Developing 21st Century Skills with Investigative Cases: Building Global Awareness and Informing Choices about Energy

Ethel D. Stanley, BioQUEST Curriculum Consortium, USA
Margaret A. Waterman, Southeast Missouri State University, USA
Darren J. S. Wong, National Institute for Education
Nanyang Technological University, Singapore
Hong Kim Tan, Department of Natural Science and Science Education
National Institute for Education, Singapore

The global availability of web-based computing coupled with the need to address pressing problems in the environment and in society have led to the articulation of new information management, problem solving and communication skills for 21st century learners (UNESCO, 2011). This paper describes how opportunities to practice these skills may be implemented in the classroom using investigative case-based pedagogy with online data and tools for making evidence-based decisions about contemporary issues such as energy utilization. In Singapore in August 2011, a group of lower secondary teachers were introduced to investigative case-based pedagogy, newly published 21st century competencies for the classroom, and an online carbon calculator developed for public use. The following paper presents a review of the project planning, methods and materials used, example products, and conclusions.

Introduction

New educational standards are being developed by various agencies, governments and educational groups to address escalating challenges in education due to the availability of web-based computing and the accessibility of information, data, and tools both inside and outside of the classroom (NSF, 2008). Today's students need to be able to manage and communicate information, develop inquiry skills, and use technology for life-long learning (NRC 2000, 2009). These requirements are recognized as "21st Century Skills" (UNESCO, 2011) or "21st Century Competencies" (Ministry of Education, Singapore, 2010 b).

Figure 1. Lower secondary teachers participating in ICBL workshop at The National Institute for Education in Singapore

Table I.

21st Century Skills from UNESCO (2011, in italics, p. 43) and P21.org (2011)	Singapore 21st Century Competencies (Ministry Of Education 2010b)
Creativity and Innovation Critical Thinking and Problem Solving • *creative, reflective, collaborative and problem-solving*	Critical and Inventive Thinking • *Includes: Thinking outside the box,* • *Taking on challenges* • *Desire to learn* • *Make sound decisions*
Communication and Collaboration • *foster cross-cultural understanding and the peaceful resolution of conflict* Social and Cross-Cultural Skills • *productive and able to participate fully in society and influence the decisions which affect their lives*	Civic Literacy, Global Awareness and Cross-cultural skills • *Includes being informed, aware and active citizen* • *Broader worldview* • *Able to work with people with different perspectives*
Information literacy • *able to use ICT tools to handle information and generate knowledge*	Information and Communication Skills • *Includes identifying information* • *Being discerning* • *Being safe*

The UNESCO *ICT Competency Framework for Teachers* (2011) directly addresses 21st century skills for teachers and learners. One stated goal is to deepen knowledge in order "to increase the ability of students, citizens, and the workforce to add value to society and to the economy by applying the knowledge gained in school subjects to solve complex, high priority problems encountered in real world situations" (p.11). The *Framework* emphasizes the ways information and communication technology (ICT) can help develop the needed skills.

The Ministry of Education for Singapore has developed an extended vision of what 21st Century learners should be able to do, as outlined in the pamphlet "Nurturing Our Young for the Future" (Singapore Ministry of Education, 2010b). In addition to ICT skills similar to those detailed in the UNESCO documents, the Singaporean vision includes developing global awareness and cross cultural skills, civic literacy, and, critical and inventive thinking. In Singapore, this vision is presently being developed into expectations and learning outcomes that will be articulated across the entire future curriculum in 2012-2014 (Singapore Ministry of Education, 2010a). We used Investigative Case Based Learning (ICBL) (Waterman and Stanley, 2000, 2010; Stanley and Waterman, 2003) pedagogies as well as online data and tools to address 21st century skills while promoting global awareness and informed energy choices in Singapore and the US.

ICBL, like other case-based methods (Herreid, 2007, Duch *et al*., 2001), helps learners connect the content learned in school to its uses outside the classroom. The settings for investigative cases describe realistic, everyday situations (contexts) that learners might encounter and relate to in a meaningful way. The recent Vision and Change Report (AAAS, p. 19, 2010) indicated that students prefer to learn science in the context of applications.

