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Edited by
Mark W Hackling

All correspondence about this publication should be directed to Associate Professor Mark Hackling
School of Education
Edith Cowan University
Bradford Street
Mt Lawley
Western Australia 6050
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Preface

The Western Australian Science Education Association (WASEA) is an informal group of science educators that meets annually for a conference at one of the Perth universities. The conference is organised by a committee of representatives from the universities and has contributed greatly to collegiality amongst the community of science educators in Perth.

The first meeting of WASEA was held at the Churchlands College of Advanced Education in 1975 and has been held each year except in 1979 and 1991 when the WASEA meeting was incorporated into the meeting of the Australian (now Australasian) Science Education Research Association.

These Proceedings comprise edited papers from the 24th meeting held in 1999.

These Proceedings are dedicated to Graham Hodgkin who recently retired from Edith Cowan University after almost 30 years of service to tertiary science teacher education in Western Australia.

This collection of papers has been made available internationally through the Educational Resource Information Centre (ERIC). Enjoy them.

Mark W Hackling
Editor
Secondary Students' Perceptions of the Role of Scientific Models in Understanding Introductory Organic chemistry

Gail Chittleborough
Thapelo L. Mamiala, and
David F Treagust
Curtin University of Technology
Keith Dale
Chisholm College

Introduction

The use of models and modelling in science teaching is a common practice; indeed, it is practically impossible for science phenomena to be explained and conducted without the use of models. Despite this common use of models in science teaching, studies have shown that students' misunderstand the reasons for using models and modelling. It is likely that students' understanding of models used in science is different from that of teachers or scientists (Harrison & Treagust, 1996). One way in which this discrepancy can be addressed is by assessing students' understanding of models and modelling so that this understanding can be utilised by teachers as they assist students in explaining scientific phenomenon.

The purpose of the study was to establish students' understanding of the use of models and modelling in introductory organic chemistry. Specifically, this paper focuses on how students make use of models to gain an understanding of nomenclature, structure and properties of organic molecules.

Theoretical Framework and Significance of the Study

A model is regarded as "a representation of an object, event or idea and modelling as a process of forming that representation" (Gilbert, 1993, p. 3). Understanding and use of models and modelling play a "central role in modern views of the evolution of science" (p. 3). Scientific models are widely used pedagogic and heuristic learning tools that utilise analogical reasoning and relational thinking (Black, 1962; Hesse, 1963). For instance, constructivism, which has become increasingly influential in science teaching and learning, is based on the recognition of the ideas that students use to represent scientific phenomena. The models used in school science are arguably constructivist and it is likely that student visualisation of models fosters conceptual development and conceptual changes by inducing Gestalt shifts in learners' mental models (Norman, 1983). The diversity of

scientific concepts helps account for the vast array of models in scientific explanations encountered in science education (Gilbert, Boulter & Rutherford, 1998).

Many secondary students view models only as copies of the scientific phenomena (Grosslight, Unger, Jay & Smith, 1991) and their understanding of the role of models is both naïve and simplistic. Grosslight et al.’s (1991) research distinguishes the ability of modellers in terms of recognising whether or not the model is an entity or a mental tool. Further, Gobert and Discenna (1997) have shown that the correlation between each student’s epistemology and use of models in making inferences about scientific phenomena is statistically significant. Research also has highlighted the significance of students’ epistemology in their knowledge integration and their ability to make full use of a model because students’ epistemology, or view of knowledge, influences their knowledge integration (Songer & Linn, 1991).

**Design and Procedures**

The study was conducted over a three-week period with one teacher and 36 Year 11 Chemistry students in a Perth private high school. The teacher, an author of this paper, and his department colleagues had previously attended an inservice that had introduced an approach for integrating the use of models and analogies in science teaching. Subsequently, he agreed to teach the introductory organic chemistry unit using a model-based approach. The topics included structures and properties of alkanes, alkenes, alkynes, cycloalkanes, nomenclature, isomerism, and substitution, addition and combustion reactions. The four types of chemical representations used were structural formulae, ball and stick models, a computer model -- *The Chemistry Set*, and space-filling models. Primarily the students used the ball and stick models while working in pairs, but they also saw some space-filling models and had access to the computer model, *The Chemistry Set*, in the library. The students recorded their chemical compounds as structural formulae in their notes.

Data were collected by questionnaires and by unstructured, audio-taped and video-recorded interviews with students. Quantitative and qualitative data were incorporated in the study as a form of "methodological triangulation" (Cohen & Manion, 1994, p. 236) in order to improve the validity and quality of data (Anderson, 1997; Burns, 1997; Mathison, 1988).

The first part of the questionnaire required students to decide if an item was a
model or not and to use given statements to best describe it, as for example, a toy car:

<table>
<thead>
<tr>
<th>ITEM</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>A static</td>
<td></td>
<td></td>
</tr>
<tr>
<td>model</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Works the</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diagram</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Description</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simulation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A toy car</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The second part of the questionnaire required students to comment on the purpose of each of the four types of chemical representations, such as the ball and stick model that they had encountered.

The Purpose of the ball and stick model is to:
- show what the molecule looks like.
- show how the molecule behaves.
- show the shape and structure of the molecule.
- show the existence of chemical bonds.
- help understand the idea of chemical bonds.
- help generate a picture in your mind.
- touch and manipulate something which is like the real thing.
- show accurate detail of the molecule.
- make and test predictions.
- solve intellectual problems.
- test ideas.

Data sources

The first two authors took on the role of participant observers (Merriam, 1998) in order to document the interaction between the students and how they made use of models in understanding the naming and identification of structures and properties of organic compounds. All the activities were audio-taped and the last one was video-recorded. Through questionnaires, the researchers were able to establish the students' knowledge on models and modelling in science and through interviews the researchers were able to establish the emerging students' perceptions of models and modelling in introductory organic chemistry.

Data analysis and interpretation

Data were analysed and interpreted on a continuous basis from the start of the classroom observation and immediately on return from the field. The researchers identified the themes that emerged from the data collected during observations as well as interviews. Audio and video tapes were reviewed after the observation to check whether the
information collected in the observation schedule was correct as well as check those activities that the researchers might have missed. The researchers made a continuous analysis of the responses by the interviewees. Field notes that were taken during the interview were examined and assessed. The Statistical Package for Social Scientists (SPSS) was used to analyse the questionnaire data (Coakes & Steed, 1996).

Result and Discussion

The findings are reported as four assertions.

Assertion 1: Students’ understanding of the generic idea of a model and modelling is limited

The results of the questionnaire data (see Table 1) indicated that students see models as very simple items. The majority of students considered the toy car (78%), model of the ear (89%), photograph of a cell (53%), diagram of atom (67%) and the computer dissection (58%) all to represent models. The high response to the questions on the toy car and the model ear reflects the commonplace definition of a model - it looks the same but is a different size - and is supported by the reasons that students gave for their choices; however, this narrow definition is not always true or appropriate for scientific models. The chemical equation (50%) and the graph (47%) were not considered to be models by the majority of the chemistry students whose understanding of those models is different from that of teachers and scientists.

The broader definition of a scientific model which includes a variety of representations, that may or may not accurately portray all aspects of the phenomenon, is commonplace in science, yet many students have little understanding of their value or role in the scientific world (Harrison & Treagust, 1996). Perhaps the phrase “scientific representation” may be a more accurate term for scientific model. The value and importance of models in explaining scientific phenomena has been analysed in detail by Gilbert, Boulter, and Rutherford (1998), who identified “one of the striking aspects of science, as a mature field of inquiry, is the high status of the mathematical (or symbolic) mode of representation, as compared with that of the visual, verbal or material modes” (p. 188). It is significant that this view is supported by the results (see table 1) indicating that students do not have a conceptual understanding of the symbolic models. The desire to improve students’ understanding of the scientific model is a significant part of improving
Table 1. Students’ Perception of Models for Describing a Range of Items (n=36)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>YES</th>
<th>NO</th>
<th>A static model</th>
<th>Works the same as the real thing</th>
<th>Looks the same but different size</th>
<th>Diagram or map or plan</th>
<th>Description in numbers</th>
<th>Description with words</th>
<th>Description using pictures</th>
<th>Simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A toy car</td>
<td>78</td>
<td>18</td>
<td>27</td>
<td>8</td>
<td>51</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>A model of the ear</td>
<td>89</td>
<td>11</td>
<td>37</td>
<td>8</td>
<td>40</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>A living animal</td>
<td>17</td>
<td>83</td>
<td>6</td>
<td>41</td>
<td>19</td>
<td>0</td>
<td>6</td>
<td>9</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>An experiment of a metal in acid</td>
<td>19</td>
<td>81</td>
<td>7</td>
<td>24</td>
<td>0</td>
<td>11</td>
<td>9</td>
<td>11</td>
<td>27</td>
<td>27</td>
</tr>
<tr>
<td>A photograph of a cell</td>
<td>53</td>
<td>47</td>
<td>18</td>
<td>5</td>
<td>16</td>
<td>22</td>
<td>2</td>
<td>11</td>
<td>22</td>
<td>5</td>
</tr>
<tr>
<td>A chemical equation</td>
<td>50</td>
<td>50</td>
<td>6</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>46</td>
<td>30</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>A diagram of the inside of an atom</td>
<td>67</td>
<td>33</td>
<td>13</td>
<td>3</td>
<td>3</td>
<td>27</td>
<td>7</td>
<td>4</td>
<td>33</td>
<td>1</td>
</tr>
<tr>
<td>A computer image of a rat dissection</td>
<td>58</td>
<td>42</td>
<td>10</td>
<td>6</td>
<td>5</td>
<td>19</td>
<td>5</td>
<td>5</td>
<td>28</td>
<td>23</td>
</tr>
<tr>
<td>A graph showing the energy changes</td>
<td>47</td>
<td>53</td>
<td>7</td>
<td>2</td>
<td>7</td>
<td>31</td>
<td>21</td>
<td>9</td>
<td>22</td>
<td>0</td>
</tr>
</tbody>
</table>

their understanding of the scientific process and enhancing the development of their epistemology of science.

Our results are remarkably similar to the study reported by Grosslight et al. (1991), upholding their conclusions that students have very naive conceptions of models. Only 14% of students in Grosslight’s study referred to abstract models (e.g. mathematical or theoretical models) and about half of the students did not have consistent notions of what models are. Our results concur with this in that students would respond that the item was not a model but go on to choose the characteristics that make it a model. This finding again reinforces the idea that the students’ conception of a model is concrete and traditional because when they are confronted with a more abstract model, they have difficulty categorising it as a model.

**Assertion 2: Despite their limited understanding of the generic idea of models, students were able to distinguish the purposes and the merits of each type of chemical representation**

As previously stated, during the lesson, students worked with structural formula, ball and stick models, a computer program, and the space-filling models to help decide nomenclature, the structure and the properties of simple organic molecules. When provided
with a specific focus, in this case organic molecules, students identified the differences and the similarities of each type of representation (see Tables 2 and 3), indicating they can use multiple representations—a significant skill necessary in chemistry. The transference from the ball and stick model to the structural formula was practised repeatedly in the laboratory. Through the teacher’s encouragement to build models and then draw the structural formula, students were able to make the link from 2D to 3D representations more easily and built up their mental model of the structure and motion of the molecule. Later, when students were confident with their mental models, they used structural formula only.

Table 2. The Reliability of Items in the Second Part of the Questionnaire

<table>
<thead>
<tr>
<th>Scale</th>
<th>No of Items</th>
<th>Alpha</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural Formula</td>
<td>11</td>
<td>.68</td>
<td>39.40</td>
<td>6.28</td>
</tr>
<tr>
<td>Ball and Stick</td>
<td>11</td>
<td>.73</td>
<td>41.90</td>
<td>5.74</td>
</tr>
<tr>
<td>Spatial</td>
<td>11</td>
<td>.85</td>
<td>34.60</td>
<td>8.14</td>
</tr>
<tr>
<td>Computer</td>
<td>11</td>
<td>.84</td>
<td>40.78</td>
<td>6.85</td>
</tr>
</tbody>
</table>

The computer software, The Chemistry Set, allowed students to look at a variety of compounds in a ball and stick image and it was possible to remove the balls and just look at the sticks and then remove the sticks and just observe the balls moving. This feature was beneficial in giving an image of the region of influence of the atoms and to emphasise that the balls and sticks are just tools to help visualise the atom. However, only translational movement was possible, either randomly or manually. The computer software was particularly advantageous in helping students visualise the 3-dimensional structure and motion of the organic compounds, it encouraged students to extend from 2D and 3D perspective to an n-dimension perspective in further developing their own mental models of the structure and motion of the molecule.

The results of the questionnaire (refer to Table 3) indicated that the students had a good understanding of the purpose of each type of model. The reliability of the items within each scale is sound (refer to Table 2). The structural formula results revealed that most students (65%) did consider that they showed what the molecule looks like, its shape and structure (72%) and the existence of chemical bonds (83%); more than two thirds of students claimed that it helped generate a picture in their mind. Most students appreciated that the structural formula was not designed for manipulation. Although the space-filling model was not used routinely in the lessons, the students appreciated its value, especially in generating a picture of the molecule and showing the shape and structure of the
Table 3. Students’ Understanding of the Purpose of Various Chemical Representations

<table>
<thead>
<tr>
<th>The purpose of the model is to:</th>
<th>Structural formula</th>
<th>Ball and Stick</th>
<th>Computer</th>
<th>Space-filling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DIS-</td>
<td>DONT</td>
<td>AGREE</td>
<td>DIS-</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>show what the molecule looks like</td>
<td>31</td>
<td>6</td>
<td>64</td>
<td>8</td>
</tr>
<tr>
<td>show how the molecule behaves</td>
<td>53</td>
<td>6</td>
<td>42</td>
<td>19</td>
</tr>
<tr>
<td>show the shape and structure of the molecule</td>
<td>25</td>
<td>3</td>
<td>72</td>
<td>3</td>
</tr>
<tr>
<td>show the existence of chemical bonds</td>
<td>6</td>
<td>11</td>
<td>83</td>
<td>6</td>
</tr>
<tr>
<td>help understand the idea of chemical bonds</td>
<td>17</td>
<td>17</td>
<td>67</td>
<td>6</td>
</tr>
<tr>
<td>help generate a picture in your mind</td>
<td>17</td>
<td>14</td>
<td>70</td>
<td>6</td>
</tr>
<tr>
<td>touch and manipulate something</td>
<td>66</td>
<td>14</td>
<td>20</td>
<td>11</td>
</tr>
<tr>
<td>show accurate detail of the molecule</td>
<td>53</td>
<td>11</td>
<td>36</td>
<td>22</td>
</tr>
<tr>
<td>make and test predictions</td>
<td>36</td>
<td>28</td>
<td>36</td>
<td>33</td>
</tr>
<tr>
<td>solve intellectual problems</td>
<td>36</td>
<td>36</td>
<td>28</td>
<td>31</td>
</tr>
<tr>
<td>test ideas</td>
<td>19</td>
<td>50</td>
<td>30</td>
<td>28</td>
</tr>
</tbody>
</table>

compound. The responses indicated that students strongly agreed that the spatial model showed what the molecule looks like, but it did not show how the molecule behaves. The students used the ball and stick model most extensively and their responses to this scale were very positive, indicating that they found these models to be powerful tools for representing compounds and most beneficial to their learning. The computer model represented ball and stick images that were manipulated by the students on the screen. The results of the questionnaire indicated that the students did not distinguish between the ball and stick model and the computer model, which is not unexpected because the computer model used the ball and stick format exclusively. The students’ support of the computer model may be blinded by the power of making use of new technology.

The ability of the students to use multiple representations successfully in the lessons with organic chemistry is most beneficial to their ability to learn and reveals a more sophisticated view of science. Grosslight et al. (1991) valued the power of the use of multiple models as is indicated by their comment, “it is especially important to think, of
models that do not just provide physically different spatiotemporal views of the object but
different conceptual vantage points” (p. 821). The use of a variety of representations
throughout the topic of organic chemistry has provided alternative ways of viewing new
concepts which are useful tools in generating mental models of the organic compounds.

**Assertion 3:** Students used the chemical representations as useful tools for naming
simple organic compounds and in identifying their properties

The comments below from students’ interaction reveal the power of using the
models and working in pairs.

S1: CH3 bond on the same side as the double bond as the chlorine
S2: I’ve already done that
S1: We have…atoms 4
S2: I say you put them both on the top, one on the bottom one on the top and both on the same side trans …
chloro propene and then we have cis chloro propene
S1: Look this one is different
S1: there are so many

S1: Next one you are gonna have two chlorines in the middle. That means 2,2 dichloropropane, it is all
dichloropropane.
S2: This is what we have just done, it is still …
S2: It is all propane and it is dichloropropane and it is just the number and the fact that the number is 1,1; 1,2;
2,2.
S2: Perhaps 1,3 … What about 1,3?
S1: Fine. 2,2 is here and 1,2 is just like this.
S2: 2,3?
S1: No it will be 1,2
S2: I see. I did not realise you were getting at it. It will be what?
S1: On what?
S2: 1,2; 1,3
S1: 1,2; 1,3
S2: and then 2,2; …1,2.
S1: What about 1,1; 1,2; 1,3 and that is it?
S2: Yeah!

