the present-day impact assessment approaches and tools to address the vulnerabilities and risk to climate change as well as the application of science into policy-making is addressed as a separate module. The trainings were provided by professionals from TERI and IGES, which involved online blended e-learning approaches with course modules, video lectures, and video conferences after every module designed for each group situated in various parts of Asia (such as Vietnam, Sri Lanka, Bangladesh, and so on). A lesson learned from these trainings is that each module needs a hands-on training component for the participants to be able to utilize their skills independently.

References

American Meteorological Society. 2010. *Bachelor's degree in atmospheric science: An Information Statement of the American Meteorological Society*. Retrieved 2011 from American Meteorological Society: http://www.ametsoc.org/policy/2010degree_atmosphericscience_amsstatement.html.

Azhar-Hewitt F and Hewitt K. forthcoming. Voice and Vulnerability: Viewpoints from those Most at Risk from Disaster in Mountain Areas, Northern Pakistan. Ch. 4 in Lamadrid A and Kelman I. forthcoming. *Climate Change Modeling for Local Adaptation in the Hindu Kush-Himalaya Region*. Vol. 11 in series Community, Environment and Disaster Risk Management. Emerald Group Publishing Ltd.

Barrett E and Lally V. 1999. Gender differences in an on-line learning environment. *Journal of Computer Assisted Learning 15*: 48–60.

de la Rubia T D and Yip S. 2008. Advocacy of computational science (Editors' preface). *Scientific Modeling and Simulations 15*: 1–2.

ESD Online. 2011. Science and policy of climate change: A blended e-learning program. Retrieved 2011 from ESD Online: http://www.esdonline.org/spcc.

Giorgi F, Jones C, and Asrar G R. 2009. Addressing climate information needs at the regional level: the CORDEX framework. *WMO Bulletin 58*:175–183.

Grosslight L, Unger C, Jay E, and Smith C. 1991. Understanding models and their use in science: conceptions of middle and high school students and experts. *Journal of Research in Science Teaching 33*:1019–1041.

Halloun L A. 2004. *Modeling theory in science education.* Dordrecht: Kluwer Academic.

Harrison A G and Treagust D F. 2000. A typology of school science models. *International Journal of Science Education 22* (9):1011–1026.

Hsi S and Hoadley C M. 1997. Productive Discussion in Science: Gender Equity through Electronic Discourse. *Journal of Science Education and Technology 6* (1): 23–36.

Justi R and Gilbert J. 2002. Science teachers' knowledge about and attitude towards the use of models and modeling in learning science. *International Journal of Science Education 24* (12):1273–1292.

Martin A M and Hand B. 2009. Factors affecting the implementation of argument in the elementary science classroom. A longitudinal case study. *Research in Science Education 39*:17–38.

Michaels S, Shouse A, and Schweingruber H. 2008. In N R Council, *Ready, set, science! Putting research to work in K-8 science classrooms* (pp. 109–126). Washington DC: The National Academies Press.

Moodle.org. 2011. Retrieved 2011, from http://moodle.org/about/

Naess M W. forthcoming. Tibetan Nomads Facing an Uncertain Future: Impacts of Climate Change on the Qinghai-Tibetan Plateau. Ch. 6 in Lamadrid A and Kelman I. forthcoming. *Climate Change Modeling for Local Adaptation in the Hindu Kush-Himalaya Region*. Vol. 11 in series Community, Environment and Disaster Risk Management. Emerald Group Publishing Ltd.

National Center for Improving Student Learning and Achievement in Mathematics and Science. 2000. High School Students "do" and learn science through scientific modeling. *In brief: K-12 mathematics & Science Research & Implications 1* (1):1–6.

National Research Council. 1996. *National Science Education Standards.* Washington DC: National Academy Press.

Penuel W H, McWilliams C, McAuliffe A, Benbow C, Mably C, and Hayden M. 2009. Teaching for understanding in earth science: Comparing impacts on planning and instruction in three professional development designs for middle school science teachers. *Journal of Science Teacher Education 20*: 415–436.

Posner G J, Strike K A, Hewson P W, and Gertzog W A. 1982. Accommodation of a scientific conception: toward a theory of conceptual change. *Science Education 66* (2): 211–227.

Prinsen F R, Volman M L, and Terwel J. 2007. Gender-related differences in computer-mediated communication and computer-supported collaborative learning. *Journal of Computer Assisted Learning 23*: 393–409.

Schwarz C V, Reiser B J, Davis E A, Kenyon L, Acher A, Fortus D, *et al.* 2009. Developing a learning progression for scientific modeling: making scientific modeling accessible and meaningful for learners. *Journal of Research in Science Teaching*: 632–654.

Schwarz C and White B. 2005. Metamodeling knowledge: developing students' understanding of scientific modeling. *Cognition and Instruction 23* (2):165–205.

Tao P-K and Gunstone R F. 1999. Conceptual change in science through collaborative learning at the computer. *International Journal of Science Education 21* (1): 39–57.

Warner T. 2011. Quality assurance in Atmospheric modeling. *Bulletin of the American Meteorological Society*, early online release, doi: 10.1175/BAMS-D-11-00054.1.

Windschitl M, Thompson J, and Braaten M. 2008. How novice science teachers appropriate epistemic discourses around model-based inquiry for use in classrooms. *Cognition and Instruction 26*: 310–378.

For further details, contact

Dr Vidyunmala Veldore
Earth Science and Climate Change Division
The Energy and Resources Institute (TERI)
Darbari Seth Block, IHC Complex,
Lodhi Road, New Delhi – 110 003

Tel.	2468 2100 or 4150 4900
Fax	2468 2144 or 2468 2145
	India +91 • Delhi (0) 11
E-mail	vidyunmala.veldore@teri.res.in
Web	www.teriin.org