

**Global climate change teaching resources: getting the message across  
to elementary school students**

**Name:** Rick Swindell and Jim Richmond

**Affiliation:** Griffith University

**Address:** Faculty of Education  
Griffith University  
Nathan Qld 4111  
Australia

**Email:** r.swindell@mailbox.gu.edu.au

j.richmond@mailbox.gu.edu.au

**Abstract**

Although this paper is research based the conference presentation is intended for elementary school teachers and will focus heavily on classroom application of new curriculum materials. The materials have been developed by the authors to assist teachers in upper elementary school and lower secondary school to engage their students in deep learning about the causes, consequences and possible solutions for arguably the most serious of all environmental problems - global climate change.

The new curriculum materials are based on research findings from a quasi-experimental study in which some 200 upper elementary school students were participants in a case-control study involving hands-on learning with novel purpose-built teaching materials. These materials were designed to encourage children to engage with the science, technology and society principles of global climate change. The results showed that students in the intervention groups performed significantly better than those in the control group and that they had replaced a number of alternative frameworks about global climate change with more scientifically acceptable frameworks. These findings have led to the development of print and CD Rom based materials for teachers and students. Preliminary findings about the efficacy of these materials are also discussed.

## **Global climate change teaching resources: getting the message across to elementary school students**

### **Introduction**

Global climate change is arguably the most serious environmental problem facing humankind. Per capita, Australia is one of the main global greenhouse gas culprits. Indeed, by some measures, Australia is the main culprit. However, all developed countries are going to have to implement much sterner measures to limit greenhouse gas emissions if the present trend of global warming is to be reversed. Moves to break society's dependence on polluting, non-renewable forms of energy and to replace these with renewable and less polluting forms of energy will require social change and financial expenditure on a very large scale. These changes cannot be achieved by mere political tinkering at the fringes.

Education is the key to social change within a democracy. Well-informed citizens are more likely to force the social agenda towards a pathway of long-term sustainability than politicians can do, because most politicians focus merely on the short-term goal of re-election. Schools are an ideal place to begin the process of ensuring that citizens have a substantial understanding of the science and social issues that fall within the widely encompassing umbrella of global climate change.

Educationalists acknowledge the importance of first hand experience in helping children to develop knowledge, skill and understanding (Stables 2000). In the case of science and technology-based ideas, deep learning as opposed to superficial understanding of important concepts is more likely to take place if students are able to relate formal learning situations to meaningful life experiences or problems (Duit 1994, Gunstone 1994, Fler and Jane 1999). Woolnough (1994) observed that the development of positive attitudes is an important part of children's science education. Positive attitudes developed during school years have an important influence on subsequent career choices.

Teaching and learning activities that encourage children to interact with novel curriculum materials have been widely discussed in educational literature over the past decades. For example, field trips to museums, science centres or other organisations that provide hands-on "real life" learning experiences have achieved considerable success in fostering inquiry. An open, inquiring mind is a prerequisite for helping children to construct deep understanding. Falk, Martin and Balling (1978) studied the influence of field trips on children's learning and demonstrated that "novelty, and the very powerful needs for exploration it generates, is an extremely important educational variable" (p. 133). Similarly, Rix and McSorley (1999) reported an improvement in elementary school children's attitudes towards science after they had interacted with a number of exhibits of the kind typically found in interactive Science Centres. They argue that for this one reason alone interactive science exhibits need to be considered as a useful resource in the development of children's science education.

The above literature provides the theoretical foundation underpinning the development of curriculum materials and teaching methodologies that are described in this paper. Specifically the paper discusses research findings relating to the development and refinement of novel science and technology-related teaching materials that have been designed to help elementary and secondary age children to understand the causes and consequences of, and possible solutions to, global climate change.

## **Background**

Griffith University is the only education institution in Queensland to offer degree-level courses to tradespersons wishing to obtain teaching qualifications as technical teachers or teachers of high school technology. In the early 1980s, in order to tailor a course to the practical needs and interests of these mature adults, we redesigned our traditional science education course around basic technology teaching/learning principles of "design, make, appraise". The science content was applied to a study of the emerging real world concerns about the global greenhouse effect. For many years successive groups of our science/technology students used their specialised trade skills and knowledge to design, construct, evaluate and modify a number of unique working models that demonstrate fundamental principles of renewable energy. Collectively the models represent thousands of person hours of intellectual capital. Each model is unique. Each would be very expensive to replicate.