The transcripts of those students’ dialogues are indicative of the discourse that was
heard among students in confirming and consolidating their nomenclature rules with the
aid of the ball and stick models. Working in pairs proved to be very positive with students
helping and challenging each other. This finding supports recommendations of Harrison &
Treagust (1998) that “learning to model should be overtly social and involve discussion
and negotiation of meaning.” (p. 424). The video of the practical test on the topic shows
students building models to match with molecular formula then using the concrete model
to aid in the drawing of the structural formula. Most revealing were the occasions where
the student finds an anomaly in his /her results and the manipulation of the model by the
students to help answer the question.
Assertion 4: Students do not value or understand the ability of a model to test ideas

The statistical analysis of the data from the questionnaire (see Table 3) revealed that the students isolated the ability of each model to test ideas and solve problems as being similar in all four models. Nevertheless, it is significant to note that the raw data reveals that approximately 30% of students respond “Don’t know” if models have the purpose of testing new ideas, solving problems, or testing and making predictions. The students give no definitive response to these questions, indicating that they do not have a clear concept of models as tools for testing ideas, solving problems or making predictions. This inference is supported by Assertion 1, which concluded that students’ understanding of models is limited. The conventional limited definition of a model does not allow for testing new ideas, problem solving or making predictions. These attributes are those of a scientific model but not features of a commonplace, non-scientific model. Gilbert (1993) has defined a model as “a representation of an object, event or idea” (p. 3), however our study has shown that most students only regard a model as a representation of an object rather than an event or an idea. Grosslight emphasised the need to “provide students with the experiences of using models to solve intellectual problems“ (Grosslight et al. 1991, p. 820). This is an area of the curriculum, that is not meeting the desired outcomes and more work is needed to accomplish this objective.

Conclusion

Students’ understanding of the role, purpose and concept of models in introductory organic chemistry have been shown to be underdeveloped. Similar to Grosslight et al.(1991), these findings suggest that students need to use models more extensively and purposefully. Most students’ only experience static models and do not have a concept of models as being useful in solving problems or testing new ideas. However, the practical uses of models have been shown to help students learn and understand concepts related to organic chemistry indicating that the importance and significance of models should not be underestimated when considering students’ assimilation of new ideas. Based on the results, the students’ perceptions of the role of models can be enhanced by model-based teaching. Students were able to distinguish the purposes and the merits of each type of chemical representation with which they had had experience.
References


Using Professional Standards and Video Cases to Investigate Good Science Teaching

Robin Groves (1), John Wallace (1) and William Louden (2)
(1) Curtin University of Technology
(2) Edith Cowan University

Abstract

This paper reports preliminary findings from a national project on professional science teaching standards. The project looks at how teachers might use professional standards as a basis for improvement and the potential of video cases to enhance professional growth. A group of experienced science teachers in WA secondary schools has so far participated in a one-day workshop and will meet regularly over the next year. Video segments of science teachers have been used as the basis for considering good science teaching and participants are arranging to video their own classrooms. At the heart of this project is the interaction between a set of standards, evidence of performance including video cases and the deliberations of a group of experienced practitioners. Many interesting pedagogical, technical, methodological and ethical issues have emerged concerning the use of video for this purpose and the nature of professional standards.

Background

Over the last ten years or so there has been a worldwide interest in professional standards for teaching. The range of purposes for teaching standards has been described as

... standards serve two purposes: to rally, and to measure. More specifically teaching standards:
- provide a necessary complement to curriculum and assessment reform efforts;
- are the foundation of the main quality assurance mechanisms in a profession: accreditation, registration and advanced certification;
- are essential for the development of career structures based on professional development; and
- are a more valid basis for accountability than standardised tests of student outcomes.

(Ingvarson, 1995, p.12)

Many sets of generic professional teaching standards have been developed in various jurisdictions with the intention of describing what beginning teachers and experienced teachers need to know and be able to do. Australian examples have been produced in at least four states and by one national project (Education Queensland, 1997; Martin, 1997; National Project on the Quality of Teaching and Learning, 1996; New South Wales Department of Education and Training, 1998; Standards Council for the Teaching Profession, 1997). These standards have been produced relatively quickly and at low cost, are closely aligned to the needs of the state education departments and have had little involvement by professional associations and other stakeholder groups (Louden, 1999).
Whilst there are benefits from these developments in that the different authorities offer a similar image of the work of teachers, there are also weaknesses common to all the Australian standards.

...these weaknesses are identified as (1) long lists of duties, (2) opaque language, (3) generic skills, (4) decontextualised performances, (5) expanded duties and (6) weak assessments.

(Louden, 1999, p. 8)

In contrast to generic professional teaching standards, age and subject specific standards have been developed by the National Board for Professional Teaching Standards (NBPTS) in the USA (Ingvarson, 1995; National Board for Professional Teaching Standards, 1999). These include standards for the teaching of science at three age levels — middle childhood (ages 7-12), early adolescence (ages 11-15) and adolescence and young adulthood (ages 14-18+) in a range of learning areas including science. Comprehensive science teaching standards have also been produced by the National Research Council (1996) as one component of the National Science Education Standards (NSES) in the USA.

In Australia one set of professional standards specifically for teachers of science has been produced by the Standards Council for the Teaching Profession in Victoria (Victoria, 1999). This has five dimensions of teaching for each of two levels — new teachers of science and accomplished teachers of science. The five dimensions are (1) Professional responsibilities, (2) Content of teaching and learning, (3) Teaching practice, (4) Assessment and reporting of student learning and (5) Interaction with the school and the broader community. This is a brief framework, with five or six indicators in each dimension at each of the two levels, with more similarities to the generic Australian standards than to the detailed information in the NBPTS or NSES science teaching standards.

Another approach to describing high quality teaching is the use of narratives and case studies. In the Foreword to Louden and Wallace’s (1996) book *Quality in the classroom*, Judith Shulman comments:

During the past decade, teacher educators and scholars all over the world have paid increased attention to case-based teaching as a way to enrich teacher education and professional development. Instead of separating theory and practice, as typically occurs in teacher education, learning with cases bridges the gap between these domains. It involves actively reflecting on and examining problematic situations in the real world of practice, often testing theoretical propositions and generating new ones. Analysing and discussing cases can prepare prospective and veteran teachers to become problem-solvers who pose questions, frame and reframe problems, explore multiple perspectives and examine alternative solutions. In short, case-based teaching can help neophytes learn to think like a
teacher and promote communities of learners among veterans.

(Shulman, 1996, p. iii)

Recently there has been increasing use of video to record and document classroom practice. The large study The TIMSS Videotape Classroom Study: Methods and findings from an exploratory research project on eighth-grade mathematics instruction in Germany, Japan and the United States contains an extensive rationale and set of protocols for the methodology of using video observations of classroom practice (U.S. Department of Education. National Center for Education Statistics, 1999). Other studies have now started to investigate the potential and implications of using video cases for exploring teaching practice in various areas. (Mousley, 1998; Tippins, Nichols & Dana, 1999).

**This Study**

The data reported in this paper were collected during a one-day meeting of a group of fourteen experienced secondary science teachers that was designed to provide professional development for members of the group and also explore several issues related to professional standards and the use of video cases. The research questions for the day were:

*With regard to high quality science teaching:*

- What knowledge, skills and dispositions do teachers think are important?
- What criteria do teachers use to differentiate between levels of performance?
- What kinds of information do teachers call upon in making judgements?
- How do teachers compare the performance of others with their own performance?

Participants in the full-day workshop were selected from personal contacts and people suggested by representatives of the Education Department, Catholic Education Office and Science Teachers' Association. They were all experienced secondary science teachers. The meeting took place in the school holidays and lasted from 8.45 am until 4.00 pm.

Participants watched three video segments. Each showed a teacher, teaching for about five minutes and then discussing aspects of their teaching for approximately another five minutes. All the videos showed experienced teachers who were not present at the meeting. The participants were asked to rank the three teachers based on what they had seen and to write down the criteria they used to make their judgement. They then discussed their judgements and criteria in groups of three and tried to reach consensus. Following
these discussions, groups reported and a whiteboard summary was compiled.

From this list, six statements of knowledge, skills and dispositions were derived. These were referred to as Standards 1 - 6 for the remainder of the day. Participants accepted that we did not wish to spend the day refining these standards or considering whether they were a complete set. Rather the day was about using standards and collecting evidence to make judgements about good teaching.

The participants then looked at three more videotape segments of the same three teachers in different situations with the same classes. Again the videos showed about five minutes teaching and five minutes discussion with the teachers about their teaching and the class. Before watching the videos it was agreed to focus on three of the standards and to rank the teachers on each of them. The criteria used, evidence noted and rankings were discussed in groups and the findings reported back to the whole group.

Table 1. Participants’ Initial Ratings Having Watched a Video Segment of Each of Three Teachers X, Y and Z

<table>
<thead>
<tr>
<th>Participant</th>
<th>Rank Highest</th>
<th>Rank Middle</th>
<th>Rank Least High</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Z</td>
<td>Y</td>
<td>X</td>
</tr>
<tr>
<td>B</td>
<td>Z</td>
<td>X</td>
<td>Y</td>
</tr>
<tr>
<td>C</td>
<td>Y</td>
<td>Z</td>
<td>X</td>
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<tr>
<td>D</td>
<td>Z</td>
<td>X</td>
<td>Y</td>
</tr>
<tr>
<td>E</td>
<td>Y</td>
<td>X</td>
<td>Z</td>
</tr>
<tr>
<td>F</td>
<td>Y</td>
<td>X</td>
<td>Z</td>
</tr>
<tr>
<td>G</td>
<td>Y</td>
<td>Z</td>
<td>X</td>
</tr>
<tr>
<td>H</td>
<td>Y</td>
<td>X</td>
<td>Z</td>
</tr>
<tr>
<td>I</td>
<td>Z</td>
<td>Y</td>
<td>X</td>
</tr>
<tr>
<td>K</td>
<td>Z</td>
<td>Y</td>
<td>X</td>
</tr>
<tr>
<td>L</td>
<td>Z</td>
<td>Y</td>
<td>X</td>
</tr>
<tr>
<td>M</td>
<td>Y</td>
<td>Z</td>
<td>X</td>
</tr>
<tr>
<td>N</td>
<td>Y</td>
<td>Z</td>
<td>X</td>
</tr>
</tbody>
</table>

| Overall     | Y            | Z           | X               |

Participants then wrote a description of a recent situation from their teaching to illustrate their own performance in relation to one of the standards. These cases were discussed in groups.

Finally, in groups of three, participants discussed the main issues arising from the day’s activities and discussions. When the groups made their reports this session was tape-
recorded. A list of the issues was also made on the whiteboard.

Results

The participants watched the first three video segments of different science teachers in lower secondary classes and were asked to rank them. The results of this are shown in Table 1.

Individual participants made a note of the criteria they had used to reach this judgement and then discussed these criteria in groups of three. These criteria were reported back and noted on a whiteboard. The responses are shown in Figure 1. Interestingly, although there was a lot of variation in the rankings, there was considerable agreement about the criteria used to make the judgements. One of the participants commented "It is amazing, we are all saying the same things." There was considerable interest in the extent to which the teachers on the videos involved the students in learning tasks and moved the management of the learning to the students. Criteria such as 'student centredness', 'students solving problems for themselves' and 'student engagement' were the most frequently mentioned. Participants also looked for evidence that the teachers on the videos tapped into students' own knowledge and experiences and at how conceptual development occurred. They also referred to behaviour management, clarity of instruction, classroom organisation, questioning techniques, planning, empathy, personality and communication.

| • Student centredness  |
| • Students solving problems for themselves  |
| • Student management of own learning / involvement of students in task  |
|  - nature of task  |
|  - skill of teacher in ensuring involvement  |
| • Tapping students' own knowledge  |
| • Behaviour management  |
| • Clarity of instruction  |
| • Relationships with students  |
| • Questioning techniques - open / closed  |
| • Classroom organisation  |
| • Student engagement  |
| • Overt opportunities for students to think about activities  |
| • Content / conceptual development  |
| • Skill of teacher in ensuring involvement  |
| • Engaging / ownership of learning  |
| • Teacher planning  |
Figure 1. Summary of Group Reports of Criteria Used to Rank Teaching Seen on Video Segments

From this list, a briefer set of standards was developed. This is shown in Figure 2.

1. Knowledge of content / resources
2. Knowledge of students
3. Skill in planning / organising for learning
4. Skill in engaging / creating ownership for learning
5. Skill in monitoring student learning
6. Disposition towards teaching - empathy

Figure 2. Six Standards Derived from Teacher Input

Participants agreed to use these ‘standards’ as the basis for discussion for the remainder of the day. Of the six standards derived from the feedback, two related to knowledge, three to skills and one to dispositions.

When the participants had watched another three video segments of the same teachers with the same classes they ranked the teaching again. Before watching the video segments they agreed to rank the teaching on standard 1 (Knowledge of content / resources), standard 4 (Skill in engaging / creating ownership for learning) and standard 6 (Disposition towards teaching - empathy). They also made a note of the evidence they had used to reach these decisions. The teachers discussed their rankings, criteria and evidence in groups of four and recorded the group consensus.

The rankings made by the participants on standards 1, 4 and 6 after viewing the second video segments are shown in Table 2. The rankings on standard 4 (Skill in engaging / creating ownership for learning) and standard 6 (Disposition towards teaching – empathy) were very consistent, which suggests that specifying standards assisted the participants in making judgements about high quality science teaching. Participants felt there was little evidence regarding standard 1 (Knowledge of content / resources) in the short video segments viewed.
Table 2. Participants’ Ratings on Agreed Standards 1, 4 and 6

<table>
<thead>
<tr>
<th></th>
<th>Standard 1</th>
<th>Standard 4</th>
<th>Standard 6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
<td>Mid</td>
<td>Low</td>
</tr>
<tr>
<td>A</td>
<td>Z</td>
<td>X</td>
<td>Y</td>
</tr>
<tr>
<td>B</td>
<td>Z</td>
<td>X/Y</td>
<td>X/Y</td>
</tr>
<tr>
<td>C</td>
<td>X/Y</td>
<td>X/Y</td>
<td>Z</td>
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<tr>
<td>D</td>
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<td>=</td>
<td>=</td>
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<tr>
<td>E</td>
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<td>H</td>
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<td>I</td>
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<tr>
<td>J</td>
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<td>Y</td>
<td>X</td>
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<tr>
<td>L</td>
<td>Z</td>
<td>Y</td>
<td>X</td>
</tr>
<tr>
<td>N</td>
<td>Z</td>
<td>X</td>
<td>Y</td>
</tr>
</tbody>
</table>

Overall | Z    | Y   | X   | Z    | Y   | X   | Z    | Y   | X   |

Table 3. Summary of Participants’ Rankings

<table>
<thead>
<tr>
<th></th>
<th>Teacher X</th>
<th>Teacher Y</th>
<th>Teacher Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>First rating Overall</td>
<td>3rd (18)</td>
<td>1st (31)</td>
<td>2nd (29)</td>
</tr>
<tr>
<td>Second rating Standard 1</td>
<td>3rd (21)</td>
<td>2nd (24)</td>
<td>1st (33)</td>
</tr>
<tr>
<td>Standard 4</td>
<td>3rd (18.5)</td>
<td>2nd (21.5)</td>
<td>1st (38)</td>
</tr>
<tr>
<td>Standard 6</td>
<td>3rd (19.5)</td>
<td>2nd (22)</td>
<td>1st (36.5)</td>
</tr>
</tbody>
</table>

Table 3 shows a summary of the participants’ rankings of the three teachers after viewing the first and second video segments. For the purpose of summarising the rankings, the teachers were given 3 points if placed highest by a participant, 2 points if placed in the middle and 1 point if placed least high. A total was calculated for each teacher after the first video segment, and a total on each of the three standards for each teacher after viewing the second video segments. Table 4 shows that after the first video segment Teacher Y was ranked first (31) with Teacher Z narrowly second (29) and...
Teacher X third (18). After viewing the second video segments, participants ranked Teacher Z the highest on all three standards, Teacher Y second on all three standards and Teacher X third.

The participants also used the video to reflect on their own performance as teachers. They each wrote a short case about their own teaching related to standard 4 (Skill in engaging / creating ownership for learning). These were written quickly and discussed in groups. It is hoped they will be refined further and provide examples of teaching and learning which clarify the standards and make them even more useful. Two of the cases are shown in Figure 3.

In the final session of the day participants worked in groups to identify issues that were important to them as a result of the day's activities. When the participants reported back a list of issues arising was made on the whiteboard (Figure 4).

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**Teacher X third (18).** After viewing the second video segments, participants ranked Teacher Z the highest on all three standards, Teacher Y second on all three standards and Teacher X third.

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**Year 9 class, working on a ‘sight & light’ topic, combining physics and physiology.**

The lessons involved using the principles of optics to design, build and test a simple optical device. This was in effect the culmination of a series of lessons about reflection and mirrors, refraction and lenses. I asked the students to select a simple optical system from a list of four (periscope, pinhole camera, telescope, trick photography), research the basic principles of its construction, plan its construction and supply materials (other than mirrors, lenses, camera) and build a prototype. Students were free to choose any other optical system but they were content to use the four I'd suggested. Evaluation of their work involved a test of the optics - did it work? - and a short discussion of the problems they had faced and how they had overcome them.