The ICBL approach was uniquely designed to engage learners in a three phase process (Stanley and Waterman, 2003):

Phase I: Analyzing the case and generating questions (posing problems),

Phase II: Investigating the case (problem solving), and

Phase III: Sharing findings (peer review).

These steps are based in steps scientists take: Problem Posing, Problem Solving and Peer Persuasion (Peterson and Jungck, 1988). Later, we will show how these three phases applied to the case *Choices* used by different groups of learners and illustrate some of the learning outcomes observed.

In July of 2011 we offered a 2-day workshop on "ICBL: Teaching Science While Developing 21st Century Competencies" for 40 lower secondary teachers (grades 6-10) in Singapore through the National Institute for Education at Nanyang Technological University. Within that workshop we engaged the participants in a case module built around an online carbon calculator for Singapore. The goals of the workshop relevant to this module were to:

- Demonstrate how using cases and investigations develops 21st century competencies as students ask questions, conduct explorations, and produce final products for peer review.
- Illustrate the use of the online carbon calculator to gather evidence for making informed decisions about home and business energy consumption.

This module was also used with 110 science instructors in the United States during a presentation at the National Center for Case Study Teaching in Science conference in Buffalo, NY, in September 2011.

Investigative Case Module Development

The module was developed to address objectives in the current Singapore *Science Syllabus for Lower Secondary* (Singapore Ministry of Education, 2008) focusing on their Science & Technology and Energy themes. Specific objectives included:

- Discuss the importance of reducing electrical energy wastage
- Appreciate the need for Singapore to conserve energy
- Use scientific inquiry skills such as posing questions, designing investigations, evaluating results and communicating learning
- Present evidence-based conclusions about the impact of energy choices

To address these objectives we planned to create a module including a case, investigations and assessments to go with an online ecological footprint calculator with which we were familiar, but whose data base did not include Singapore. Further searching, however, uncovered a better option: a Singapore-specific carbon calculator developed by the NGO Singapore Environment Council (SEC). This online tool supported meaningful case-based learning specific to experiences of Singaporean learners. (Interestingly, the SEC carbon calculator was later used to challenge American teachers to extend exploration of energy choices outside their borders.)

To understand what this calculator is measuring, we examined the concept of a carbon footprint. Weidmann and Minx (2008) surveyed relevant literature from 1960-2007 and found the term "carbon footprint" began to be used in 2005 and was derived from the broader concept of ecological footprint. They also found that while enjoying wide use, the term is poorly and variously defined. A common definition is the amount of greenhouse gases emitted as a result of our daily activities, usually measured as mass of CO_2 emitted. Unfortunately, this common definition is ambiguous and they recommend a more specific definition.

The definition provided by the company Carbon Footprint Ltd. (2011), a firm specializing in assessing carbon footprints, is more specific. A carbon footprint includes primary (or "direct") emissions (resulting from direct burning of fossil fuels) and secondary (or "indirect") emissions. These secondary emissions usually involve a Life Cycle Assessment, that is, an evaluation of the amount of CO_2 resulting from all facets of the production and delivery of goods or services over the course of their lifetime.

The SEC Carbon Calculator "provides a lifestyle carbon assessment tool which is targeted at households in Singapore. It also includes a transport carbon calculator specific to Singapore" (Singapore Environment Council, 2010). We believe that this calculator focuses on direct emissions arising from activities that burn fossil fuels (such as driving a car) and indirect emissions that arise from electricity usage. We did not see evidence that it includes Life Cycle Assessment level data for goods and services. This Carbon Calculator meshes well with the Singapore National Climate Change Strategy which aims to mitigate greenhouse gas emission by improving energy efficiency; it includes an individual's choices about energy (Singapore Ministry of Environment and Water Resources, 2008).

We saw the potential of the Carbon Calculator as a tool to test hypotheses about how carbon emissions could be reduced by making different choices. With this in mind, we wrote a case scenario - *"Choices*", instructions for using the Carbon Calculator, instructions for designing tests of hypotheses, guidelines for a poster to present findings, and an assessment form for peer review of a poster.

Implementing the Module
Phase I. Analyzing the Case and Generating Questions (Posing Problems).