Every semester each new group of students exhibited their models at a daylong display in the Brisbane city square. The students also provided conservation advice to the general public. In addition to these twice-yearly public displays, our students also ran energy open days for local schools. Many schools transported groups of children to the campus in order to take part in these displays. Our students used these occasions to interview children and further refine their exhibits. The popularity of the displays and the number of requests by schools for access to the models and associated curriculum materials led to our students designing plans for a caravan that could store and transport the materials. In 1993 the Federal Government provided funds for the construction of such a caravan, which was named Greenhouse Lab.

Schools, conservation groups and other appropriate organisations may borrow Greenhouse Lab for periods of up to a week. For the past nine years Greenhouse Lab has made an important contribution to students' and members of the wider public's understanding of the global greenhouse problem and the pros and cons of possible solutions. The exhibits are presented in a detailed but non-technical way so that the problem, as well as ways by which individuals and groups can help to lessen the problem, can be readily understood. Evaluation sheets from schools show that more than an estimated 60,000 schoolchildren have actively used the resource to date in over 180 visits to schools.

Greenhouse Lab and associated curriculum materials are the practical outcomes of a traditional science course that was completely redesigned around basic principles of technology education as the fundamental way of operating.

## **Investigating the effectiveness of global climate change curriculum materials**

### **A1: Greenhouse Lab (quantitative)**

#### **Method**

The Griffith University Greenhouse Lab is a caravan that has been designed and equipped principally to help elementary and secondary school students to understand the causes and consequences of the enhanced Greenhouse Effect. Teachers may borrow Greenhouse Lab for up to five days after they have completed a daylong seminar on the safe and effective use of the facility. The exhibits encourage student learning through hands-on interaction with a

number of working models and commercially available renewable energy devices. Interactive exhibits include a solar hot water heater, wind energy devices, solar barbecue, solar still, solar cells, solar reflector, Stirling engine, solar sausage cooker, solar oven, a model roof hot water heater, and a solar powered, water saving shower display. A number of futuristic, sustainable, alternative energy solutions have been included to challenge students to think creatively and critically about future alternative energy sources. Eight illustrated information panels covering different aspects of the Greenhouse Effect (eg. how a greenhouse works, the global greenhouse effect, the influence of human activity, possible short and long-term consequences, possible solutions) are complemented by video programs operated by a solar powered television and video player unit. Cross-curricular teaching/learning materials, which outline a range of interdisciplinary classroom activities that the teacher may use with or without Greenhouse Lab, have been designed specifically for elementary or secondary school use.

A quasi-experimental study was designed to investigate whether hands-on interaction with Greenhouse Lab equipment and curriculum materials would result in a change in Grades six and seven level children's conceptual understanding of the Greenhouse Effect. The research program had a number of quantitative components, which involved comparison of questionnaire scores by a control group and two intervention groups in a pre-test post-test sequence. In addition audio taped responses from student interviews were undertaken with a view to providing deeper insights into students' qualitative understanding of greenhouse concepts.

The main data-gathering instrument was a written questionnaire, which was developed following recorded interviews with focus groups, about global climate change principles. The interviews were held with three small groups of Grade six/seven students (15 boys, 14 girls) from schools that had had no prior contact with Greenhouse Lab. Students' responses were used to select and modify statements that were adapted from a 36-item instrument originally developed by Boyes and Stanisstreet (1993) for students in England. The preliminary questionnaire was pilot tested by Grade six students and a panel of four researchers in science and environmental education. The final version (the research instrument) comprised twelve of Boyes and Stanisstreet's original statements, ten of which were modified to better reflect Australian children's language and terminology.

A sample of 215 Grade 6 and Grade 7 children (120 boys, 95 girls) was randomly selected from the available Grade 6 and Grade 7 classes in three schools in metropolitan Brisbane. One of the 9 classes was randomly designated a control group, the other 8 classes were randomly allocated to two experimental groups. The two experimental groups experienced different levels of intervention. The "lab only" groups (4 classes) received two interactive class periods with Greenhouse Lab. During one of these sessions the researcher worked with half the group and discussed the Greenhouse Effect ideas that were illustrated on the information panels. Students were encouraged to complete worksheets and ask questions during the session. At the same time the class teacher worked with the other half of the class using worksheets to help provide specific learning experiences with the interactive exhibits. In the second session the groups changed over and received similar teaching. The researcher and teacher each attempted to carry out identical tasks with both halves of the class.