My role was purely advisory and where feasible I avoided direct answers to 'how do we do this?' questions. I prefer to have students try things out for themselves if time and facilities permit. In all cases the student groups built successful models, altho' the group building a telescope had some unforeseen problems - their design was completely different to any telescope I've seen, but it did work. Towards the end it occurred to me that they could use a digital camera to record their success - for example, taking a photo though a periscope. The end result was idiosyncratic - every design was in some way different - and very much the students' work. It reflected their understanding of the optics work they had done and involved considerable problem-solving. At a very basic level it freed me from being the centre of attention - for about three periods I was just the guy walking around that could hint at different ways to overcome obstacles and get the job done.

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**Year 8 students designing their own experiments on ‘separating’**

I wanted to increase participation of students with my Year 8 class and give them ownership over their experiments. I didn’t want to use the structured Open Investigations sheet because I wanted them to think about what an experiment meant to them. I gave them a simple scenario - I've accidentally spilled sugar in the sand and want to recover the sugar. What do I do?

Some students worked in groups to prepare a way of doing that. I also told them that I would select three groups' experiments and the whole class would try them out.

The groups wrote and drew diagrams to explain the experiment that their group thought up. I
selected three named experiments -
• Using a magnet to separate the two.
• Mixing all the sand and sugar in water and filtering it.
• Mixing with water, filtering and evaporating it.

The class had to follow instructions and find the best way. We had a discussion on the results and also how easy it was to follow the instructions. This led to discussion on setting up experiments. The kids whose work was chosen felt good about it and so during the year I highlighted named pieces of work and shared with the whole class.

I felt that this activity led to kids thinking for themselves, having a go at an unfamiliar task, having engagement and ownership, and importantly being recognised for their efforts. I pointed out that even the experiments that didn’t work gave us information that was useful.

Figure 3. Cases Written by Two of the Participants

Discussion

This study is concerned with the interactions between professional standards, evidence of good teaching, including video evidence, and experienced practitioners. Issues have been raised by the participants in the project that relate to each of these three. The following comments represent tentative suggestions, which will be investigated further as the project continues

- Standards are complex and subjective and value laden
- Discourse of the ‘state’ may constrain thinking
- How will the standards be implemented?
- Will they be tied to performance management?
- Standards - generic vs context specific
- Need for standards to evolve
- Standards should be learning driven
- Video questions could be more focused on Framework or standards
- Need to understand the wider context of lesson / class
- Willingness of teacher to be explored (ethical)
- Professional motivation
- Good consensus today - similar value basis - why?
- Is video the best form of evidence basis? Yes, but....
- Incentives?
- Standards - consistency for pre-service, beginning and experienced

Figure 4. Summary of Issues Raised by Participants at the End of the Workshop
Standards

(a) Standards should be few and simply worded. The participants found it helpful to focus on three simply worded standards when viewing teachers on video segments and to observe evidence related to each. Six standards were developed in total, which covered all the major criteria regarding good science teaching mentioned by the participants after viewing initial video segments.

(b) Standards should be focused on science teaching / learning. The participants were very focused on teaching and learning. Although the lists of criteria and standards in Figures 1 and 2 do not mention science or science teaching, all the examples and discussions were rich in science-specific contexts. It will be important to draw out this science-specific context as the project continues.

(c) Standards should be fad free. It is important that good science teaching should not be seen as only allowing one approach or methodology. The participants commented on the need for teachers to be able to teach in a way that is suited to their personalities and that good teaching can take place in many contexts including whole class, small group, theory, practical and outdoor classes.

Evidence

(a) The use of video seems promising. The participants enjoyed viewing the video segments and they served as an excellent stimulus for discussion about science teaching. The video segments served as a stimulus for a discussion that ranged much more widely than the specific instances occurring on the video.

(b) There are many issues around the use of video, including technical, pedagogical, methodological and ethical ones. These will be explored further as the project continues. This project used segments of video that each consisted of about five minutes of teaching and five minutes of discussion with the teacher about their teaching. This length appeared to provide enough stimulus and information for discussion about high quality science teaching. It does seem that a segment of teaching will provide information about several standards, and it may not be productive to attempt to make a video segment specifically related to a particular standard.

The experience so far with filming is that students in the classes were not affected greatly by the presence of the camera, although one of the teachers did say that he thought the class were extra good on that day. Decisions about what to video and
how to do it are very important: it is not possible to record everything that is occurring in a classroom. Technically it is also difficult to obtain good quality sound when the teacher is moving around the class interacting with small groups of students.

Care needs to be taken with ethical considerations such as the identity of the teacher and the school in the video and the rights of students who appear in the video. In this project the methodology has only been used with teachers who are volunteers and so far all teachers approached have been willing to have the video camera in their classrooms. Permission has also been obtained from all students who appear in any video.

(c) It proved important that commentary was supplied to accompany the video segments. The participants found the commentary by the teachers very useful and requested a brief introduction to set the context before viewing the video. Participants were assisted in their judgements by the teachers’ explanations about the goals and contexts of the lessons.

(d) Many times during the course of the day the participants commented on the need for further kinds of evidence. It is anticipated that the video will form part of a portfolio of evidence, the exact nature of which will depend on the purpose of the process engaged in.

Experienced practitioners

(a) There was general consensus among the experienced practitioners about what was important in relation to good science teaching. Both the list of criteria used to make the initial judgements and the set of six standards derived from them were arrived at quickly and easily. There was a shared view of what high quality science teaching in lower secondary school includes. The participants found the process an illuminating one and commented that they learned a lot. It seems that they appreciated the chance to reflect on good practice and be explicit about what it entails.

(b) The discussion added value to judgements. There is no doubt that the expert practitioners formed an essential part of the process of defining and exemplifying teaching standards. The participants’ knowledge about good science teaching grew during the study as a result of the interactions with their colleagues about standards and video evidence.

(c) At the start of the day of the study the participants shared common criteria for good
science teaching but different judgments were made about the quality of the teaching observed on the video segments. During the course of the day there was considerable consolidation of participants’ ratings of the teachers on the video segments. The standards became clearer, the evidence on the video became more apparent and the discussion with their colleagues added new insights. As this occurred the participants demonstrated more confidence in making judgements and their judgements became more consistent. The interaction between the experienced practitioners was essential to clarify the standards and the video evidence.

The project has made a good start in exploring the research questions listed earlier. Using video of science teaching as a stimulus, the participants discussed what knowledge, skills and dispositions they thought were important for high quality science teaching. They derived criteria and standards for good science teaching and used them to make judgements about levels of performance. They also considered their own performance in relation to the standards and the teaching on the video segments. The project will continue to explore the use of standards and video segments with the aim of helping teachers to make decisions about improving their own teaching.

References


Learning Environments in Senior Secondary Science Classrooms in a WA School

David Henderson  
*Rossmoyne Senior High School*  
Darrell Fisher  
*Curtin University of Technology*

**Abstract**

This paper describes the validation and use of a learning environment questionnaire specifically designed for use in senior secondary science classrooms, the Science Classroom Environment Study (SCES). The initial validation of the SCES was with a large sample of students in Tasmania. The SCES was then used with a sample of 383 senior secondary students in 21 science classes at a school in Western Australia. The use of actual and preferred versions of the SCES enabled comparisons between students’ perceptions of their actual environment with the environment ideally liked or preferred. Because previous studies have shown that achieving a closer match between students’ actual and preferred environments is likely to lead to more favourable student outcomes, this kind of study can be used by classroom teachers to provide meaningful information about science learning environments and so guide teachers’ attempts to optimise student outcomes. Analysis of students’ responses indicated that students preferred a more positive learning environment than that which they perceived to be present. Responses to two attitudinal questionnaires indicated that students had a generally positive attitude to their science classes, but few students felt positively about a career as a science teacher.

**Learning Environment Research**

Literature reviews (Fraser, 1986, 1994, 1997; Fraser & Walberg, 1991) show that science education researchers have led the world in the field of classroom environment over the last two decades, and that this field has contributed much to understanding and improving science education. For example, classroom environment assessments provide a means of monitoring, evaluating and improving science teaching and curriculum. A key to improving student achievement and attitudes is to create learning environments which emphasise those characteristics which have been found to be linked empirically with student outcomes. As well, the use of appropriate classroom environment scales has the potential to contribute to our understanding of why science classes typically provide greater success and enjoyment for males than females.
The instruments that have been used in studies of learning environments often are related to the theoretical framework for human environments proposed by Moos (1974) who identified three sets of broad dimensions: the nature and intensity of *personal relationships* (such as how involved the people are, how much they help each other and how spontaneously they express their feelings in a setting); the extent to which *personal development* in areas such as independence and achievement is encouraged or stifled; and *system maintenance and system change* aspects such as how orderly and organised the setting is, how clear expectations for behaviour and outcomes are, how much control is maintained and how responsive the system is to change. Studies which built on Lewin’s (1936) influential field theory and Walberg’s (1981) theory of educational productivity found that students' perceptions of the classroom psychosocial environment are associated with, and actually could predict, their affective, behavioural and cognitive learning (Fraser, 1986, 1994; Fraser & Fisher, 1982; Haertel, Walberg & Haertel, 1981).

A distinctive feature of many classroom environment questionnaires is that they have not only a form to measure perceptions of *actual* classroom environment but also a form to measure perceptions of *preferred* classroom environment. The preferred, or ideal, form is concerned with goals and value orientations and measures perceptions of the classroom environment ideally liked or preferred. Importantly, for this study, learning environment research which has adopted a person-environment fit perspective (Hunt, 1975) revealed that a similarity between the actual environment and that preferred by students leads to improved student achievement and attitudes (e.g., Fisher & Fraser, 1983; Fraser & Fisher, 1983a; 1983b). The practical implication of these findings for this study is that student achievement could be enhanced by attempting to change the actual classroom environment in ways that make it more congruent with that preferred by the students. It was thus decided to investigate differences between students' perceptions of their actual and preferred classroom environments.

Earlier classroom environment studies were based on the assumption that there is a unique learning environment in the classroom that all students in a class experience. Variations in scores on learning environment instruments were considered as error variance, with the class mean representing a good measure of the learning environment in the classroom. However, this assumption was challenged in
qualitative interpretive studies in the latter half of the 1980s (Fraser & Tobin, 1991). For example, groups of students (termed ‘target’ students), who were involved more extensively in classroom discussions than the other students, had more favourable perceptions of the learning environment than those students less involved, suggesting that there could be discrete and differently-perceived learning environments within the one classroom (Tobin, 1987). Therefore, there is a problem with using the traditional ‘class form’ of learning environment instruments when studying differences between groups of students in a classroom (e.g., males and females) because these instruments elicit the student’s perceptions of the class as a whole rather than the student’s personal perceptions of his or her role in that classroom (Fraser & Tobin, 1991). These studies and influences led Fraser, Giddings and McRobbie (1995) to propose a different form of a learning environment instrument which asked students for their personal perceptions of their role in the classroom environment rather than their perception of the learning environment of the class as a whole; this form of the questionnaire was called the ‘personal form’. Because differences in the perceptions of individual students within a classroom were relevant in this study, a personal form of learning environment scales was used.

The learning environment questionnaire that was used in this research, named the Science Classroom Environment Survey (SCES), contains nine scales thought to be important in senior science classroom environments. The scales are named, Cooperation, Teacher Support, Involvement, Leadership, Relevance, Task Orientation, Open Endedness, Integration and Independence. A description and a sample item for each scale in the SCES are presented in Table 1. It employs a five-point Likert response scale (Almost Never, Seldom, Sometimes, Often, Almost Always).

**Assessment of Student Outcomes**

Until about 20 years ago, research involving science students’ outcomes focussed primarily on educational objectives in the cognitive domain, but in more recent times, attention has been paid to outcomes in the affective domain, and the study of student attitudes has formed a primary component of this research (Weinburgh, 1995). The promotion of positive attitudes towards science is seen as a major aim of science education. Mager (1968) outlined three reasons for promoting
positive attitudes in students. First, research has indicated associations between positive attitudes and enhanced academic achievement. Second, a positive attitude is more likely to sustain interest in the field of study in the future. Third, peers are influenced by the attitudes of others. Shulman and Tamir (1972) suggested that affective outcomes in education are at least as important as cognitive outcomes; acknowledgement of the importance of affective outcomes is reflected in their increasing emphasis in curricula (Gardner & Gauld, 1990; Hough & Piper, 1982; Mathews, 1974).

Students' attitudes to their class were assessed with a seven-item *Attitude to This Class* scale based on selected items from the *Test of Science-Related Attitudes* [TOSRA] (Fraser, 1981). This scale has been used in several previous studies involving students in science classes and has been shown to have satisfactory internal consistency (e.g., Fisher, Fraser, & Rickards, 1997; Fisher, Henderson, & Fraser, 1995). The reported Cronbach alpha reliability coefficients for this attitude scale were 0.85 and 0.78, respectively, when using the individual student as the unit of analysis. Students' career interest in science was measured using a five-item scale which also was based on the TOSRA.

Table 1. Description of Scales and a Sample Item for Each Scale of the SCES

<table>
<thead>
<tr>
<th>Scale Name</th>
<th>Description of Scale</th>
<th>Sample Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooperation</td>
<td>Extent to which students cooperate rather than compete with one another on learning tasks.</td>
<td>I cooperate with other students when doing assignment work.</td>
</tr>
<tr>
<td>Teacher Support</td>
<td>Extent to which the teacher helps, befriends, trusts and is interested in students.</td>
<td>This teacher talks with me.</td>
</tr>
<tr>
<td>Involvement</td>
<td>Extent to which students have attentive interest, participate in discussions, do additional work and enjoy the class.</td>
<td>I discuss ideas in class.</td>
</tr>
<tr>
<td>Leadership</td>
<td>Extent to which the teacher leads, organises, gives orders, determines procedures and structures the classroom situation.</td>
<td>The teacher talks enthusiastically about his/her subject.</td>
</tr>
<tr>
<td>Relevance</td>
<td>Extent to which the learning is relevant to students' lives.</td>
<td>In this science class, I learn about the world outside of school.</td>
</tr>
<tr>
<td>Task Orientation</td>
<td>Extent to which it is important to complete activities planned and to stay on the subject matter.</td>
<td>I know what has to be done in this class.</td>
</tr>
<tr>
<td>Open Endedness</td>
<td>Extent to which the laboratory activities emphasise an open-ended, divergent approach to experimentation.</td>
<td>There is opportunity for me to pursue my own science interests in this class.</td>
</tr>
<tr>
<td>Integration</td>
<td>Extent to which laboratory activities are integrated with non-laboratory and theory classes.</td>
<td>My regular science class work is integrated with practical activities.</td>
</tr>
<tr>
<td>Independence</td>
<td>Extent to which students are allowed to make decisions and have control over their own learning and behaviour.</td>
<td>I have a say in deciding what activities I do.</td>
</tr>
</tbody>
</table>

Items are scored by allocating 5, 4, 3, 2, 1, respectively, for the responses Almost Always, Often, Sometimes, Seldom, Almost Never.
Methodology

The objectives of this study were to:

1. Investigate differences between students' perceptions of their actual and preferred science classroom learning environments using the SCES.
2. Investigate students' attitudes to their science class; and
3. Investigate students' interest in a career in science.

Following a description of the purpose of this research study during a teachers' professional development day, science teachers were invited to participate in the study. Ten teachers administered the actual and preferred versions of the SCES and the two attitudinal scales to 383 students in 21 senior science classes.

Validation of the SCES

Table 2 reports validation information for the SCES based on its use in secondary colleges in Tasmania. The alpha reliability coefficient was used as the index of scale internal consistency and ranged from 0.72 to 0.86 for the actual version and from 0.75 to 0.89 for the preferred version, suggesting that all scales of both versions of the SCES possess satisfactory internal consistency. The mean correlation of one scale with the other scales ranged from 0.28 to 0.42 for the actual version and from 0.32 to 0.46 for the preferred version of the SCES. These values can be regarded as small enough to suggest that each scale of the SCES has adequate discriminant validity, even though the scales assess slightly overlapping aspects of classroom environment.

The $\eta^2$ statistic was calculated to provide an indication of the degree to which each scale could differentiate between the perceptions of students in different classes. The $\eta^2$ statistic, which is the ratio of 'between' to 'total' sums of squares and represents the proportion of variance in scale scores accounted for by class membership, ranged from 0.14 to 0.32 for the SCES. This indicates that each scale of the SCES is capable of differentiating significantly between classes ($p<0.01$).
Table 2. Internal Consistency (Cronbach Alpha Coefficient), Discriminant Validity (Mean Correlation with Other Scales) and Ability to Differentiate between Classrooms for the SCES

<table>
<thead>
<tr>
<th>Scale</th>
<th>Alpha Reliability</th>
<th>Mean Correlation with Other Scales</th>
<th>ANOVA Results (eta²)</th>
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<tr>
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<td>0.86</td>
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*p < 0.01  n= 1080

Principal components factor analysis followed by varimax rotation resulted in the acceptance of both versions of the SCES comprising 66 items in nine scales. The a priori factor structure of the questionnaire was replicated with nearly all items loading on their a priori scale and no other scale (Table 3).