Open and read the case.
Participants received the case, *Choices*, at the start of the session - not before. We gave each learner a copy of the case and also projected it on a screen. We asked a volunteer to read the case out loud while everyone else followed along silently. Then we asked participants to spend 2-3 minutes silently reading the case again and noting words or phrases that seemed to be important to understanding what the case is about. The case scenario is shown below.

Choices
Jiaming sat across from one of his favorite clients, Mrs. Seng. His partner, Siti, joined them by computer conferencing. Today's discussion was focused on web advertising for the client's new line of instantaneous gas water heaters. As usual, Mrs. Seng provided useful background materials. Her project fit easily into their work schedules and the meeting ended well. (cont. next page)

Figure 2. Image of commuter train courtesy of S. Hoffman.

While Jiaming returned to his office, Siti decided to Google an unfamiliar term used during the meeting. "Just what is a *carbon footprint*," she thought, "and what does it have to do with water heaters?"

Although Jiaming and Siti lived in the same neighborhood and worked for *eSolutions*, only Jiaming rode the train to work. Siti preferred to work from home. She couldn't imagine riding ten stations down the line every day. The pair made an excellent team, but they had very different lifestyles.

"I wonder," Siti said to herself, "if working from home makes much of a difference between Jiaming's and my carbon footprints?"

Figure 3. Small group case collaboration during the Teaching Science While Developing 21st Century Competencies in July 2011.

Case Analysis

Next we distributed a blank "Case Analysis Sheet" This sheet contains a "Know/Need to Know" chart where students can keep track of their thoughts about what they already know related to the case as well as questions they have about aspects of the case (what they need to know).

We asked participants to consider:

- What is this case about?
- What do you already know about these topics?
- What do you need or want to know about to understand this situation?

Individual participants were asked to write down one thing they knew and one question they had. A minute or two later we asked them to form groups of 4-7 people to share their ideas and further develop their questions. After about 10 minutes, we debriefed the groups asking each to contribute one thing they knew and the most important question they had agreed upon. Finally we asked them to consider what kinds of resources might be useful to answering their "Need to know" questions.

Choices CASE ANALYSIS SHEET with responses from Singaporean participants in italics.

1. Recognize potential issues and major topics in the case.
What is this case about? Underline and list terms or phrases that seem to be important.
Then, list 3-4 biology-related topics or issues in the case.

Working at home versus commuting
Carbon footprints
Environment
Technology versus preserving green
Choices*: work at home/children*
Consumer choices

2. What specific questions do you have about these topics? By yourself, or better yet in a group, list what you already know about this case in the "What Do I Know?" column. List questions you would like to learn more about in the "What Do I Need to Know?" column.

What Do I Know?	What Do I Need to Know?
●*Singapore government encourages people to take public transport to make country go Green* ●*There is instantaneous information available at the press of a button* ●*Most families have water heaters (electric)* ●*The concept of carbon footprint is getting more popular and in common knowledge* ●*Understand computer conferencing and working from home* ●*A person's life style can affect the size of the carbon footprint* ●*Our carbon footprints are a measure of our contribution to global warming* ●*On average if you use a gas heater on a daily basis, the carbon footprint will be 21 Kg C/year (just looked this up)*	●*How much loss of man hours occur while traveling to work on public vs private transport?* ●*How to calculate carbon footprint?* ●*Does working at home mean we are more environmentally friendly than working at the office?* ●*How can we reduce our carbon footprints effectively?* ●*How does the individual lifestyle impact the carbon footprint?* ●*What is the difference between a conventional water heater and an instantaneous gas heater (green)?* ●*What exactly is a carbon footprint?* ●*How can we save the Earth by the pedagogies we use in our classroom?* ●*How much fuel does it take for the train versus the personal vehicle?* ●*Does working at home have any adverse effects on one's health?* ●*Does Siti get as much pay as Jiaming?* ●*How does Siti create a relationship with coworkers and clients when she communicates by computer?* ●*How much energy generated in festivals, laser shows?* ●*What other forms of measure can we use instead of carbon footprint?*

3. Put a check mark by 1-3 questions or issues in the "What do I need to know?" list that you think are most important to explore.