The second intervention groups designated the "lab plus teaching" groups (4 classes), were provided with identical Greenhouse Lab activities to those received by the "lab only" group.

However these activities were complemented by three one-hour classroom teaching sessions. The complementary teaching/learning activities were developed from the associated classroom teaching ideas that accompany Greenhouse Lab and focused on ideas like the responsible use of energy in home and community, and addressing misconceptions that had been identified during initial taped interviews.

A pre-test questionnaire was administered to the eight experimental groups during the week before Greenhouse Lab was scheduled to visit their schools (Time 1). An identical version of the questionnaire was administered as a post-test to the same groups, one week after the use of Greenhouse Lab (Time 2). Twenty-two days later the same test was again administered to the same groups, under similar conditions (Time 3). A ninth group (the control group) received only the pre- and post-tests, one week apart. They neither had contact with Greenhouse Lab, nor were they formally taught about the global greenhouse effect or related environmental issues. Difference scores on the questionnaire were used to determine whether conceptual change had occurred and, if so, whether the change persisted. Children were not told that they would be asked to repeat the questionnaire.

One way ANOVA was employed as the statistical procedure for analysis of questionnaire scores across the three different levels of intervention (control, lab only and lab plus teaching groups).

### Results and discussion

Figure 1 illustrates the interaction pattern for group by time through a plot of mean scores for the three groups at pre- and post-test 1. A post hoc comparison (Scheffe) of the three groups at the pre-test found no significant difference between the mean scores. However, an identical post hoc comparison at the post-test found a significant difference between the groups ( $F(2, 201) = 18.21, p < .001$ ). Scores for each group were then compared at the two times using t-tests. No significant difference was found for the control group. The lab only comparison indicated a significant difference following teaching with the Greenhouse Lab ( $t(85) = 13.01, p < .001$ ). The lab plus teaching group also showed a significant difference ( $t(92) = 8.28, p < .001$ ). These data support the hypothesis that teaching that involves interaction with the Greenhouse Lab results in a change in students' conceptual understanding of the enhanced greenhouse effect.

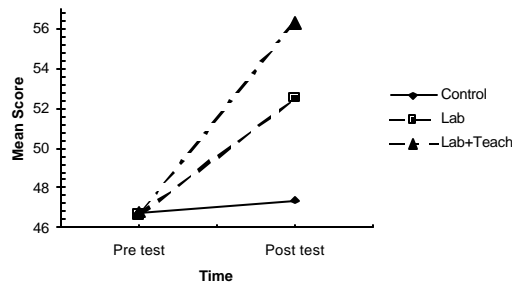


Figure 1: Mean scores for control and two experimental groups (N = 215) before and after intervention

An additional analysis examined the relationship between the two intervention groups. One way ANOVA for both group scores at pre-test, post-test 1 and post-test 2 (22 days after post-test 1) were run. Figure 2 illustrates the interaction pattern for group by time through a plot of mean scores for the two groups at pre-test, post-test 1 and post-test 2.

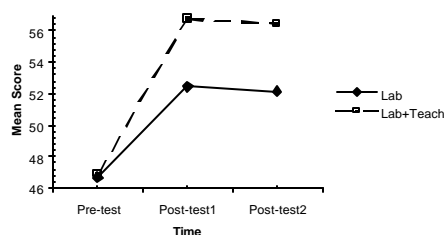


Figure 2: Mean scores for both intervention groups at the pre-test, post-test 1 (7 days after pre-test) and post-test 2 (22 days after post-test 1)

The interaction pattern between the two intervention groups at three different times is shown through a mean scores plot in Figure 2. The difference ( $F(2,320) = 12.34, p < .001$ ) was significant. A post hoc comparison (Scheffe) of both groups at post-test 2 indicated a significant difference between the groups ( $F(1,160) = 12.53, p < .001$ ). T-tests for both groups at pre-test 1 and pre-test 2 were not significant. These results show that the students' level of understanding of the Greenhouse Effect was sustained and that neither level changed significantly during the 22-day period between the two post-tests.