**Differences in Students’ Perceptions of Actual and Preferred Environment**

Table 4 presents the observed differences between students’ perceptions of their actual and preferred classroom learning environments. There is a consistent difference existing between actual and preferred mean scores for all the nine scales. Preferred means were higher than actual means for all scales. In particular, this suggests that students would prefer to have their classes more task oriented, more personal relevance and to be given more opportunities for independent learning than was perceived to be present in the science classrooms. Overall, the learning environment dimensions measured by the scales of the SCES could all be addressed in order to align the classroom environment more closely with that preferred by students which could result in an improvement in student attitudes and achievement.
Table 3. Factor Analyses of Actual and Preferred Versions of the SCES

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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 4. Scale Means for the Actual and Preferred Forms of the SCES

<table>
<thead>
<tr>
<th>Scale</th>
<th>Form</th>
<th>Scale Mean</th>
<th>Mean Difference (P-A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooperation</td>
<td>Actual</td>
<td>3.80</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>Preferred</td>
<td>4.13</td>
<td></td>
</tr>
<tr>
<td>Teacher Support</td>
<td>Actual</td>
<td>3.23</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td>Preferred</td>
<td>3.61</td>
<td></td>
</tr>
<tr>
<td>Involvement</td>
<td>Actual</td>
<td>3.04</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>Preferred</td>
<td>3.31</td>
<td></td>
</tr>
<tr>
<td>Leadership</td>
<td>Actual</td>
<td>3.88</td>
<td>0.32</td>
</tr>
<tr>
<td></td>
<td>Preferred</td>
<td>4.20</td>
<td></td>
</tr>
<tr>
<td>Relevance</td>
<td>Actual</td>
<td>3.15</td>
<td>0.52</td>
</tr>
<tr>
<td></td>
<td>Preferred</td>
<td>3.67</td>
<td></td>
</tr>
<tr>
<td>Task Orientation</td>
<td>Actual</td>
<td>3.88</td>
<td>0.59</td>
</tr>
<tr>
<td></td>
<td>Preferred</td>
<td>4.47</td>
<td></td>
</tr>
<tr>
<td>Open Endedness</td>
<td>Actual</td>
<td>2.27</td>
<td>0.52</td>
</tr>
<tr>
<td></td>
<td>Preferred</td>
<td>2.79</td>
<td></td>
</tr>
<tr>
<td>Integration</td>
<td>Actual</td>
<td>3.79</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td>Preferred</td>
<td>4.16</td>
<td></td>
</tr>
<tr>
<td>Independence</td>
<td>Actual</td>
<td>2.22</td>
<td>0.94</td>
</tr>
<tr>
<td></td>
<td>Preferred</td>
<td>3.16</td>
<td></td>
</tr>
</tbody>
</table>

**Students’ Attitudinal Outcomes**

Table 5 reports the mean scores for each item of the Attitude to This Science Class scale. The figures indicate that students generally have a positive attitude to their science classes; this is particularly evident when the influence of practical activities is considered.

Table 6 reports the mean scores for each item of the Career Interest in Science scale. Of particular note is students’ general lack of interest in pursuing a career as a science teacher.
Table 5. Mean Scores for Responses to Items in Attitude to This Science Class Scale

<table>
<thead>
<tr>
<th>Item</th>
<th>Mean Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>I look forward to the class</td>
<td>3.46</td>
</tr>
<tr>
<td>I feel confused during this class</td>
<td>2.54</td>
</tr>
<tr>
<td>This class is a waste of time</td>
<td>1.82</td>
</tr>
<tr>
<td>This class is among the most interesting at this school</td>
<td>3.35</td>
</tr>
<tr>
<td>The thought of this class makes me tense</td>
<td>2.11</td>
</tr>
<tr>
<td>I enjoy this class</td>
<td>3.74</td>
</tr>
<tr>
<td>I have a sense of satisfaction after this class</td>
<td>3.19</td>
</tr>
<tr>
<td>Practical activities make me interested in this class</td>
<td>3.57</td>
</tr>
</tbody>
</table>

Table 6. Mean Scores for Responses to Items in Career Interest in Science Scale

<table>
<thead>
<tr>
<th>Item</th>
<th>Mean Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>When I finish my education, I would like to undertake research in science</td>
<td>3.08</td>
</tr>
<tr>
<td>Working in a science laboratory would be an interesting way to earn a living</td>
<td>2.84</td>
</tr>
<tr>
<td>I would like to teach science when I finish my education</td>
<td>1.74</td>
</tr>
<tr>
<td>A job as a scientist would be interesting</td>
<td>3.26</td>
</tr>
<tr>
<td>I would like to be a scientist when I finish my education</td>
<td>2.61</td>
</tr>
</tbody>
</table>

Qualitative Observations

The reaction of science teachers to the study was most positive, and the majority of the teachers were keen to be involved. Participating teachers were very interested to compare their students' actual and preferred perceptions of their learning environment and in comparing figures for their classes with those for the total sample. Additionally, teachers taking more than one class for the same subject
often had commented on the differences in the classroom climate of these classes and were interested to see whether the differences that they observed were reflected in differences in students’ perceptions of their learning environment, and intend to make these comparisons as soon as all the data were made available.

Many teachers felt that receiving quantitative feedback from their students was a most important part of the study and the reason they agreed to participate. Teachers wanted to know what they were ‘doing right’ in the view of their students as well as what they could improve upon. Clearly, the opinions of their students about the classroom learning environment was important to the teachers.

On being presented with the data for each of their classes, some teachers were keen to find ways of achieving closer congruence between students’ actual and preferred perceptions, using the scale descriptions as a guide, and expressed the possibility of introducing appropriate changes and then, after a suitable period of time, asking their students to respond to the actual version of the SCES, as recommended by Fraser and Fisher (1983a, 1983b). Comparing responses of students to the questionnaire before and after the changes would provide important feedback about the effectiveness of such changes.

**Significance of Study**

The SCES has been shown to be an economical, easily administered questionnaire that takes students only 10-15 minutes to complete and can provide meaningful information about senior secondary science learning environments. This information can then be used by teachers as a tangible basis to guide improvements. The data clearly indicate that students prefer a more positive learning environment than that which they perceive to be present. Because previous research has indicated that achieving a closer match between students’ actual and preferred learning environments is likely to lead to more favourable student outcomes (Fraser & Fisher, 1983a, 1983b; Fraser, 1994), such use of the SCES could provide science teachers with information about aspects of the learning environment which, if altered, could lead to increases in students’ attitudinal and achievement gains.

Qualitative observations indicated that participating in the study stimulated teachers to reflect on their teaching and to discuss various aspects of the classroom learning environment with other teachers. The use of such a questionnaire can
therefore act as a means by which teachers can focus on various aspects of their classroom teaching and think about ways of optimising the learning environment, and so further improve the quality of the teaching and learning process.

References


Fraser, B. J., Giddings, G. J., & McRobbie, C. J. (1995). Evolution, validation and


Students’ Knowledge, Awareness, Worldviews, Beliefs and Involvement in the Environment

Irene Teh-Cheong Poh Ai and David F. Treagust
Curtin University of Technology

Abstract

One of the benefits of science and technology is that they can be used to solve environmental problems and improve the environment for all citizens. In this regard, science education in schools can play a part by helping to develop students’ understanding and awareness of environmental concepts. In their programs and classroom teaching, science teachers need to take account of students’ concerns, attitudes, responsibilities and commitments. But what is actually taking place in science classrooms to address these environmental issues? In this study conducted in a developing country, Brunei, questionnaires and focus group interviews were administered to investigate young people's environmental knowledge, worldviews, beliefs and involvement. The findings of this research are reported in this paper.

Theoretical Underpinnings and Significance

It is believed that the long-term solution to environmental problems falls on the appropriate education of the young to prepare them to be able to prevent, and solve these environmental problems. Science education that concentrates mainly on developing of content knowledge will not enable young people to cope with the environmental issues or problems in the real world. Traditional thinking suggests that people can be motivated to act toward the environment in more responsible ways by being more knowledgeable about the environment and its associated issues. However, a meta-analysis of the behavioural research literature in environmental education (Hines, 1987) showed that a person’s responsible environmental behaviour is effected by situational factors (economic constraints, social pressures and opportunities) as well as intention to act. In addition, a person’s intention to act on an environmental issue is merely an artefact of other variables acting in combination. These variables are the person’s cognitive knowledge of environmental issues, knowledge and skills in environmental action strategies and the person’s personality factors. The personality factors or desire to act include the individual’s locus of control, attitudes (toward the environment and toward the taking action) and personal responsibility (toward the environment). Hence this study investigated the environmental attributes such as environmental knowledge, awareness, concerns, worldviews, attitudes, beliefs, involvement, and information in young people.
Cultural Setting and Students’ Environmental Awareness

This study was conducted with Bruneian students in their unique cultural setting of a post British protectorate, with rich natural resources in a small state. The population of Brunei is only about 300,000 people, most are Muslim Malay with the main minorities of Chinese, Indian and Indigenous people. The importance of culture and the knowledge of the indigenous people throughout the world to environmental capability have received recognition in environmental education. For example, the Inuit people were found to have far richer and more subtle understanding of the characteristics of ice and snow than non-indigenous people (Emery & Associates, 1997). Indigenous people perceive the land in a more complex, more detailed way than do the non-indigenous people even though both groups are concerned with maintaining the quality of the environment in which they live, illustrating that there are differing bases for such concerns (Shute & Knight, 1995). Young Kenyan children can draw sophisticated place representations and can recall their local environment in vivid terms, different to those of their age-sex-counterparts from Britain. Culture can therefore influence expressive style if not cognitive ability (Matthews, 1995). Only a few studies have explicitly examined the importance of cultural settings to children’s environmental awareness, especially in a non-Western context.

Methodology

The research questions in this study were as follows:
1. What are the young people’s knowledge and awareness of environmental issues?
2. What are the young people’s worldviews and beliefs concerning the environment?
3. What were the young people’s involvement towards environment improvement and the support received in their involvement?
4. Where were the sources of environmental information and which were believed to be reliable?
5. What are the relationships between the constructs – knowledge, beliefs, and involvement?

Instruments

Questionnaires and focus group interview protocols designed for an international research project involving 12 countries were adapted for this study (Fein, Yencken, & Sykes, 1996). The questionnaire was designed to solicit worldviews and attitudes, beliefs,
awareness and knowledge, commitment and involvement, sources of information and discussion on environmental issues of students and their teachers. Some key issues that were concerned in the approach to the design of the questionnaire surveys are the nature of attitude, the development of models about attitude, the relationship between attitude and behaviour (Ajzen & Fishbein, 1972); (Bentler & Speckart, 1979) and the measurement of environmental attitudes, beliefs systems and environmental concerns (Dunlap & van Liere, 1984), (Hausbeck, Milbrath, & Enright, 1992). The focus group interviews investigated further the students' views and perceptions on the above environmental attributes.

Sample
The questionnaire was administered to 421 students of which 38% were males and 62% were females, and 45.5% were 16 years old. These Year 11 students were from five best performing schools, the criteria being established by the international research project, as these students were believed to become the leaders in the scientific, business and political areas for the next generation. The focus group interviews lasting about half to one hour were conducted with smaller groups of the same students.

Analysis of Data
For the questionnaire, questions and answers were coded by the researcher prior to data entry. The research questions were made up from one or several question items or question part items from the questionnaire in accordance with the scoring made in the international research project. The data from the focus group interviews were analysed by looking for patterns or categories in the students' responses that emerged (Patton, 1987). The categories that emerged are illustrated with quotations from the students where relevant research questions are answered.

Results
The results are discussed in terms of the five research questions previously stated.

What are the young people's knowledge and awareness of environmental issues?
The questionnaire contained 11 key environmental concepts to solicit knowledge and awareness of the young people. Generally, although the young people were confident of their familiarity or awareness of the environmental concepts, their knowledge scores were much lower (see Table 1).
Table 1. Bruneian Students’ Familiarity and Knowledge of Environmental Concepts.

<table>
<thead>
<tr>
<th>Environmental Concepts</th>
<th>Familiarity (percent) Mean 7.5 Max.11 SD 1.94</th>
<th>Knowledge (percent) Mean 4.99 Max.11 SD 2.43</th>
</tr>
</thead>
<tbody>
<tr>
<td>ozone layer</td>
<td>98</td>
<td>38</td>
</tr>
<tr>
<td>greenhouse effect</td>
<td>97</td>
<td>64</td>
</tr>
<tr>
<td>renewable resources</td>
<td>96</td>
<td>71</td>
</tr>
<tr>
<td>carbon cycle</td>
<td>91</td>
<td>60</td>
</tr>
<tr>
<td>ecology</td>
<td>87</td>
<td>46</td>
</tr>
<tr>
<td>interdependence</td>
<td>69</td>
<td>71</td>
</tr>
<tr>
<td>bio-diversity</td>
<td>55</td>
<td>53</td>
</tr>
<tr>
<td>sustainable</td>
<td>50</td>
<td>14</td>
</tr>
<tr>
<td>development</td>
<td></td>
<td></td>
</tr>
<tr>
<td>carrying capacity</td>
<td>45</td>
<td>41</td>
</tr>
<tr>
<td>precautionary</td>
<td>34</td>
<td>25</td>
</tr>
<tr>
<td>principle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>intergenerational</td>
<td>23</td>
<td>50</td>
</tr>
<tr>
<td>equity</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The focus group interviews that sought to obtain students’ understanding of the word “environment” were analysed into six categories, that is, surroundings, living things, non-living things, habitat, interaction between people and living things and self. From the focus group interviews that solicited students’ thinking about the causes of environmental problems in general, students’ responses were categorised into these areas; attributes of human beings - “greedy and selfish many ways”; their country’s development needs - “countries who try to develop faster”; the structure of the government - “should be more strict to enforce laws and fines”; the society, economic and other systems - “construction sites it is easier to get rid of rubbish by burning”; as well as the peoples’ attitudes and behaviour - “ I don’t care attitude”, “why should I be cleaning up his rubbish?; If they know they are going to be fined then they are not going to do it – attitude”.

Some students think that the problems are less serious in Brunei than the rest of the world as “we still have our forest but we should be alert”, “we do not have much industry”. “Brunei is a small country with less people” and “do not use a lot of technological things that cause a lot of problems”, therefore the environmental problems are “insignificant compared to the world”. However, a small group of students felt that the environmental problems are more in Brunei “in terms of (poor) attitude”; that the environment is “better in other countries”, and that although” we have less population now, the population is increasing fast”.
What are the young people's worldviews and beliefs concerning the environment?

The majority of the students (60%) believe in protecting the environment even if there is reduction in economic growth. However, a larger majority of students (84%) believe it is possible to have both a prosperous economy and a healthy environment at the same time. Almost half of the students believe that the change that is needed in Brunei for environmental improvement was for communities to work together (44%). Meanwhile, about a quarter of the students believe the government legislation and regulation (26%), personal lifestyle changes (19%) and radical restructuring (11%) are needed for significant improvements in environmental quality and performance.

About 30% of the students selected “protecting the environment” as the most important goal for Brunei while about 19% selected “improving education standards” and 16% selected “preventing war and nuclear threats” and “strengthening the economy”. The three most important local environmental issues for the students were “Household rubbish and garbage” (40%), “Cutting down of forests” (16.5%), “Water pollution” (15%). As for the global situation as the most important environmental issue for the students were “Destruction of the ozone layer” (37%), “greenhouse effect” (13%) and “Cutting down of forests” (13%).

In the responses given in the focus group interviews, the students’ hopes and fears were investigated. The students’ fears for the future were categorised into two main features, individual concerns and non individual concerns. The former include job uncertainty, “failure in getting job wanted”; and happiness “not leading a happy life”, the later were categorised into five main concerns, resources - “not be enough resources and people are using the resources again and again without making sure there is enough for next time”; earth - “living in a terrible world”; wars -“nuclear radiation”, “atomic bomb”, “nuclear war and death”; environment - “pollution of air and water”, “destruction of and no forest”, “future will be more polluted, lot of pollution”, “radiation”; and survival - “might have to move to another planet”.

The students’ hopes for the future also can be categorised the same way as their fears. They hoped that the earth would be a “beautiful place to live in” and that they would be “no aliens”. They hoped that there will not be “another Hitler”, and they “do not have to see pictures of bombing” in wars. They would “like to see less discrimination (racial), and that people are friendly in “how they treat each other, how they think” and that there would be “peace”. In environment, they hope that “people’s attitude towards environment change
so that life is not always to work towards success economically only”, that there will be a “cleaner environment” with “no pollution” and “no traffic congestion”. The survival hopes are “not having to worry about diseases” and “to be protected from danger (diseases, no AIDS)”. In order to obtain the belief system of the students, they were asked to respond to a 5 point scale for 2 pairs of semantically different statements consisting of two different points of view, that is from the technological and environmental paradigm. The majority, about 66% of the students who responded, hold environmental belief and a further 13% hold strong environmental belief. No students hold strong technological beliefs and about 16% have technological beliefs (see Table 2).

Table 2. Bruneian Students’ Science/Technology and Environmental Belief Systems.