The most often checked question was *Does working at home mean we are more environmentally friendly than working at the office?*

4. What kinds of references or resources will help you answer or explore these questions? Identify two different resources and explain what information each resource is likely to give that will help you answer the question(s). Choose specific resources or types of resources.

- *Ministry of Health website (to look at data on benefits of working at home)*
- *National Environment Agency website*
- *Public Utilities Board website (*http://www.pub.gov.sg)
- *Online carbon footprint calculator* (Figure 4)
- *Survey different groups of people about lifestyle*
- *World Wildlife Fund website (info on carbon footprints and impacts)*
- *Log sheet of what you do every day and how it impacts*
- *Check utility bills in office versus at home*
- *Case studies from both the general public (newspapers) and scientific articles*
- *Earth hour in Singapore, when people shut off lights/power*
- *Singapore power services (SPS)*
- *Google carbon footprint and look for journal publications*
- *Interview staff at MRT (rapid transit system)*
- *Sharing of knowledge among ourselves*
- *Textbooks*

Figure 4. Singapore Carbon Calculator: A Tool for Investigation http://www.climatechange.sg/html/?link=4

Phase II: Investigating the Case (Problem Solving)

With investigative cases, students can engage in investigations at many levels. They can be entirely teacher-designed or entirely student-designed. They can be open-ended, as with experiments, simulations, and/or models. Or they can be close-ended, such as interpreting data, reading a map, making a graph, or critiquing an experimental design (see Waterman and Stanley, 2010 for examples).

Choosing appropriate resources can be the responsibility of either the instructor or the learners or both. Since we were working with an audience new to case-based learning, we chose the major resource, an interactive carbon calculator simulation (Figure 4) designed for Singaporean citizens to learn more about their energy choices.

There are two entry points for the carbon calculator simulation, Household and Small Business. You can interactively assess energy use in terms of carbon emissions by describing the duration and frequency each specific type of appliance turned on within a room inside the home or small business. You can add the distance and frequency of travel for each type of transport outside the home or small business as well. The carbon footprint for each use is displayed and added to an overall summary for an individual. Further, recommendations for reducing that carbon footprint are suggested at the end of the simulation.

Investigations

We chose to begin with a specific question for learners to answer using the Carbon Calculator. Then we asked them to use this simulation to test a hypothesis in an experiment of their own design. The tasks included:

1. Compare the carbon cost of transportation to work for Jiaming and Siti.
2. Design and run an experiment using this simulation to answer other questions stemming from the case analysis.

- State hypothesis
- Experimental design (identify and operationalize variables)
- Collect data in data table
- Make inferences from evidence

Phase III: Sharing Findings (peer review)

Another way to think of this phase is that students will produce materials that explain their methodologies, provide data, and support their conclusions. These materials are easily assessed. Scientists present evidence to support their conclusions and they publicly present their evidence as talks, posters, online sessions and publications. Their peers review their work and make recommendations about the publication readiness of the work.

Rubrics (scoring guides) are useful to provide to students before they begin to make their products. For this particular setting, working with teachers, we chose to illustrate a formative type of assessment, one that will help students learn what to look for and to reflect on their experience in viewing the work of others and talking with others about their work. In a subsequent poster session, we might ask peers to also score the poster based on a given set of criteria.

Mini Poster Instructions

Use a single sheet of newsprint. You may use it in portrait or in landscape mode. These posters are not meant to be final products, so they will be somewhat unpolished. You are encouraged to illustrate your poster to enhance the reader's understanding and to better communicate your findings.

Your poster needs to include the following:

1. The title of your investigation
2. The investigators' names
3. The hypothesis being tested
4. A description of how the hypothesis was tested
5. Data
6. Inferences drawn from the data

You will have about 30 minutes to prepare the poster.

We will be doing a poster session for 20 minutes. During that time, each person needs to visit the other posters. One person needs to be at your poster to answer questions. Work this out so that everyone gets 15 minutes to view the other posters.

Mini Poster Rubric

You will need to be at your poster to answer questions for 5 minutes. We will announce the end of each period of 5 minutes, so you can expect to have 15 minutes to view the other posters. Be prepared to ask questions and consider the presenter's answers.