## A2: Greenhouse Lab (qualitative)

The initial pilot study identified four main student misconceptions. These were: the hole in the ozone layer is the cause of the Greenhouse Effect; the Greenhouse Effect can cause more people to get skin cancer; the amount of the Sun's energy reaching the Earth's surface is increasing; and, using unleaded fuel does not add to the Greenhouse Effect. Immediately after the first post test (Time 2) interviews were held with eight different focus groups drawn from the intervention groups. Children's answers to seven questions were tape-recorded. The seven questions were:

1. Do you now consider the Greenhouse Effect a major environmental problem?
2. How has your understanding of the Greenhouse Effect changed?
3. What have you learned about greenhouse gases?
4. How is human activity contributing to the increase of greenhouse gases?
5. What will be the results of an increasing Greenhouse Effect?
6. What can we do and how will it affect your choices in the future about using energy?
7. Have you become clear in your understanding of the difference between the Greenhouse Effect and the hole in the ozone layer?

In all, eight focus group interviews were held with a total of 42 students drawn from all the experimental groups. Their answers were transcribed and reviewed by a method of agreement proposed by Neuman (1994, p. 413).

Question 1. *Do you now consider the Greenhouse Effect a major environmental problem?*  
This question related to the section of the main research questionnaire that asked students what they thought was the most important environmental problem in the world.

A component of the quantitative aspect of the study had asked students to rank their opinions about the importance and significance of ten environmental problems. Before intervention the Greenhouse Effect ranked about midway on a list of student ranking of global environmental problems, with most groups placing the ozone layer, water pollution, forest destruction, and air pollution ahead of the Greenhouse Effect. Following intervention, both experimental groups ranked the Greenhouse Effect as their first choice. In contrast, the control group ranking slipped from third to fifth in importance.

The following examples are indicative of responses that typically showed that after teaching with Greenhouse Lab the students had developed an understanding of the global significance of the problem.

"I think it is a pretty bad problem because if the weather patterns change then a lot of people will be flooded out, and the little islands will be washed out, and the desert will spread if it keeps going."

"It is a very bad environmental problem. It's melting the polar ice caps and it'll probably go from 6° to 12° [Celsius] rise up there, and 5° down here, and when [the sea] rises it's going to take most of the beach away, and when we move we'll be clustering altogether, and it'll be very very hot, and hardly any land for animals . . . and we've got all these wonderful ways of making electricity without making the world any hotter than it already is. We're not using them."

Question 2. *How has your understanding of the Greenhouse Effect changed?*

This question was related to the main research question regarding whether change in students' conceptual understanding of the Greenhouse Effect can occur as a result of the teaching of an environmental unit involving the Greenhouse Lab.

"I didn't really know there was a Greenhouse Effect but I did know about the hole in the ozone layer, and I didn't know it was really important. So I've learnt a lot and I'm cutting down on electricity at home."

"When we started I didn't know [any]thing. I didn't even know what the Greenhouse Effect was until the Greenhouse Lab came along and I read those little panels and they actually told me a bit more."

Questions 3 and 4 related directly to the *causes* category of statements in the questionnaire.

Question 3: *What have you learnt about greenhouse gases?*

The purpose of this question was to discover what the students had learned about the atmospheric gases that cause the enhanced Greenhouse Effect problem.

"I knew CFCs made holes in the ozone layer but I didn't exactly know what CFCs were. I looked it up in the dictionary and found out what it was. I think that I didn't really

know that all the fossil fuels would run out . . . and I know the cars' exhaust pipes and the stuff that comes out the back is bad for the ozone layer and it is bad for the Greenhouse Effect as well."

"Well, I've learnt that they're harmful and there's a lot more than just CFCs and we're going to keep on feeding them into the atmosphere, if we don't stop and start using . . . solar energy, wind energy and sea energy and wave energy and physical energy, and I think the worst one is CFCs because like we use the fridge everyday. It keeps running."

Question 4: *How is human activity contributing to the increase of greenhouse gases?*

Looking at the causes of the enhanced Greenhouse Effect from a different aspect, this question was intended to determine whether students had made the connection between human activities and the atmospheric increase of greenhouse gases.

"Well, human activity [has] been affecting all this since the industrial revolution making all these factories and now people aren't working by hand. They're using machines and that creates more greenhouse gases, and that contributes a lot to the Greenhouse Effect. We're wasting our electricity."

"Everybody in the world, we're using too much electricity, and here we burn coal to make electricity, and eventually we're going to run out if we keep using electricity."

Question 5: *What will be the results of an increasing Greenhouse Effect?*

This question related to the *consequences* category of questionnaire statements which was aimed at discovering whether the students understood the consequences of an enhanced Greenhouse Effect. Understanding the consequences of the enhanced Greenhouse Effect is believed to be fundamental to building a deep understanding of the overall significance of the problem.