<table>
<thead>
<tr>
<th>Belief (mean score 5.8 (SD 5.83) out of a possible score of 48)</th>
<th>Percentage of students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong technological belief (scores of -24 to -13)</td>
<td>0</td>
</tr>
<tr>
<td>Technological belief (scores of -12 to -1)</td>
<td>16</td>
</tr>
<tr>
<td>Neutral position (score of 0)</td>
<td>5</td>
</tr>
<tr>
<td>Environmental belief (score of +1 to +12)</td>
<td>66</td>
</tr>
<tr>
<td>Strong environmental belief (score of +13 to +24)</td>
<td>13</td>
</tr>
</tbody>
</table>

In response to the question soliciting the students concerns about the environment, the answers of the students could be categorised into the following concerns: global “ozone layer”, “effect of El Nino”; local – “Water pollution at the local water village (Kampong Air)”, “Air pollution”, “haze effects”; war - “nuclear waste”, “nuclear testing in the sea”, “nuclear events”, “biological weapons”; living things / cycles – “many wildlife could become extinct and that the forest cannot regenerate itself through the carbon and nitrogen cycles”; and survival – “famine”, “human race might disappear”.

When asked what it was that made the issues a concern for the students, their responses were grouped into three main categories, people’s behaviour - “nobody is doing anything about it”, “people still destroy the environment even though they know it”; lack of information - “the problem is most people are aware but do not know what to do about it”, “do not know much about it (environment) to know if it will come back in 100 years” and the concern for themselves as well as for the future generation - “worried that the future generation will not have much to live on”, “not going to be able to live like before”, “world will come to and end”, “extinction of mankind”, “everything in the future will be expensive, e.g. water, air; more things will become endangered therefore more expensive”, “resources will be gone” and “nothing left for the future”.


Many expressed their feelings in terms of anger - “angry that something wasn’t done earlier to prevent it from getting so out of hand”, “everyone, no one took enough notice”, “upset and disappointed at how the government is treating the environment problems”; helplessness - “don’t have the authority to get everyone’s attention to solve the problem”, “powerless”, “people are having trouble handling it” and “not comfortable as I do not know what I am are drinking or eating”; guiltiness “we might have contributed to the problem too”, worries - “scared”, “worried”, “worry about the children”, “worry about the future generation”; wanting to act - “our race is actually destroying our own world and we should be the ones to save it for ourselves and others”, “orangutan crying.make me feel I need to do something”; and wanting to run away - “not worth living if the future is going to be that bleak”.

Many of the students do not feel that the older people share their concerns; “the older people think they are always right even though certain times they may be wrong”; “can’t be bothered mentality”, “God wants it to be so that’s the way it should be”. Some students justify the older people behaviour with “lack of knowledge”, “some don’t understand”, “.. people take it for granted that other countries have problems but not this country”, and they are “too old”. Some students are not so forgiving and say that “a lot (of older people) do not care”, and “do not think about the next generation”, “all they think about, is as long as they get the profit”, they are “going to die early” so they feel it is “not their future, it’s our future”. However few students think the older people “do share the worry about the children surviving”, are “worried about their children’s future” and that “some (older people) feel similarly”.

Although they are optimistic that “it will get better” and there would be “less problems” and that “technology will find a way out of problem” such as in “space travel and the use of space and other planets”, some of the students feel that these environmental problems are “very serious and downplayed especially here in Brunei”, and “going to be worse in future”, that people are “not looking at long term effects, only looking at the short term effects”. They feel that “prevention is better than cure hasn’t sunk in yet”. However they are some students who think that the environmental problems are “not that serious in Brunei but in other countries big problem”, and that there is “more chance of Brunei people to survive than other countries”.

What were the young people’s involvement towards environment improvement and the support received in their involvement?

Ninety three percent of Brunei students were committed to being involved in improving the environment. However, most of these students perceived that they do not have the skills to bring about environmental improvement and participation in environmental actions. The overall mean score for environmental involvement (“have done” or “would consider doing”) of students was 11.25 (SD 3.43) out of a possible maximum score of 20. Although the level of involvement in environmental actions was mostly moderate (67%), the actual deliberate actions taken by the students to improve the environment was very low. Their past 12 months involvement on specific environmental actions, seemed to be higher and included taking part in cleaning campaigns and anti-litter schemes (48%), deciding to re-use or recycle something instead of throwing it away (44%), trying to encourage someone else to change an activity or practice that they thought was harmful (37%) and choosing household products that are better for the environment (34%).

When asked about their feelings about environmental actions that they have taken, 26% students in Brunei felt really good and motivated to do more, 24% felt positive about the experience and okay about taking action. About 39% of the students did not respond to this item.

When asked who was giving full support when the students are involved in environmental actions, 38% stated teachers, 29% their immediate family, 28% close friends, 27% others who were involved and 15% other friends. The overall mean score for support that students get for environmental involvement is 3.99 (SD 1.46) out of a possible maximum score of 10.

The reasons given by the students for any of their environmentally unfriendly behaviour were that they did not think their actions would make much difference and that there were no practical alternatives (19%), that they feel there are no practical alternatives (16%), that they do not have time (12%) or they are more concerned with saving money (10%), or that they did not understand what is harmful or not (8%). The students optimism of what's being done to improve the environment is apparent in responses such as, “more of our generation are involved now”, “commitment for “reduction gas emission”, “in Kampong Air, there are improved proper sewage system”, “new laws for no open burning”, “government commercials in TV warn people”, “water (from the oil production
and processing company) is recycled and not deposited into the sea". Nevertheless there is some pessimism evident from comment such as, “cannot see countries coming to an agreement”, “US cut their CFC gases but they themselves export the CFC gases”, “.exporting what they do not need anymore (to poorer countries)”, “no reply when they (students) write letters”, “nothing (is being done), people are talking but not doing anything”. While some students felt that enough was being done to improve the environment, some students feel that we are not. Positive comments were, “for the amount of knowledge we have, we are”, “we can only do so much in the existing systems”, “globally, we are”, “yes (in Brunei as there is) weekly water monitoring in Kampong Air” now. Negative comments come in the form of, “ in Brunei we are doing enough but problems take time when mistakes of 100 years cannot be corrected in the last few years”, “a lot done but not enough”, and “teaching is one thing, actually doing things is another thing”.

Where were the sources of environmental information and which were believed to be reliable?

The students’ major sources of environmental information appeared to be television (61%), newspapers and magazines (49%) and school (46%). Television programmes quoted were the Discovery, Royal Television Brunei, National Geographic, British Broadcasting Corporation and CNN. Magazines quoted were the National Geographic, Times, Economist, Teen, Readers Digest, Asia week and the Regal. Newspapers quoted were the local Borneo Bulletin, the Malaysian New Straits Times and Singaporean Strait Times. Some considered school to provide enough information about the environment “but only in school academic matters”. They say they “learnt about the environment, how the pollution affects the environment but it was not detailed enough”. For example, when the haze occurred, they “did not understand”, whether it was “harmful or not”, “how it affects your health in the long term”, “what PSI means”, “where it came from (burning)”, “how go about to change or improve the environment”, “how to do something about”. “I don’t feel that I can do something about the environment like things I can do individually to help the environment”. One student said that “not enough (is) done in school because many do not take geography as an option, some take geography and biology but not all do those subjects”. When asked 5 out of 10 agreed that they should have more environment studies. However, one emphasised that there were “too much in our subjects for exams but if
environment is on the exams then they will accept more topics in”. Suggestions for improvement in their lessons included “interactive approach”, “projects”, “more field trips . went to the farm once . once in a blue moon event”, “.need to explain in more detail, not use the textbook . what is happening in true life, how government, people can change the course for the environment”, “. tell us what not to do, do not tell why and how .”; “. need to take students out and see how beautiful the environment is (role of everyone)”, “. need to experience to be part of the forest, so that you will feel that if the forest is cut then you feel part of you is being cut off”. They feel that a lot of their environmental lessons “depend on teachers who are keen about the environment” who “put in more enthusiasm” as most of the environmental learning is “not (specified) in the syllabus”. The radio and internet as well as information from environmental bodies such as Greenpeace and Friends of Earth represented some sources of environmental information of the students.

Brunei students felt that television (51%) information was reliable, but “this depended on where the programme comes from”. They believed they watch more television than read. Although school information was trusted (37%) they feel it is boring, not relevant and not enough for them to give own opinion. They also felt the syllabus was insufficient. Newspapers and magazines (35%) and environmental non government organisations (30%) were more reliable sources of information than government environmental bodies or family or friends or businesses, but “some magazines are biased”. Information obtained from the internet and hearing from friends and experts was trusted by a minority. The frequency of discussions of environmental issues outside schools with family or friends was found to be lacking. Students indicated that they would like to discuss environmental issues more in school.

What are the relationships between the constructs – environmental knowledge, beliefs, and involvement?

The environmental beliefs, knowledge, involvement of each student and the support received were correlated. The Bruneian students’ beliefs were found to be statistically significantly related (p< 0.001) to knowledge (r = 0.375) and involvement (r = 0.405) while involvement has a weak significantly relationship to support (r = 0.225) (see Table 3).
Table 3 Pearson's Correlation (r) of Environmental Beliefs, Knowledge, Involvement and Support for Year 11 Brunei students

<table>
<thead>
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Note: *p<0.001; number of students less than 421 where responses were incomplete.

Conclusions and Educational Implications

Brunei being a rich, small and developing country with plentiful resources, limited industrialisation, a conservative society with strict religious practices still has its own environmental problems. The education system could be described as balanced with content orientation, skill enhancement and value developing. However, the results of the study show that its unique economic situation and culture has produced behaviours that are not environmentally responsible. Although the young people are aware of environmental issues, they are not so knowledgeable of the issues. Even though these young people are concerned for the environment and have desires to act for the environment, their perceived skills to be involved and actual involvement in environmental action are low. The beliefs of the students fall on the environmental paradigm rather than the science technology paradigm. Their environmental knowledge as well as skill to act for the environment, if enhanced, might increase the environmental involvement since there is a correlation between knowledge and involvement. Their feelings of anger, helplessness and worries and desires to act or run away, similar to what has been found in western developed countries (Szagun & Pavlov, 1995), need to be considered if they are to be helped to cope with environmental problems when they are adults. Although teachers give support to young people in their environmental involvement, the support level is low and could be further enhanced. The influence of the media for environmental information could be tapped by the teachers to the students' advantage by increasing interest in their courses.
References


Village Elders’ Explanations of Natural Phenomena in Papua New Guinea

Soikava Pauka and David F. Treagust
Curtin University of Technology

Abstract

This study attempted to investigate the traditional knowledge (stories) or beliefs that respected village elders hold about natural phenomena in Papua New Guinea (PNG). Village elders from various tribal groupings in PNG are perceived to be the source of all wisdom and the recognised authority on tribal knowledge. As these villagers live within their own natural environments, they are considered to have a better understanding and explanations of certain ideas. For this study, interviews conducted with eight village elders probed their understanding of natural phenomena that included erosion and deposition; drought; sunrise and sunset; burning; moon; rain; thunder and lightning; clouds and plant growth. The interviews were conducted and recorded in the local language called ‘Toaripi’, then transcribed and translated into ‘English’. Explanations of these natural phenomena were categorised in relation to spirits, magic spells and sorcery; personal experience; religion; and modern science. It was found that some village elders hold on strongly to their traditional beliefs but that there were similarities between the categories of personal experience and modern science.

Introduction

Research (Waldrip & Taylor, 1999) stated that village elders from many tribal groupings are perceived to be the source of wisdom and the recognised authority of tribal knowledge. In many PNG traditional societies, traditional knowledge appears to be finite and is passed down from generation to generation by word of mouth by the older members to the younger generation of the tribe as a survival tactic. Such knowledge includes the skills of hunting, trading expeditions, building canoes, gardening (planting and harvesting), building shelter, healing diseases, forecasting weather, initiation ceremonies, funeral rites, protection against crocodile, fishing expeditions, and various activities associated with cultural heroes. The most respected elder in a community usually conducted the teaching and learning that occurred through practical absorption (observation) and participatory activity embedded in each villager’s daily life. Specialists teach the tasks to a selected few who have gone through the primary and secondary streaming processes by way of pre-initiation (Kelontii, 1996). Pre-initiation is mainly done through observing the child’s interests at an early age. For example, if a child is found to possess aggressive behaviour, he is singled out and given a warrior’s initiation.
Emery and Associates (1997) state that traditional knowledge comes from a wide
diversity of experience in nature, from teaching and apprenticeship, working with the land,
by absorbing the feel of the wild animals and plants, and by listening to legends and
stories. Therefore traditional knowledge is organised and based on integration, not on
analysis into parts. In addition, basic assumptions about classification of plants and animals
or cultural actions and rituals are often very different to those of technology-based
societies. The characteristics of traditional learning are through observation, imitation, and
verbal instruction; by personal trial and error through demonstrations; mostly with real life
activities; and being context specific and person oriented (Harris, 1992). In many villages,
learning of indigenous languages, folklore, personal-social relationships, traditional
vacations and dances and the nature of family structures, still depend heavily on these
procedures and experiences from the past. During puberty, secret or true knowledge
concerning the tribe and life originating from the gods were passed on through sometimes,
painful initiation ceremonies.

Because of its divine origin, McLaughlin (1996) highlights several features in
describing Melanesian concepts of knowledge. Firstly, unlike Western knowledge, which
is meant to be challenged, Melanesian knowledge was finite and not tested. It dictated a set
of moral principles that guided behaviour and maintained the spiritual strength of the
community. The young learners were schooled in the accurate reproduction of received
knowledge and customs. At no point were they encouraged to question or innovate as these
would alienate them from adult society (McLaughlin, 1995). Similarly, Emery and
Associates (1997) assert that in many indigenous cultures, the elders speak the truth and
the hunters' words are unquestioned. Indigenous people understand that there are different
qualities of knowledge from people who have different levels of experience and wisdom,
so they accept the knowledge the way it is presented. They do not attempt to challenge the
wisdom of an elder.

Flannery (1998) claims that the Melanesian worldview incorporates humans and
animals, the seen and the unseen, the living and the dead, in a way that is vastly different
from the European outlook. What Europeans call 'supernatural' factors are for New
Guineans simply the non-visible parts of a single continuum of life. Indeed, they are
eminently 'natural' (p. 200). Furthermore, Waiko and Jiregari (1982) state that PNG
societies view nature as a whole: as a continuity from the past to the present and into the
future; the clan is linked with the surrounding land, water, forests, animals and heavens. The knowledge base contains the accumulated tools and wisdom for dealing with, and living in the environment. The community pursues and disseminates this knowledge base through repetitious learning, reinforced rituals, sanctions of the ancestors or rewards from the spirits. For example, Kiki (1963) in his autobiography 'Kiki Ten Thousand Years in a Lifetime' confirms that his mother's people referred to the dead as 'going to the west' because their dead were not buried in the ground but placed high up in tree branches facing the sunset. The people did not believe in the last judgement and had no concept of heaven or hell. But they believed that the dead were ever present and they can be called upon to help in any dangerous situation. Similarly the 'Toaripi' of the Gulf Province referred to their dead ancestors to a dwelling place of the dead called 'alaua-ipi kivokipi' which connotes a place beyond the western horizon where spirits of the dead were supposed to dwell. Thus the exclamation 'alaua-ipi meaforoe a' is often said where there is a beautiful sunset, 'what lovely weather in the spirit land' (Brown, 1968). Thus, Australia is referred to as the spirit land where the dead were supposed to dwell.

**Purposes of the Study**

This study has its origins from an earlier study on 'Children's understanding of natural phenomena' (Pauka, 1988). It also relates back to my early years of teaching secondary school science (1978 to 1983) and also is my involvement in writing distance learning materials (1983 to 1986 and 1989 to 1994) in which the importance of traditional knowledge that most students bring to science classes had not been researched in detail except Kelontii's (1996) study. This interest allowed me to go back to my village of 'Lelefiru' where I interviewed eight village elders on their understanding of natural phenomena between October and November of 1997.

I had continued to maintain strong ties between my village and my growing-up in Port Moresby in the late 1950s and early 1960s after my parents moved there. My parents were among the first 'Toaripi' people to move into Port Moresby, first as an indentured labourer (my dad) and then as a family group (my mother) after World War 2 (Ryan, 1989). I remember that my mother said that she and my elder sister sailed on a 'lagatoi' (double hulled canoe with crab-claw sails) during one of the last of the famous Hiri Trade expeditions back to Motuan villages around Port Moresby. During the early Hiri expeditions in 1940s, the Motuans traded their clays pots for the sago and betelnuts of the
Elema people in the Gulf Province (Kiki, 1963). It was also through the many stories that my parents told of a big village called 'Lelejiru' near the sea and how the villagers used to paddle up and down a once fast flowing 'Meporo' river to cut and make sago and plant new gardens. The name 'Lelejiru' if separated into 'lele' meaning 'a bird called an egret' and 'jiru' meaning 'an island', therefore fully it means 'island of the egrets'. Most interesting of all was that this long beach near the village has been eroded gradually away by the sea; village elders like my mother, blame the event on the use of magic spells ('seseva'). It is beliefs such as this that interested me into identifying the common ideas and beliefs that village elders hold on natural phenomena.

As these villager elders live within reach of their own natural environments, perhaps maybe they would have an in-depth understanding in explaining certain ideas (Waldrip & Taylor, 1999). As a result, this led to several interviews which probed the elder's understanding of occurring natural phenomena. The task was mainly to discover the traditional beliefs, worldviews and explanations held by these village elders on natural phenomena. The interviews were conducted on the front veranda of my brother-in-law's house. It was a comfortable and relaxing atmosphere with conditions very warm at that time between October and November of 1997 because it was during one of the worst droughts in PNG.