1. List one of the questions you asked about another group's poster.
2. Describe in your own words the answer the presenter gave.
3. Did your question and/or the presenter's response help you understand more about their experiment?

Examples of Group Products: Posters with notes

Group 1. Hypothesis tested:

If a person works from home, their energy expenditure will be less than a person who works from an office.

The cartoon graphic (Figure 5) provides a visual summary of the problem and is followed by a hand drawn graph comparing the total kg C/yr for the categories of Laptop, Air Conditioning, Lights, Printer, and Transport. Shaded columns represent working at home.

In the poster session, presenters from this group indicated surprise at the expenditure of energy in working from home.

Members of the group wanted to do more simulations with this carbon calculator as well as try other carbon footprint calculators.

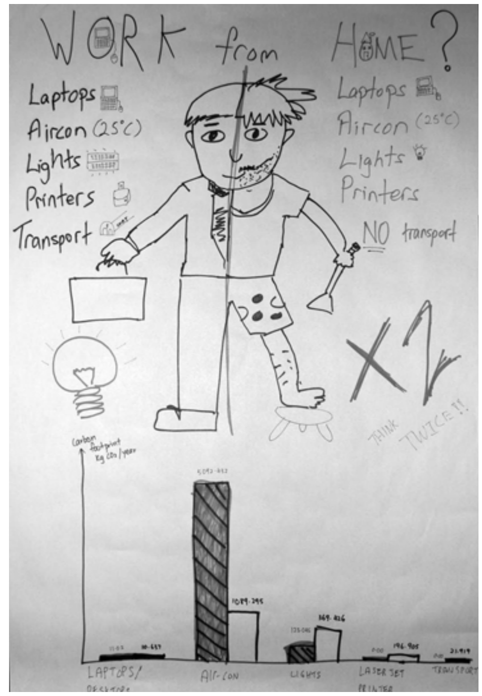

Figure 5. *Work from Home?* poster compares total kilograms of carbon produced per year in office and home work settings.

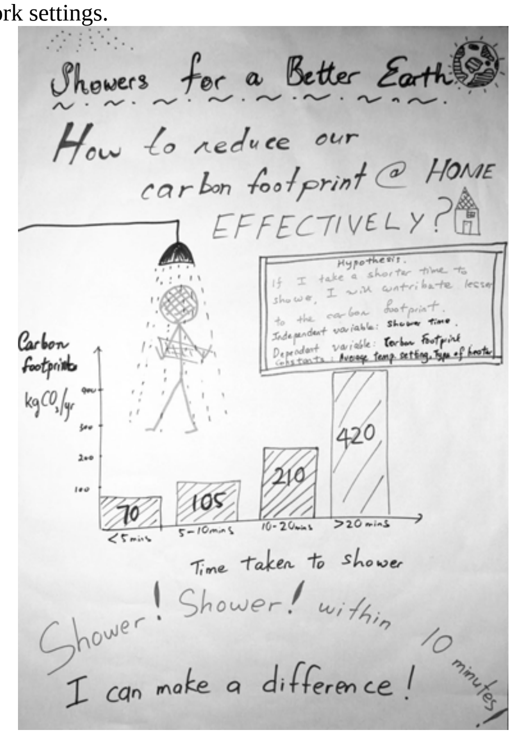

Figure 6. *Showers for a Better Earth* poster compares the total kilograms of carbon per year produced by different showering duration times.

Group 2. Hypothesis tested:

If I take a shorter time to shower, I will contribute less to my carbon footprint.

A cartoon graphic (Figure 6) accompanies their hand drawn graph comparing the total kg C/yr for showering duration categories of less than 5 minutes, 5-10 minutes, 10-20 minutes, and over 20 minutes.

The independent variable was shower time, dependent variable was carbon footprint, and the constants in this investigation were average temperature setting and type of water heater.

The poster provides a strong message in their conclusion. Members of the group also expressed an interest in further exploration.

The *Choices* case was also presented at the Fall 2011 Conference sponsored by the National Center for Case Study Teaching in Science in Buffalo, New York. As part of a plenary address entitled "Cases, Social Networking, and Workspaces" to about 110 participants from K-12 and undergraduate institutions, *Choices* provided an example of investigating science with open source simulations designed for use by individuals facing real decisions in their everyday life.