"Well, if the Greenhouse Effect [increases] it will affect the temperature. [It] will go up and the ice around the Antarctica will melt and that means the sea level would rise and heaps of places will be flooded, and that means the water cycle . . . would make more storms and even more drought around some places."

"The sea level will rise because the polar ice caps are melting. We're going to have to move to higher ground if it does rise, and then there'll be less room for us to live and produce food . . . and storms will get worse. There'll be flooding where it rains a lot, and the deserts will get hotter and expand."

The above exemplars are indications of the students' ability to put into words, some of the long-term implications of global warming, particularly the potential consequences of the melting of Antarctic ice.

Question 6: *What can we do and how will it affect your choices in the future about using energy?*

This question related to the *actions to reduce* category of questionnaire statements. The objective was to probe what the students viewed as responsible action choices to stop enhancing the Greenhouse Effect.

"We can use less electricity, we can use our cars less and how it'll affect us in the future, well, if we use less of the things that produce the gases in the Greenhouse Effect, the greenhouse could get smaller but if we don't it will get bigger and everything will get worse".

"[Using] solar power, wind power and water power, stop cutting down trees and plant more trees, [and] cut down on pollution."

A change in attitude toward energy use is present in these exemplars. They suggest that education *for* the environment had occurred. This hopefully will continue to affect students' future choices of energy use.

Question 7. *Have you become clear in your understanding of the difference between the Greenhouse Effect and the hole in the ozone layer?*

Confusion about the depletion of the ozone layer as a cause of the Greenhouse Effect is a common misconception among students (Boyes et al., 1993). This supplementary question was intended to probe whether the students had developed an understanding of both environmental problems and were able to differentiate between the two largely unrelated problems.

"It's clear, I know the Greenhouse Effect has nothing really to do with the ozone layer. The ozone layer is from CFCs, anything from [spray] cans and refrigerators and air conditioners. I think the Greenhouse Effect is when the heat gets trapped inside the Earth but the ozone layer doesn't have much to do with it".

"The only connection that it has between the ozone layer and the Greenhouse Effect is the chlorofluorocarbons. We can reduce it because now that the chlorofluorocarbons aren't in so many products and a lot of people tried to reduce the problem".

These qualitative findings support the quantitative analysis finding that change had occurred in students' understanding of the Greenhouse Effect.

### **Summary**

The above findings suggest that:

- teaching of an environmental education unit involving the Greenhouse Lab led to change in the conceptual understanding of the Global Greenhouse Effect in Grade six and seven students;
- the change in conceptual understanding was more pronounced if students receive additional teaching as well as interaction with the Greenhouse Lab; and,
- the change was sustained, at least in the short term.

## **B: Interactive web-based greenhouse curriculum materials**

Greenhouse Lab remains a highly sought after resource but it can travel only to relatively nearby destinations. In order to help to satisfy growing numbers of requests from teachers and members of the public from many parts of Australia for greenhouse curriculum materials and renewable energy information, two additional resources have been developed. These have allowed us to considerably broaden our assistance to a much wider community than can be served by Greenhouse Lab alone.

The first of these resources comprises print materials in the form of three booklets, each written for a different audience and each based on the research and development activities that originally led to the idea of the Greenhouse Lab. The first booklet entitled “The global greenhouse effect: Ideas and activities for teaching in elementary schools” (52 pages) was co-authored with a elementary school science adviser. The booklet is highly rated by teachers for its practicality and suitability for the elementary school and has been sold to many elementary and secondary schools throughout Australia. The second booklet entitled “The do-it-yourself solar energy project book” is written for the home handyperson. This booklet contains detailed instructions on how to construct a mini solar hot water heater, a solar swimming pool heater, a solar barbecue and a solar still (42 pages). The third booklet “Energy in society ...and 101 ways of saving it” (16 pages) has been written for children of reading age of about 11 years. Many schools have purchased multiple copies of this booklet as class readers. All booklets were developed with the aid of small Federal Government or Griffith University Community grants. Therefore they can be sold on a cost-recovery basis. They are available for a nominal cost of about \$5 each through the Griffith University EcoCentre and the Mt Gravatt and Logan Campus bookstores.