Methodology

The method used in this study build on an ethnography-interpretive fieldwork conducted through qualitative interviews that were semi-structured (Agar, 1996; Denzin, 1970; Glaser & Strauss, 1967) on natural phenomena. Interviews were conducted and related to things in nature with which the interviewees were familiar in their natural surrounding. An interview is a conversation that is allowed to flow freely in order to bring out a person's understanding of a particular topic. The interviews followed a structured format with a set of questions based on natural phenomena that included erosion and deposition, drought, sunrise and sunset, burning, moon, rain, thunder, lightning, rainbow, clouds, and plant growth to identify the village elders' responses. This type of interviewing served as a means to determine what people talk about or perceive various aspects of their lives and how to classify things (Agar, 1996). The eight village elders come from 'Lelejiru' village in the Malalaua area of the Gulf Province. By means of these interviews conducted over a period of ten days, I had planned to learn about the traditional worldview and
I had intended to seek explanations of a range of natural phenomena which, from my experience, form an important focus for traditional stories in many Melanesian cultures. Indeed I wanted to record stories of for example, why the sand on the beach near the village gets eroded all the time and where does it go, what causes the drought, what causes the red sunrise and sunset and what causes the wind to blow. The binding features of an interview is the collection of textual data through audiotape recording.

The reason for choosing ethnography as a framework for this study is that it is based on people in their natural settings in their own culture. According to Spradley (1979), ethnography is ‘the work of describing a culture’ and the goal is ‘to understand another way of life from the native point of view’ (p. 3). It studies the culture from within, the attempt through filed observation to record how individuals perceive, construct, and interact within their social and economic environment. Again Spradley (1980) describes ethnography as ‘the study of both explicit and tacit knowledge’ and defines culture as “the acquired knowledge people use to interpret experience and generate behaviour” (p. 8). In ethnographic research, emphasis is placed on the subjective reality of individuals and the relativistic nature of the social world. Furthermore; Spradley (1979) suggests it as a useful tool for ‘understanding how people see their experience (p. iv) and emphasises that ‘rather then studying people, ethnography means learning from people’ (p. 3). According to Taft (1988), ethnography is ‘naturalistic enquiry’ which emphasises the subject realities of individuals as the focus of the researcher’s attention. This is in common with the philosophy of naturalism which purports that ‘there exist multiple realities which are, in the main, constructions existing in the minds of people’ (Guba & Lincoln, 1988).

Village Elders

Initial contact with all the eight village elders were made through my brother in-law who is a respected retired Reverend of the United Church and also his invaluable knowledge of the structures of the different clans in the village. Morauta (1984) affirms this stronghold of Christianity which relates back to the early arrival of Reverend James Chalmers in 1881, from the London Missionary Society (LMS) who was the first European to visit the two big villages of ‘Uritai’ and ‘Mirihaea’ where a mission station was set up in 1884. Several of these elders may have been either educated by the early missionaries to Grade 6 and held different positions within the government or private sectors and have
retired and come back to live in the village. Several of them have also been actively involved in church activities in the village and in Port Moresby. Pou, the oldest is in his late 70s and is the only surviving member of his clan with knowledge of folklore. Mora in his early 70s is a known fisherman and when I met him, he was mending his fishing nets. Mesea in his late 50s is a businessman and owns a truck which brings garden produce and transports people to and fro from Malalaua and Kerema. Mai in his late 60s is a retired government employee and has come back to live in the village through fishing and making gardens and is involved in church activities. He has been involved with the Native Corporative Society business in the village. Ivan, Tati and Sari in their early 60s have all lived and worked in Port Moresby but have retired and moved back to live in the village. They all live through gardening and fishing and taking part in church activities. Sevese in his late 60s has been involved with the Native Corporative Society business in the village and also lives by gardening and fishing.

All the village elders were interviewed in ‘Toaripi’, the common language spoken in this village with which I am familiar. In order to ensure that the elders perceived the interview process as meaningful, they were told that whatever they said was judged not to be right or wrong and would be kept confidential as it was based on their own understanding. The initial questions focused on the context of their involvement within their village, that is the ocean or the land environment. Each elder was asked about the sand on the beach, what happened to the sand when it was eroded and where it was deposited. From where the interview was conducted on the veranda of the house, the beach was in full view with the sea and the wind blowing through the swaying coconut palm trees. Each elder interviewed fully understood what the interview was about and at some stages thought that some of the questions asked were interesting such as what is a rainbow, what is lightning and thunder, and what causes winds to blow.

**Building a framework**

During the transcribing and translation of the interviews from ‘Toaripi’ into ‘English’, all the main ideas and explanations relating to the ten natural phenomena were sought as a means to discover and identify systematic patterns or relationships among categories (Agar, 1996). In this instance, four main categories were identified by means of phenomenological analysis, under which the ideas, beliefs and explanations were tabulated as spirits, magic spells and sorcery; personal experience; religion; and modern science. It
was found that there were similarities amongst explanations for the personal experience category with that of modern science. For example, inland rivers and creeks are blocked due to the felling of trees for food gardens and as a result the water cannot assist in the deposition of sand downstream and onto the beach. The following section shows two examples of how the ideas and explanations were sourced from the interviews on natural phenomena.

Results - Interpretation of Natural Phenomena

Erosion/Deposition of sand along the beach (Miri folo ma sa faveai/foreovai)

To probe the village elders' understanding of ‘erosion and deposition’, they were asked the following questions in stages from which the following explanations were derived.

Our village 'Lelejiru' used to be an island in the deep sea. But because of the sea continuously crashing on the beach, it has taken the sand on the beach away to another part of the beach. What do you think makes the tide come up and then down the beach. When the tide crashes on the beach, where do you think it takes the sand to. The tide breaking on the beach makes the sea come in closer to the village and the houses. So what makes the tide hit the beach and when it hits the beach, where does it take the sand to. The sea waves, when it crashes on the beach, the sand on the beach does not stay there. Where do you think the sand goes. The sea waves, what makes it hit the beach.

Category 1: Explanations using spirits, magic spells and sorcery
* Three of the village elders said that traditionally and nowadays magic spells ('seseva') was used to move the sand along the beach. The sand moves or walks depending on the waves and rapids of the water and deposits it at the requested place. Interestingly, another elder said that without the use of magic spells, the sand will remain in one place and not get eroded.

Category 2: Explanations relating to Christianity
* Three of the village elders mentioned that it was a punishment from God ('Ualare-Iehova') as most young people are turning away from God.
* Three other village elders interpreted that in former days, there was no erosion because the old people’s beliefs in God were positive and respectful and as a result they were blessed with good things.
* Three other village elders said that nowadays too many young people have turned away from God and do many wicked things. So as a punishment, the sand on the beach continuously erodes away.

Category 3 and 4: Explanations relating to personal experience and modern science
* Three of the village elders said that changes in the wind directions and tides causes the erosion and deposition of the sand on the beach.
* Four other village elders said that inland rivers and creeks are blocked due to the felling of trees for food gardens and as a result, the water cannot assist in the deposition of sand downstream and on to the beach.
Three more village elders said that only tidal waves caused by the wind erodes the soil on the beach.

Five other village elders mentioned that the erosion and deposition of sand on the beach is the result of tidal changes caused by the south-west and south-east trade winds.

Five of the village elders said that strong river currents take the sand down to the sea.

Three of the village elders said that erosion occurs at the mouth of rivers during heavy rainfall.

Four of the village elders said that river currents help build the sand up on the beach.

Red sunrise/sunset (Sare patei eata fauki ta soa kauri ovoseseai)

To probe the village elders' understanding of 'red sunrise' and 'sunset', they were asked the following questions in stages from which the following explanations were derived. *When you wake up in the morning, you see the sun rising and it is very red. Why is this so? When we burn the bush and in the morning when the sun comes up, you see that it is very red. Because there is haze all around created by the smokes from the burning fires. This is the same when the sun sets. What do you see? What is happening around us? What do you think the sun is? When we see the sun rising and then setting in the evening, what do you think the sun is. The sun when it rises in the morning, we follow it until it sets in the evening. What do you think is the sun? What does it mean? Does the sun stay in one place or it has many places? When we see the sun in the sky, does it follow one path or has many paths? We say the sun is very hot, like when we light our fires with hot roaring flames to cook our food. Do you think the sun is very hot?*

**Category 1: Explanations using spirits, magic spells and sorcery**

* A village elder interpreted that a spirit ('Epe Savora') helps and directs the sun in its path from sunrise to sunset. When the sun sets, the place becomes dark. The sun is looked after by the eponymous ancestor ('Epe Savora') of the 'Savoripi' clan; hence the honorific title for menfolk of the clan. It is the traditional term for 'ivuta', the iguana (Brown, 1968).

**Category 2: Explanations relating to Christianity**

* Five of the village elders said that God created the sun which is hot and burns all the time and gives warmth to living things.

* Two other village elders said that the red sunset and sunrise is a sign interpreted as a punishment from God

* An elder mentioned that it is God's plan for the sun to rise and set.

**Category 3 and 4: Explanations relating to personal experience and modern science**

* Six of the village elders said that the sun stays in one place and follows the same path. Interestingly, they mentioned that the earth revolves around the sun.

* One of the elder's observation when interpreted indicated that the sun when observed follows a different path due to its tilt from January to June and from July to December.

* Five of the elders said that the red sunrise and sunset were due to the results from burning which gives
off smoke into the atmosphere. The smoke causes the redness of the sun in the sky when it rises and sets.

* An elder mentioned that the sun is a very hot burning furnace.
* Two of the elders said that during rainfall, the rain causes all smoke, smog, haze to disappear. There is bright sunshine after the rain.

**Conclusion**

The research identified similarities amongst explanations for the personal experience category with that of modern science; for example, in response to questions on erosion and deposition, inland rivers and creeks are blocked due to the felling of trees for food gardens. As a result, the water cannot assist in the deposition of sand downstream and on to the beach making the river get shallow. Several village elders gave numerous and interesting explanations for the Christianity category based on their active involvement in church activities with the village United Church and which is also evident from the education they got from the village mission schools they attended.

Some village elders still hold on strongly to their traditional beliefs which can be seen from the way they perceive, interpret and explain their natural environment surroundings. In addition, because they have lived closely within their natural environments they are able to give explanations of natural phenomena from their own perspective and perception which complement with those of science. Traditional beliefs are those where the sun and the moon are looked after by spirits, magic spells ("seseva") are used to move the sand on the beach near the village, or sorcery ("maeasiri") (pointing the bone) is used to kill people. Interestingly, George (1991) study supports and states that traditional beliefs are still strong among PNG tribes where the universe and everything in it were created by a powerful spirit called 'Patip/Yangela'. Each component of the universe is associated with its own spirit, like the spirit of the garden, spirit of the animal, spirit of weather and spirit of the forest. The spirit of lightning is considered to be an angry spirit and this makes the people fearful of him.

In dealing with traditional knowledge, it is important to take advantage of rural village settings where local knowledge is still strong. Elders in these villages who possess valuable knowledge on natural phenomena should be identified so that interviews can be conducted to record this knowledge. The knowledge may be that of plants and animals found in the immediate locality which can be used as an introduction to modern science education. School students may be encouraged to carry out projects and compile this information into learning materials like a natural history book. Here the use of vernacular
names, description of patterns of distribution and narration of myths and folk stories in respect to the plants and animals could be promoted. This book can form the basis of a study of all the plants and animals in the local area as a viewpoint in harmonising traditional knowledge with school science.

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Measuring the Impact of Informal Learning Experiences: What Variables Should We Choose?

Léonie J. Rennie and Gina F. Williams
Curtin University of Technology

Introduction

This paper reports our attempt to measure the impact of a series of evening lectures about human genetics held at Scitech Discovery Centre. The attempt was part of an evaluation of the lecture series carried out at the request of Scitech, and although we report some of the results, this paper focuses on the methodological issues involved in the research. We consider the nature of a sponsored lecture series in terms of the potential for learning, the constraints this places on data collection and our approach to resolving some of these issues.

The lecture series was entitled Genetics: The Facts, Fiction, Issues and Ethics. It was held at Scitech Discovery Centre, sponsored by the Hereditary Disease Program, Health Department of Western Australia and supported by the Human Genetics Society of Australasia. The series of nine, monthly evening lectures was presented by Western Australian scientists involved with Perth universities, hospitals or Research Institutes. The lectures usually lasted for about an hour, including time for questions from the audience. During refreshments served after the lecture, attendees had the opportunity to approach the lecturer for further questions and discussion.

Public lectures like this series have several features in common. Usually lectures are short, they are open to any one, and they cover topics thought to be of interest to the community. Often there is a notion of service to the public, offering them the opportunity to learn about new things in science. This was the case for the series of lectures evaluated here. "Scitech Discovery Centre wanted to educate, inform and enlighten the community about the exciting developments in DNA and genetics, and the Human Disease Program wanted to promote [public understanding of] genetics, inherited diseases and the outstanding genetics research being carried out in Western Australia, nationally and internationally" (Durston, Ghisalberti, & Moore, 1999, p. 3). Like most other kinds of informal learning experiences, lecture series are not evaluated in a comprehensive way, so we found it difficult to find material that might help us to design our own study. In the
following discussion, we refer to the specific lecture series on which our study is based, but a great deal of the discussion may be relevant to other situations.

**The Potential for Learning from a Series of Lectures**

People who make the effort to come to lectures are likely to be willing to learn, or at least listen and be entertained, so this predisposition to learn may enhance the likelihood of an impact. Cognitive learning during a lecture can occur when the experience or new information interacts with fragments of previous knowledge, linking them together in a meaningful way. Similarly, knowledge gained from the lecture can be extended and consolidated by later experiences, provided the learner is receptive. If attendees find their experiences during the lecture to be rewarding and enjoyable, then it is likely they will be motivated and willing to engage in further opportunities to learn, and this will be an important affective outcome of the lecture. The social context of the lecture may also be important because the lecture provides opportunities for informal social interaction with others with similar interests. Discussion with others, possibly including the lecturer, enables people to rework their knowledge and understanding, leading to further learning.

Despite the promising potential for learning, the impact of the lectures is likely to be quite difficult to capture. The lectures are short, transitory events, usually about one hour including questions at the end. This short time span limited the potential impact of each lecture. Further, different people attend different numbers and combinations of lectures, so they are likely to experience different levels of impact.

Lectures vary in their content, and some topics may have greater potential impact than others, depending on their intrinsic interest, attention from the media, and so on, and the level of cognitive complexity. People also vary. They have different combinations of background knowledge, past experiences, current circumstances and expectations of the lecture, leading to different potentials for learning. For example, the more extensive a person's background and the more positive their attitude, the less opportunity there is for growth in either the cognitive or affect aspects of learning, and the so potential for impact may be lessened. A person with limited knowledge might find the lecture too difficult to follow, and again, the potential for impact its lessened.

The match between the cognitive level of the audience and the cognitive level of the lecture material is important. Learning is less likely to occur when there is serious mismatch, and the lecture content so simple it is boring and irrelevant, or so complex that it
is frustrating. More learning is likely to occur when the topic is particularly relevant to the attendee, who is able to recontextualise the issues into his or her own life, and has the opportunity to ask questions for further clarification of the issues. The lecturer's presentation is important, too, in terms of ability to engage the audience, communicate the message and respond to questions. Even the most perfect match in cognitive level will not result in learning if the audience is asleep.

The Consequences for Data Collection

The nature of the lecture series has implications for the amount and type of data that can be collected. We made six decisions.

1. **Data should be collected quickly to place minimal demands on the attendees.**

   Because the lectures occupy such a short period of time, in fairness to the attendees and the lecturer, very little time should be spent gathering data. People come to the lectures for their own purposes, not to have their time taken up by the evaluators, especially if it interferes with their enjoyment or opportunity to talk to with others, including the lecturer, during the refreshments at the end. We needed to limit inconvenience to the attendees by minimising the time and effort required for data collection.

2. **A set of data must be completed in one lecture.**

   Most people attend lectures irregularly, so it is not possible to rely on a longitudinal process of data collection. Further, people's privacy must be respected, so the evaluators were unwilling to collect names and addresses for data matching over a period of time.

3. **A written instrument would enable more data to be collected in the time available.**

   People arrive (sometimes a little late) and leave (sometimes immediately) in their own time. It is not possible to get them all together in a formal way for group data collection. Each person or small group has to be dealt with individually to be given instructions. It is not possible for the two evaluators (sometimes only one) to interact with many attendees in the short time available before and after the lecture itself. This indicates that written rather than oral data collection might be more effective, because data could be collected from more people at each lecture than would be possible by interview.

4. **The instructions and the items must be unambiguous and easily understood.**
What ever the data collection method, it must be efficient in the sense that people understand unambiguously what information they are being asked to give and the nature of the response required. There is little time available to "coach" respondents.

5. *The instrument should be flexible enough for use at any lecture, with a variety of attendees.*

Apart from its title, there was no information prior to the lecture about its content in terms of knowledge and attitudes which might be affected, so it was not possible to target specific knowledge, understanding or attitudes for measurement. It is possible to ask people for their perceptions of what they have learned, but this would cause further problems in how to score the data and how to combine it over lectures with different contents. There may be unexpected outcomes from the lectures, stimulated by discussion of issues peripheral to the topic, for example. Data collection must be flexible enough to capture a range of ideas or outcomes, including cognitive and affective aspects.