When a question arose about providing a different carbon calculator for U.S. students, an interesting discussion arose about the merits of asking American students to use the SEC carbon calculator from the point of view of a Singaporean. Providing an opportunity for students to develop greater global awareness of how energy choices are made in other parts of the world seemed a logical extension of the case objectives.

Conclusions:

Teaching with cases is a useful strategy for environmental science education. Investigative cases provide opportunities for learners to explore scientific concepts in the context of making decisions in their everyday lives. Not only can we address critical issues such as energy choices, but also the emerging needs of our 21st century learners.

In addition:

- the SEC Carbon Calculator simulation facilitated exploration and data collection required by learners to make evidence-based energy choices;
- the investigative case pedagogical approach provided an opportunity for inquiry as learners worked in groups, sharing their prior knowledge and building new knowledge through posing questions, solving problems and presenting their solutions for peer review (Figure 7);
- the *Choices* case provided an opportunity for learners to use multiple 21st century competencies/skills; and,
- the *Choices* case may be used to encourage learners to develop global awareness of energy choices beyond their own borders.

Figure 7. Working on investigative cases requires collaborative problem posing, problem solving, and peer review (Waterman and Stanley, 2000).

References:

Anonymous. Framework for 21st Century Learning. The Partnership for 21st Century Skills March 2011. http://www.p21.org/storage/documents/1.__p21_framework_2-pager.pdf

AAAS (formally American Association for the Advancement of Science). (2010). *Vision and Change in Undergraduate Biology Education: A Call to Action.* Washington, DC: AAAS.

Carbon Footprint Ltd. (2011). *What is a Carbon Footprint?* (Accessed Dec 2011) http://www.carbonfootprint.com/carbonfootprint.html

Duch, B., S. Gron and D. Allen. (2001). *The Power of Problem-Based Learning*. Herndon VA: Stylus Publishing, LLC.

Herreid, C.F. (Ed.) (2007). *Start with a Story: The Case Study Method of Teaching College Science*. Arlington, VA: National Science Teachers Association.

National Science Foundation. (2008). *Fostering Learning in the Networked World: The Cyberlearning Opportunity and Challenge*. Washington, DC: NSF.

National Research Council. (2000). *How People Learn: Brain, Mind, Experience and School*. Washington, DC: National Academy Press.

National Research Council. (2009). *A New Biology for the 21st Century*. Washington, DC: National Academy Press.

Peterson, N. and J. R. Jungck. (1988). *Problem-Posing, Problem-Solving, and Persuasion in Biology.* Academic Computing 2(6): 14-17 and 48-50.

Singapore Environment Council. (no date). *Climate Change Portal: Carbon Calculator.* (Accessed Dec 2011) http://climatechange.sg/html/?link=4

Singapore Ministry of Education. (2008). *Science Syllabus, Lower Secondary.* (Accessed Dec 2011) http://www.moe.gov.sg/education/syllabuses/sciences/files/science-lower-secondary-2008.pdf

Singapore Ministry of Education. (2010 a). *MOE to Enhance Learning of 21st Century Competencies and Strengthen Art, Music and Physical Education.* (Accessed Dec 2011) http://www.moe.gov.sg/media/press/2010/03/moe-to-enhance-learning-of-21s.php

Singapore Ministry of Education. (2010 b). *Nurturing Our Young for the Future: Competencies for the 21st Century.* (Accessed Dec 2011) http://www.moe.gov.sg/committee-of-supply-debate/files/nurturing-our-young.pdf

Singapore Ministry of Environment and Water Resources. (2008). *National Climate Change Strategy*. (Accessed Dec 2011) http://app.mewr.gov.sg/web/Contents/ContentsNCC.aspx?ContId=457

Stanley, E. and M. Waterman. (2003). *Using Investigative Cases in Geoscience*. (Accessed Dec 2011) http://serc.carleton.edu/introgeo/icbl/index.html

United Nations Educational, Scientific and Cultural Organization. (2011). *ICT Competency Framework for Teachers.* (Accessed Dec 2011) http://unesdoc.unesco.org/images/0021/002134/213475E.pdf

Waterman, M. and E. Stanley. (2010). *Biological Inquiry: A workbook of investigative cases.* 3rd. ed. San Francisco: Benjamin Cummings.