The second resource comprises Web-based interactive materials that promote understanding of the science and social issues relating to global climate change. The interactives are not specific to any country or climate and therefore they have the potential to assist educators and elementary and secondary school children from many countries. Stage one of this project was completed early this year and four of the interactive modules are currently accessible by elementary school teacher trainees. Preliminary evaluations from the teacher trainees rate these interactives highly. Table 1 shows responses by one group of 48 elementary school teacher trainees to three "global" questions about one specific module entitled The Greenhouse Effect.

*Table 1: Teacher trainees' evaluations of one of the web-based interactives (n = 48)*

<b>Module 1: The Greenhouse Effect</b>	SA	A	N	D	SD
It is more effective than traditional lesson format	10.4	45.8	31.3	12.5	
It would be better used as an addition to normal lessons	37.5	60.4	2.1		
It is more interesting than the traditional lesson format	22.9	54.2	16.7	6.3	

The high proportion of responses in the Strongly Agree/Agree categories suggests that teacher trainees, who for the most part have been brought up with computers playing a major role in their everyday lives, see value in interactive science resources of this kind.

Table 2 shows responses from all elementary teacher trainees (N = 196) indicating that they believe the materials are suitable for elementary age children.

*Table 2: Teacher trainees' rating of the suitability of all modules for use in elementary schools (n = 196)*

All Modules	SA	A	N	D	SD
It would be suitable for elementary age children (N = 196)	59.2	36.7	4.1		

In order to test the materials' applicability to the real world of teaching, a sample of the interactive materials was sent by CD Rom to about 40 elementary and secondary school teachers inviting them to critically comment on the modules. They were also asked to suggest ways by which the interactives might be modified to better suit their needs as teachers and to meet the needs of upper elementary and early secondary school students. A number of very useful comments were received and these are currently underpinning the restructuring of the modules prior to resubmitting to teachers for further evaluation.

In general the positive tenor of the comments reinforces the opinions obtained from our teacher trainees. The interactives will be a useful classroom teaching/learning resource. For example, one Grade 6 teacher from a low socio-economic status suburb of Brisbane commented on the importance of interactive technology for helping children to understand science principles when conventional hands-on equipment in the schools is inadequate for this purpose. In addition, she could see the benefit of providing educationally meaningful opportunities for children to use computers.

"Having just completed this unit I rate this CD Rom highly. It fully & capably fulfills the requirements of outcomes based syllabus. In the classroom activities we used VERY basic resources, so it was good to see this presentation using technology - a must for children in low socio-economic areas such as the one I teach in."

Another teacher of Grade 7 noted the importance of providing children with experiences that help them to understand the problems caused by society's reliance on fossil fuels and for gaining an understanding of ways by which society can begin to replace its dependency on fossil fuels.

"These children are our future, and with our predecessors not having looked after the environment very well, it is important for them to learn about alternative ways of providing energy."

Over the years Australia's immigration policies have given rise to many different ethnic groups speaking languages other than English. The Science Project Officer of a large independent schools organisation in the State of Queensland commented on the suitability of the greenhouse materials for assisting children from non-English speaking backgrounds.

"The interactive graphics are great. Students with a language background other than English and those students with reading difficulties will benefit from these visual representations."

## **Conclusion**

Research findings indicate that the hands-on minds-on equipment and curriculum materials in the Greenhouse Lab are effective in bringing about measurable conceptual change related to the global Greenhouse Effect, among elementary school aged children. However, the effect that this learning has upon personal lifestyle choices and actions is unknown. It would be interesting to follow up a sample of Greenhouse Lab users in a few years time to see whether as adults they retain the understanding of basic global climate change principles and, more importantly, whether they are actually doing, or want to do anything, about the problem.

The unique equipment contained within Greenhouse Lab cannot be cheaply replicated for use in other settings. The cost of materials and the time involved in their construction precludes these resources from becoming widely available for general educational purposes. However, in developed and many developing countries, the very rapid and widespread penetration of the Internet into all levels of education offers hope that the Internet can become the vehicle for the rapid dissemination and uptake of new educational materials, including those that concentrate on the betterment of the global community. Interactive web based materials, such as those discussed in this paper, may be able to assist teachers who are constrained by time and lack of equipment from addressing the science and societal issues of real world problems. Hurd (2002) is one of the forward thinkers in science education who argues for a modernisation of outmoded science curricula found in school textbooks, which are not adequate for life and living in today's world. Among a number of suggested emphases Hurd maintains that science education should be student-centered, be up-to-date on the nature of science technology, be focussed on the utilisation of science technology for the welfare of the public and the benefit of humans, and connect instruction to the new information highway.

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