6. *The needs of the sponsors must be met.*

Sponsors need to have access to some basic demographic information for their own use to determine what kind of people the lectures are reaching and assist them to target future audiences. This kind of information is also useful to the evaluators, so collecting this data serves two purposes. However, sponsors also requested that information be collected about people's source of information about the lectures, where they heard about it, whether they wanted further information about the subject or Scitech, and if so, their names and contact addresses. While this information was useful to the sponsors, it did not provide useful input to measuring the impact of the lectures. Also, the time taken to complete requests for this information took time away from answering questions relating to the evaluation, and imposed limits on the amount of data collected.

**What Kind of Data Could be Collected?**

The short period of time available for data collection and the need to be able to complete a set of data from respondents over just one lecture, suggested that a survey design was appropriate. There were three parts to the survey devoted to the evaluation. Part A attempted to measure the impact of the lecture and was used as both a pretest and a posttest. Part B measured people's reactions to the lecture, in terms of their interest, enjoyment, and so on, and it was used as a posttest only. Part C collected other information
for the sponsors which was peripheral to the evaluation. The focus of this paper is Part A only. Details of the full evaluation are available in Rennie and Williams (1999).

Most of the development work involved Part A, which needed to measure the kinds of cognitive and affective aspects which could reasonably be expected to be relevant to all of the lectures, yet be specific enough to measure the kind of impact the lecture might make. Measuring the impact of any science-related experience requires careful consideration of what is important to measure and what is possible to measure. The key word, of course, is science. What is it about science that we would like people "to have more of"? The current catch-all phrase is scientific literacy, that is, we would like people to become more scientifically literate. But what does this mean in the context of a series of lectures on human genetics?

We will not review the literature on scientific literacy here, but point out that for our purpose, we found Shamos' (1995) argument to be a useful basis for our needs. According to Shamos, "what we seek is a society that (a) is aware of how and why the scientific enterprise works and of its role in that activity, and (b) feels more comfortable than it presently does with science and technology" (p. 219). We thought it reasonable that human genetics and its research were parts of science and the scientific enterprise about which society ought to be more informed and feel comfortable with, and this was consistent with the purposes of the sponsors of the lecture series. Importantly, Shamos does not emphasise the need for knowledge and understanding of science content, and this suited our situation because, as explained above, we were not able to design an instrument which could target specific science concepts. Hence we decided to design an instrument that could measure people's perceptions, ideas and opinions about human genetics in a way consistent with Shamos' position, that is, people's awareness about human genetics and research in it, and how comfortable they felt in dealing with it. By using a generic measure of cognitive and affective items concerning people's perceptions, ideas and opinions about human genetics, the nature of the data was not dependent on the specific knowledge content of the lectures, therefore it could be combined more easily over several lectures.

**Development of the Instrument and Data Collection**

Part A of the questionnaire, The Perceptions about Human Genetics Survey was designed to measure attendees' perceptions, ideas and opinions about human genetics. It employed a modified semantic differential format. Each item includes two oppositely worded sentences or phrases, that is, bipolar statements rather than the bipolar adjectives
used in the traditional semantic differential. Respondents chose one of seven points between the end statements in the usual way, and a "don't know" box was also included. There were seven items under each of two headings, *Research in Human Genetics* and *Learning about Human Genetics*. During its development, the questionnaire was revised several times after reviews by a group of science educators and staff from Scitech, and also field-tested with a small external group. Each item was analysed separately, providing a "profile" of responses to the instrument as a whole.

To measure the impact of their attendance at the lectures on people's ideas about science and human genetics, the survey was used as a pretest-posttest measure. At the beginning of the last six lectures (the period of the evaluation) each person who was attending for the first time was asked to complete the survey prior to the lecture and again at the end. The pretest was collected before the lecture began and, by assigning it a numbered sticker, was able to be matched to the posttest completed at the end of lecture. Numbered stickers were used to avoid asking attendees for their names. Although this method measured impact over only one lecture, this was considered to be the best compromise, as it could not be assumed that any particular person would be present to complete a posttest at some later date. Over the six lectures, a total of 72 people completed the pretest and posttest.

**Results**

**The Impact of the Lecture**

Using the Perceptions about Human Genetics Survey as a pretest and posttest measures attendees' change in responses after just one lecture, which obviously limits the effect. Each lecture is different and they possibly have different effects. However, because the numbers were small, the data were collated over all six lectures and the combined results for 72 first time attendees are presented in Figures 1 and 2, which give the percentage responses to each of the seven items for *Research in Human Genetics* and the seven items for *Learning about Human Genetics*, respectively. Note that these results have the wording of the items arranged so that the right hand side represents the more positive or scientific view about science and human genetics, and the left hand side represents a less positive or scientific view. On the actual questionnaire, some of the questions were worded in the reverse order. Each graph shows the percentage of people responding to
each of the seven response categories and, on the far right hand side, the percentage who responded "don't know".

These results might be interpreted as representing the average effect of a lecture in the lecture series. We used a non-parametric test (Wilcoxon matched-pairs signed-rank test) to determine whether the change between pretest and posttest was statistically significant. These results are presented in Table 1. The second column in this table shows the number of people (totalled over all six lectures) who changed their response negatively (that is, towards the wording on the left of the figures), and the third column shows the number of people whose responses changed positively (that is, towards the wording on the right of the figures). The final column shows the statistical significance of the changes. In Figures 1 and 2, the items with statistically significant differences in the patterns of responses are marked with *.

Table 1. Wilcoxon Matched-Pairs Signed-Ranks Test Results Perceptions about Human Genetics

<table>
<thead>
<tr>
<th>Item</th>
<th>No. Negative Ranks</th>
<th>No. Positive Ranks</th>
<th>z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Results important</td>
<td>8</td>
<td>9</td>
<td>-0.40</td>
<td>0.687</td>
</tr>
<tr>
<td>2. Public funds</td>
<td>7</td>
<td>12</td>
<td>-1.01</td>
<td>0.314</td>
</tr>
<tr>
<td>3. Practical applications</td>
<td>8</td>
<td>19</td>
<td>-2.56</td>
<td>0.011*</td>
</tr>
<tr>
<td>4. Proper use of knowledge</td>
<td>14</td>
<td>22</td>
<td>-1.16</td>
<td>0.245</td>
</tr>
<tr>
<td>5. Risk-benefit</td>
<td>10</td>
<td>22</td>
<td>-2.20</td>
<td>0.028*</td>
</tr>
<tr>
<td>6. Communication of findings</td>
<td>14</td>
<td>17</td>
<td>-0.42</td>
<td>0.674</td>
</tr>
<tr>
<td>7. Concern for consequences</td>
<td>18</td>
<td>18</td>
<td>-0.35</td>
<td>0.724</td>
</tr>
<tr>
<td>8. Everyone needs knowledge</td>
<td>9</td>
<td>24</td>
<td>-2.48</td>
<td>0.013*</td>
</tr>
<tr>
<td>9. Helpful for understanding</td>
<td>9</td>
<td>10</td>
<td>-0.38</td>
<td>0.702</td>
</tr>
<tr>
<td>10. Everyone can understand</td>
<td>19</td>
<td>14</td>
<td>-0.06</td>
<td>0.950</td>
</tr>
<tr>
<td>11. Interesting to me</td>
<td>4</td>
<td>9</td>
<td>-1.92</td>
<td>0.055</td>
</tr>
<tr>
<td>12. Comfortable seeking information</td>
<td>9</td>
<td>6</td>
<td>-0.91</td>
<td>0.364</td>
</tr>
<tr>
<td>13. Confident talking about genetics</td>
<td>10</td>
<td>20</td>
<td>-2.03</td>
<td>0.042*</td>
</tr>
<tr>
<td>14. Uncertainty in knowledge</td>
<td>24</td>
<td>11</td>
<td>-2.51</td>
<td>0.012*</td>
</tr>
</tbody>
</table>

n = 72; * p < .05
People's Perceptions and Ideas about Research in Human Genetics

The results for the first item concerning the importance of the results for ordinary people are very positive and reveal little change. The next item, that research should be supported by public funds (Item 2) shows a slightly positive change in response. More positive results are recorded for Item 3, that research has many practical applications, with a statistically significant change. As the lecture focus was associated with the relevance of genetics research to understanding human diseases, this result is pleasing, especially since attendees' opinions were so positive to begin with.

The other four items had well-spread pretest responses, so a ceiling effect was not an issue. However, there were mixed responses to these items. In each case, around 30 people changed their response choice. For Items 4 and 5 dealing with use of misuse of knowledge and risks versus benefits, there was an overall positive change (which was statistically significant for Item 5). For Items 6 and 7, however, about as many people changed their views positively as negatively, so overall, the changes more or less cancelled out.

![Graphs showing responses to items](image)
Figure 1. Responses for Pretest and Posttest for First Time Lecture Attendees to the Items about Research in Human Genetics.

**People's Perceptions and Ideas about Learning in Human Genetics**

The seven items on learning about human genetics had a more personal focus than those about research. Responses to this part of the questionnaire were also rather mixed. Posttest results were more positive for Item 8 (everyone needs knowledge about genetics) and Item 13 (I feel confident talking about genetics to others) with statistically significant changes. Three other items with very positive responses were Item 9 (helpful for understanding health issues), Item 11 (interesting to me), and Item 12 (feel comfortable seeking information) but as these items had very positive pretest responses, there was little room for a positive impact.
Figure 2. Responses for Pretest and Posttest for First Time Lecture Attendees to the Items on Learning about Human Genetics

Item 10 (ordinary people can understand genetics) showed no change over the lecture. The final item, Item 14, referred to the uncertainty of knowledge in genetics. The more scientific response to this item is to indicate that knowledge in genetics, like most scientific knowledge, has an element of uncertainty rather than being factual. The scientific position is that current knowledge in genetics is the best explanation for a particular phenomenon given what we know, but we continually seek better explanations. The response patterns for Item 14 indicate that some people (a third of them, in fact) became more of the view that genetics knowledge is factual, rather than uncertain. In fact this item had a statistically significant change towards a less scientific view. This suggests that most of the lecturers conveyed a persuasive degree of certainty in their presentation.
There are two final points to be made from these results. First, for all items where there were some "don't know" responses on the pretest, the percentage responding "don't know" decreased on the posttest, suggesting that following the lecture many of those attendees felt they now had sufficient information to form an opinion. Second, examination of the results lecture by lecture indicated a good deal of variation in responses to some items. Numbers were too small to do a meaningful analysis of this variation, but it must be remembered that only average results have been reported.

Discussion

People's perceptions, ideas and opinions about human genetics were measured by a new 14-item instrument, the Perceptions about Human Genetics Survey. It was developed in an attempt to measure the impact of a lecture series in human genetics on the kinds of perceptions and ideas that it might be hoped that people comfortable with science would hold. The impact of the lecture series focused on the change in people's perceptions and ideas brought about by attendance at only one lecture. Although this limits the potential of measuring the impact, which might reasonably be considered to strengthen after further lectures, it was a decision based on compromise. We wished to retain anonymity of respondents, so we could not track people from one lecture to another. Further, many people attended only once or twice and we could not be sure we would see them again. Because of the small numbers of people available to respond at each lecture, that is, first time attendees, we decided to combine the data over the six lectures, and regard any change that was measurable as an average effect for attendance at one lecture.

Considering the constraints to measuring any impact, and the very positive pretest responses of the attendees to most items, the results were quite pleasing. On 10 of the 14 items, the number of positive changes exceeded the number of negative changes, although only four of these reflected a statistically significant difference. On average, people became more positive about the practical applications of research in human genetics, that benefits were likely to outweigh risks, that everyone needs some knowledge about human genetics, that it was interesting to them and they were confident talking about it. One statistically significant change occurred towards a less scientific view: the attendees became more likely to believe that genetics knowledge is factual rather than having an element of uncertainty. As an aside to these generally positive results, it must be re-emphasised that the responses varied to some extent over the different lectures.
The use of any instrument as a pretest-posttest design has both advantages and disadvantages. The main advantage is that using the same items is the best way to see whether change has occurred on the variable measured by the items. Using the instrument over only one lecture reduced the possibility of extraneous variables causing the change. Another advantage is that it gave some measure of control over exposure to the lectures. By using this instrument on first time attendees only, then the impact of only one, rather than a varying number of lectures, could be measured reasonably consistently. A major disadvantage was that the number of first time attendees would be small, in fact it averaged about 12 people over the six lectures. The sample was one of convenience so it could not be claimed to be representative of the wider population. However, it did include all attendees, so it was, in effect, the attending population. Another disadvantage of pretest-posttest designs is the problem of pretest sensitisation. Completing the pretest only an hour before the posttest meant it was unlikely that people would forget all of the questions. Further, the pretest might sensitise the attendees to issues in the lecture which they might not otherwise have considered. A control group could have assisted in solving this problem, but a control group was not available.

One problem of using written measures is always present. Whether the respondents understand the question in the same way as the evaluators intended can never be solved conclusively. We attempted to ensure that the questionnaire was readily understandable by extensive field-testing, and also by having a "don't know" response.

Because the audience is self-selecting, in that people choose to attend the lecture, they are probably well-informed and have positive perceptions about the topic. Other data collected as part of the evaluation indicated that this was so. The attendees were usually very willing to help us with our data collection, although we were very conscious of the intrusion on people's time, and attempted to minimise this. The demographic and other data requested by the sponsor was a problem here. Because the same questions were asked each time, people became bored with completing them, and we reduced them (with permission) towards the end of the series. Although we were reasonably satisfied with the performance of our instrument, and the sponsors were very happy with the evaluation results, a better estimation of the value of the instrument will come with further use.

References

Australia: Human Genetics Society of Australasia, Western Australian Branch and Hereditary Disease Program, Health Department of Western Australia.


Curriculum Integration in Science, Mathematics and Technology in Middle School Contexts: Some Findings from a Three-Year Study

John Wallace, Léonie Rennie and John Malone
Curtin University of Technology

Introduction

This paper reports on findings from a three-year research project examining curriculum integration in science, mathematics and technology. We draw on our observations of integrated teaching and learning in several middle school settings across a range of demographic and socio-economic areas. We sketch what we believe we know about curriculum integration and what we still need to learn.

In recent years, there has been an upsurge of interest among teachers and administrators in Australia, and also internationally, on the subject of curriculum integration, particularly at the middle school level (Curriculum Council of WA, 1998; National Council of Teachers of Mathematics, 1995). Integration often has been proposed as a potential cure for many of the ills associated with teaching young adolescent students, such as their perceived alienation from traditional curriculum subjects and structures (Bean, 1991; Cormack, 1996; Cumming, 1996). A provocative analogy is presented by Kleiman (1991), for example, who argues that if we taught music the way we traditionally teach science or mathematics, students would practice scales for years without playing a song or that students of art would draw lines and shapes without ever getting to create a picture. If we viewed teaching and learning from an humanistic perspective, Kleiman (1991) argues it “provides a vehicle for thinking, a medium for creating and a language for communicating” (p.48). According to advocates of integration, science and mathematics should be used in rich environments integrated with other learning areas so that students can learn to appreciate the contextual utility and elegance of the subject matter.

Hargreaves, Earl and Ryan (1996) point out that integration promotes greater relevance, especially between high status, academic subjects (like science) and lower status, practical ones (like technology, manual arts or home economics). However, integration threatens the advantage of people who traditionally have benefited from an academic curriculum, including teachers. This is because integration usually involves the recognition of forms of achievement and intelligence that are beyond the established methods of evaluation. Complaints that an integrated curriculum lowers standards,
destroys ‘real subjects’ and results in a ‘wissy washy’ curriculum are criticised by Hargreaves et al. (1996) as resulting from political and philosophical manoeuvres to maintain structures of power and control. The structures of power and control that Hargreaves et al. refer to are maintained within high schools by practices such as formal subject based exams and subject departmental divisions.

Research examining integration in practice is still relatively rare (Berlin, 1989; Hargreaves et al., 1996) and teachers and researchers do not know the answers to questions about the advantages and disadvantages of integrated teaching practice and the consequences in terms of student learning. Questions remain about whether students learn the basic science and mathematics concepts when teaching and learning occurs in an integrated environment and whether, indeed, integration addresses the fundamental problems associated with teaching adolescents. This paper attempts to fill part of the void by reporting a summary of findings from a three-year study of integrated practice in several schools.

Methods

The research reported in this paper resulted from visits to 16 schools, including 12 high schools and four primary schools in the metropolitan and country districts of Western Australia. The schools were selected on the recommendation of several key Education Department of WA curriculum personnel who advised that curriculum integration had been attempted in these schools in Years 6-9. School visits involved classroom observation, interviews with teachers, students and other school personnel, and document analysis. Some of the visits focussed on teaching, others on learning, some on science teaching in integrated contexts, and others on mathematics or technology teaching in integrated contexts. The three-year research project has been reported in several presentations and journal articles (Venville, Wallace, Rennie & Malone, 1988, 1999a, 1999b, 1999d, in press) and in a monograph casebook (Venville, Wallace, Rennie & Malone, 1999c). In this paper, we use a cross-case analysis to report a synthesis of our findings over this three-year period, focussing on what we believe we now know about integration and what we still need to know.
Discussion

What we believe we know about curriculum integration

1. *Integration is a curriculum ideology*

Our first proposition is that integration is an idea or stance about curriculum which is associated with a particular value position about schooling for adolescents and about the importance of subject matter. While this value position has broad acceptance in the educational community, it is not without its critics and questioners (Lederman & Niess, 1997). There is some evidence from our work of uncritical adoption of the integration idea without a sound understanding of its ideological basis (Venville, Wallace, Rennie & Malone, 1999c). Many schools and teachers in our project found themselves so consumed by the issues of implementation (scheduling, meetings, forming teams, designing curriculum themes, activities and assessments) that they had little time for critical debate.