Waterman, M.A. and E.D. Stanley. (2000). *LifeLines OnLine: Investigative Case-Based Learning for 21st Century Learners.* Proceedings of the International Union of Biological Scientists BioEd 2000. Paris, France. http://www.iubs.org/cbe/papers/waterman_stanley.html

Wiedmann, T. and Minx, J. (2008). A Definition of 'Carbon Footprint'. In: C. C. Pertsova, *Ecological Economics Research Trends*: Chapter 1, pp. 1-11, Hauppauge NY: Nova Science Publishers. Originally published 2007 online at http://www.censa.org.uk/docs/ISA-UK_Report_07-01_carbon_footprint.pdf

Ethel D. Stanley is the Director of the BioQUEST Curriculum Consortium which actively supports educators interested in the reform of undergraduate biology education through collaborative development of curricula. Dr. Stanley leads or collaborates on multiple BioQUEST projects, which feature teaching strategies that support inclusivity, open-ended inquiry and numeracy while using simulations, tools, data, cases and other resources for problem posing, problem solving, and peer review. Dr. Stanley earned her MS in botany at Wayne State University and her Ed.D. in science education at Illinois State University. To her leadership of reform in biology education, Dr. Stanley brings over two decades of teaching experience at Millikin University and Oakland Community College where she taught innovative courses for preservice teachers, biology majors and majors outside of the sciences. She has served as President of the Association of College and University Biology Educators, Chair of the Teaching Section of the Botanical Society of America, and Editor of *Bioscene: The Journal of College Biology Teaching*. She presents on reform in biology education nationally and internationally, as well as works with teachers and college faculty in professional development workshops. She has co-authored three books and over 30 articles on biology education, visual learning and investigative case based learning.

Margaret Waterman is a science teacher educator and professor of biology at Southeast Missouri State University. Before coming to Southeast, she taught biology at Kenyon College and Emory University and did faculty development work at the University of Pittsburgh and Harvard Medical School. Her M.S. in plant pathology and Ph.D. in science education were completed at Cornell University. Dr. Waterman is recognized for her work on problem based and investigative case based learning (ICBL) in the sciences. She works with science faculty and high school teachers on developing materials and approaches for using ICBL to integrate new content, approaches and skills in biology curriculum. In addition to numerous presentations at scientific and education organizations in the U.S., Dr. Waterman has presented internationally on investigative case based learning and sustainability education, and has worked with school teachers in India, Peru, South Africa and Singapore. She was President of the Association of College and University Biology Educators and has written over 30 papers and book chapters on undergraduate science education. With Collaborator Dr. Ethel Stanley of the BioQUEST Curriculum Consortium, she has developed ICBL approaches and materials and conducted grant-funded research and development. Their book *Biological Inquiry: A workbook of investigative cases*, 3rd ed. (2010) is used by undergraduates around the world. Their website at <http://bioquest.org/icbl> has a catalog of more than 50 cases ready for use.

Darren Wong is currently a teaching fellow at the Singapore National Institute of Education where he is involved in physics and science teacher education. Prior to this, he was a junior college physics lecturer, before being posted to the Singapore Ministry of Education to serve in the area of curriculum development. His interest lies in the development of educative curricula materials that promote the learning and teaching of science and physics as inquiry.

Hong Kim Tan is currently a teaching fellow at Natural Sciences & Science Education, National Institute of Education, Nanyang Technological University, helping to train primary and secondary science teachers at this teachers' training institute. Before his secondment to NIE, he was a curriculum specialist for Biology at the Singapore Ministry of Education Headquarters where he was involved in facilitating the implementation of science curriculum as well as the development and evaluation of biology syllabuses, assessment modes and teaching materials. Prior to his posting to MOE HQ, he was a Head of Department for Science at a secondary school where, besides carrying out administrative duties, his primary role was to teach Biology, Chemistry and Lower Secondary Science. His current research interest is in the area of assessing and creating better learning environments in the Biology laboratories.