2. *Integration comes in many forms*

Curriculum integration is often described as if it were a single form of instruction. Indeed, integration is like a big tent under which many people are saying many things. Fogerty (1991), for example, suggests a continuum of integration with ten models arranged upon it. At one end of the continuum is a fragmented model and the other end, what Fogerty calls, a shared model, where disciplines share overlapping concepts and skills within a framework of shared planning and teaching between disciplines. In our own work, we have found that integration ranges from deliberate and explicit attempts to integrate, including thematic and cross curricula approaches to curriculum planning and delivery, through to more incidental and informal forms such as encouraging student involvement in the Science Talent Search and local community projects (Venville, Wallace, Rennie & Malone, 1999c). Other approaches included technology-based projects that provided a centrepiece for student work in science, mathematics and technology, and school specialisations (for example in horticulture and marine studies).

3. *Integration challenges the grammar of schooling*

Our third finding is that integration challenges what Tylack and Tobin call "the grammar of schooling" (as cited in Hargreaves et al., 1996, p. 86) and vice versa. While the teachers in our project were being urged by school authorities to integrate the
curriculum, the grammar (or apparatus) of schooling including teaching training, curriculum materials, subject departments, professional associations, assessment structures, school timetables and students' university futures seemed to work against this rhetoric.

This phenomenon was expressed in many different ways. In one example, high school mathematics teachers expressed concern at the heterogeneous nature of integrated classes and the difficulty of changing from the traditional arrangement where classes are streamed into heterogenous ability groups. Many science teachers felt that students needed the basic content courses in subjects like chemistry before integrated teaching could proceed. There was often a tension in schools between teachers' loyalty to their subject colleagues and leaders, and their colleagues and leaders in the integrated learning team.

The curriculum documents also delivered some confusing messages. For example, the *Curriculum Framework for Western Australia* (Curriculum Council of WA, 1998) seems to be encouraging teachers to teaching in an integrated manner:

> [Students] should be encouraged to understand the arbitrariness of any division of knowledge into learning areas and subjects or categories; to appreciate the interconnectedness of all knowledge. (p. 27)

However, the document itself is organised into eight distinct learning areas with little cross-referencing of learning outcomes. Support documents provided to schools (from the Education Department of WA and the Curriculum Council of WA) came in the form of learning area rather than integrated resources.

4 **Instances of successful integration are idiosyncratic**

We found that instances of successful integration — where teachers seemed to be making genuine attempts to integrate and the classroom atmosphere seemed conducive to learning — were patchy. Rarely was integration a school-wide phenomenon, instead it relied on a few dedicated teachers or teaching teams. We noticed that over time teachers tended to drift away from integrated practice towards discipline-based teaching. Over the three-year period of the project, we noticed several examples of integrated teaching, identified at the beginning of the project, reverting to more traditional forms at the end of the period. Integration also ebbed and flowed as teaching teams configured and reconfigured. Changes in methods of curriculum delivery were often associated with changes to staff and school leadership. In one case, an Education Department of WA local area planning decision led to the closure of a school with a strong integrated program
Integrated teaching works best in inclusive contexts

According to Bean (1991), integration is about wholeness and unity rather than separation and fragmentation. We documented several examples of this kind of integration where students were able to make interdisciplinary links and transfer knowledge and skill from one context to another. These linkages were enhanced in inclusive contexts, where students and teachers were also found to be working in team environments and where students were able to call upon community and family support. In one school, for example, where students designed and made electric powered vehicles, the science, mathematics and technology teachers modelled teamwork by working together to support the program. The students also worked in teams, often calling upon family and friends to assist with technical or other advice in the design and construction of their projects.

Integrated learning involves gains and losses

The gains we noticed in students' capacity to transfer knowledge were often offset by deficiencies in specific subject matter knowledge. While our findings in this area are tentative, we recorded several instances of students retaining naive scientific understandings and an absence of remedial teaching to address such deficiencies. For example, in a technology program based on bridge design, we found students with several important scientific misconceptions about forces (Venville, Wallace, Rennie & Malone, 1999b). In another technology-based project on rocketry, students were found to have misunderstandings about mathematical concepts, such as circumference and parallel, used in the rocket design (Venville, Wallace, Rennie & Malone, 1999d).

There were also gains and losses for teachers. The gains in terms of developing viable and interesting integrated programs were often offset by the time required to do so and the energy invested in forming new relationships. The resources were not readily available and teachers often found that they needed considerable extra time outside school hours (Venville, Wallace, Rennie & Malone, 1999c).

What we still need to know

What is the problem that integration is addressing?

This has been a continuing question for the research team. As mentioned previously, we noticed many instances of uncritical adoption of integrated teaching
methods and observed the large amount of time invested by teachers to develop integrated support materials. However, we wonder if sufficient consideration has been given to the nature of the problem itself. Hargreaves et al. (1996) propose several related problems in the schooling of young adolescents, including student anxiety and alienation, adjustment to the transition to secondary school, and fragmentation of the curriculum. Here we ask what are the problems surrounding the schooling of adolescents and are there other ways (perhaps even more effective ways) of addressing them?

2 *How is integration addressing this problem?*

If we do recognise the problem as one of alienation, for example, how is integration supposed to be a solution? In our own work, we have observed several instances of integrated learning environments which appear to be addressing such problems. We have also observed other less successful learning environments. Is the key to the problem good teaching (of science and mathematics and technology) rather than integrated teaching per se? If integrated practice is seen as a solution, should it be seen as one several complementary strategies for schooling rather than a curriculum panacea.

3 *What are students actually learning in integrated contexts?*

While we can report on some instances of successful integrated teaching and learning (at least superficially), we are still short of solid evidence of what it is that students are actually learning. Part of this problem lies in the nature of the learning and the absence of measures for such learning and part lies in the dearth of close-up research into what students know and can do in integrated settings. In raising this question, we join other scholars who point out that there is currently little empirical support for the superiority or desirability of thematic or integrated approaches to teaching and learning (Lederman & Niess, 1997).

4 *How can integration be scaled up and sustained over time?*

We observed that integrated teaching appears idiosyncratic and erodes over time. If indeed, as many commentators would have us believe, it transpires that integration does provide an answer to the problem of adolescent schooling, we are still faced with the problem of scaling up. How, in the face of the constraints identified earlier, can integration be visioned as some kind of broad-based solution to the systemic issue of adolescent schooling? How can the grammar of schools be reconfigured to facilitate rather than
challenge integrated teaching and learning?

Acknowledgments

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Development of a Test for Thermally-Challenged Students

Shelley Yeo and Marjan Zadnik
Curtin University of Technology

Abstract

This paper describes the development of a pen and paper test designed to provide a measure of a range of student beliefs about thermal phenomena. The trial version of the test, administered to 478 Western Australian high school and university students aged 15–18 years, was able to distinguish belief changes between the Year 11 and first year university (Year 13) populations. The revised version of the test may be used as a pretest and posttest to evaluate conceptual change in relevant physics classes as a result of instruction. It is available for interactive use on the Curtin University of Technology Department of Applied Physics Website.

Introduction

Many studies have explored and exposed the existence and resilience of children's various naive understandings about the physical world (Osborne & Freyberg, 1985; Pfundt & Duit, 1994). Despite the diversity of children's views, different researchers have repeatedly reported similar results across age and cultural groups. It is generally agreed that traditional instruction, which does not take into account the existing beliefs of students, is largely ineffective in changing students' naive scientific ideas. Many students leave school (and often, university) with their intuitive physics understandings intact or existing along side more accepted scientific views (White & Gunstone, 1989). Conceptual change research has lead to the development of a variety of teaching methods and strategies which encourage students to actively reflect on and evaluate their existing knowledge. Such strategies involve fostering a learning environment which is supportive of conceptual change learning, selecting appropriate teaching strategies and learning tasks (Scott, Asoko, & Driver, 1991).

Evidence for the effectiveness of different teaching initiatives may take the form of an initial and final assessment of students' conceptual beliefs. The Force Concept Inventory (Hestenes, Wells, & Swackhamer, 1992) and more recently, the Force and Motion Conceptual Evaluation (Thornton & Sokoloff, 1998) have enabled teachers of introductory mechanics to conveniently assess the alternative conceptions of their students as well as the gains made by students as a result of instruction. Such comparative
information has facilitated the comparison of different courses and instructional methods (Hake, 1998).

**Alternative Thermal Physics Conceptions**

Thermodynamics presents students with many conceptual difficulties (Clough & Driver, 1985; Erickson, 1980; Lewis & Linn, 1994). Adolescents who are unable to differentiate between the concepts of heat and temperature, for example, do not have an adequate knowledge framework for thinking about thermodynamic processes such as conduction of thermal energy, at deeper levels. This, in turn, limits the extent to which appropriate new knowledge can be constructed. Alternative conceptions also inhibit the development of more correct conceptions because students perceive no need to seek different explanations.

Some specific findings about thermal understandings learned from research are:

1. Many students’ conceptions are context-dependent and explanations are related to single or isolated situations. Appropriate generalisations are often not recognised.
2. Students are inconsistent in their explanations; they use different conceptions to explain similar phenomena and generally do not recognise contradictions.
3. Students do not apply ideas learned in school to ‘everyday’ situations; they are more likely to express alternative conceptions when explaining real-life situations.
4. Students’ knowledge frameworks often allow them to accept a statement of what is as a sufficient explanation of why. For example, children believe that ‘heat rises’ and many use this as a definitive explanation for convection currents.
5. Even when students make correct statements, they often admit to not being clear about their ideas (Harrison, Grayson & Treagust, 1995).

**Origin of alternative thermal conceptions**

Lewis and Linn (1994) attribute alternative thermal conceptions to ‘action knowledge’, physical experiences or cultural use of imprecise language. Action knowledge is described as a student’s initial, unreflective response to a situation. As part of making sense of the world, students actively amalgamate their observations and personal experiences into alternative conceptions. For example, when using skin to judge the temperature of objects, they become accustomed to materials which usually feel warm or cool to touch and combine such experiences into a generalisation that provides some
explanation for that experience. The intuitive conception may give some explanation for
that experience but at the same time, inhibits the development of more appropriate
scientific principles. Knowledge is also gained by children through cultural and family life
experiences. Common statements such as ‘white heat’ or ‘to take one’s temperature’ lead
to beliefs which may be in conflict with scientific views. Society’s use of materials for
heat-related purposes, for example using aluminium foil to keep things cold, leads to
confusion about conductors, insulators and the mechanism by which they work in different
situations.

Thermal conceptual beliefs appear to undergo a developmental progression. Erickson (1980) investigated the prevalence of three viewpoints, Children’s, Caloric and
Kinetic, in 10 to 14 year olds. The Children’s Viewpoint was a set of naïve idiosyncratic
ideas commonly expressed by children. Children with a Caloric Viewpoint saw heat as
particle-like and heat transfer as the movement of heat particles. Children with a Kinetic
Viewpoint attributed heat phenomena to behaviour of the particles of the substance.
Erickson found older students less likely to adopt a Children’s Viewpoint and more likely
to adopt a particle approach to explanations of thermal phenomena but they did not,
however, indicate a preference for either a Caloric or Kinetic Viewpoint and used both
equally. Kesidou and Duit (1993) found that 15 year-old students seldom used kinetic
explanations for thermal phenomena, and when they did, had much difficulty because they
brought to their explanations a variety of alternative conceptions about inertia, force and
motion.

Some ‘misconceptions’ are introduced to students as a result of instruction. Bauman (1992) apportions the blame to poorly understood and inconsistent use of
terminology in textbooks, teachers’ inadequate knowledge and the inherent conceptual
difficulty of the topic. Through necessity, definitions of physics terms in student textbooks
are often more simplistic than the meaning understood and agreed on by experts.

Lucid scientific explanations of heat transfer processes, conduction, convection and
radiation require a knowledge of many concepts and processes, including heat,
temperature, particle motion, energy and wave motion. Children who hold different beliefs
about each of these concepts will construct variable understandings about different heat
transfer mechanisms.
This Research

This paper describes the development of the Test of Thermal Physics Conceptual Understanding.

The specific aims were to

1. Construct a trial test and generate sufficient data for specific item analysis.
2. Develop a final test.
3. Assess the potential of the test for measuring the conceptual learning gains of two key populations i.e. Year 11 physics students and first year university physics students.

The construction and testing of a ‘trial’ version is described in Part A. The modification of the trial test into the ‘final’ version is described in Part B.

Part A

Construction of trial test

A list of alternative conceptions was developed from various thermal studies reported in literature (see Table 1). Many are expressed in the naïve form. The trial test consisted of 32 multiple-choice items. Question 11 was divided into three parts, A, B and C. There were a variable number of distracters depending on the possible alternative conceptions which students might bring to bear in answering the questions.

Table 1. Links Between Possible Alternative Conceptions and Questions for the Trial Test.

<table>
<thead>
<tr>
<th>Alternative conceptions</th>
<th>Question Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group A: Concept of heat</strong></td>
<td></td>
</tr>
<tr>
<td>1. Heat is a substance.</td>
<td>16, 30</td>
</tr>
<tr>
<td>2. Heat is not energy.</td>
<td>16, 20, 21</td>
</tr>
<tr>
<td>3. Heat and cold are different, rather than opposite ends of a continuum.</td>
<td>12, 14, 16, 17, 24</td>
</tr>
<tr>
<td>4. Heat and temperature are the same thing.</td>
<td>16</td>
</tr>
<tr>
<td>5. Heat is proportional to temperature.</td>
<td>10, 13, 14</td>
</tr>
<tr>
<td>6. Heat is not a measurable, quantifiable concept.</td>
<td></td>
</tr>
<tr>
<td><strong>Group B: Concept of temperature</strong></td>
<td></td>
</tr>
<tr>
<td>7. Temperature is the ‘intensity’ of heat.</td>
<td>25</td>
</tr>
<tr>
<td>8. Skin or touch can determine temperature.</td>
<td>17</td>
</tr>
<tr>
<td>9. Perceptions of hot and cold are unrelated to energy transfer.</td>
<td>17, 19, 25, 28</td>
</tr>
<tr>
<td>10. When temperature at boiling remains constant, something is ‘wrong’.</td>
<td>6</td>
</tr>
<tr>
<td>11. Boiling is the maximum temperature a substance can reach.</td>
<td>8, 22</td>
</tr>
<tr>
<td>12. A cold body contains no heat.</td>
<td>13, 17</td>
</tr>
<tr>
<td>13. The temperature of an object depends on its size.</td>
<td>11A, 11B, 11C, 19</td>
</tr>
<tr>
<td>14. There is no limit on the lowest temperature.</td>
<td>26</td>
</tr>
</tbody>
</table>
Group C: Heat transfer / temperature change

15. Heating always results in an increase in temperature. 6
16. Heat only travels upward. 23
17. Heat rises. 23
18. Heat and cold flow like liquids. 16, 21, 22, 28
19. Temperature can be transferred. 16
20. Objects of different temperature that are in contact with each other, or in contact with air at different temperature, do not necessarily move toward the same temperature. (Thermal equilibrium is not a concept.) 7, 9, 11a, 11b, 11c, 18, 22, 25
21. Hot objects naturally cool down, cold objects naturally warm up. 11b
22. Heat flows more slowly through conductors making them feel hot. 11a, 17, 19, 28
23. The kinetic theory does not really explain heat transfer. (Explanations are recited but not believed.) 23, 30

Group D: (Thermal) properties of materials.
24. Temperature is a property of a particular material or object. 11a,c, 19, 25, 27, 28
25. Metal has the ability to attract, hold, intensify or absorb heat and cold. 11b, 19, 23, 28
26. Objects that readily become warm do not readily become cold. 11b
27. Different materials hold the same amount of heat. 27
28. Ice is at 0°C and/or cannot change temperature. 2
29. Water cannot be at 0°C. 3, 9, 13
30. Steam is more than 100°C. 18
31. Wool (for example) has the ability to warm things up. 11e, 17, 24, 25, 29
32. Some materials are difficult to heat: they are more resistant to heating. 25, 29
33. Bubbles mean boiling. 5
34. The bubbles in boiling water contain "air", "oxygen" or "nothing". 15

Question design

About two thirds of the questions were constructed to model a conversation occurring between adolescents in a school/university canteen/common room. The general question style took the form of the presentation of a scenario followed by statements representative of the opinions of students holding one or more alternative conceptions. Each scenario was a situation as familiar to students as possible, featuring everyday objects that students are likely to have handled or experienced. Diagrams or graphical representations were not used to avoid unintended misinterpretation or misunderstanding. The reading level was kept low to reduce the cognitive load but students still had to keep the initial scenario in their mind while they consider the veracity of four or five alternative statements.

In the majority of questions, students were asked to select an opinion which matched their own, rather than select a ‘right’ answer. This was done to elicit a belief rather than an idea to which the student was not personally committed. By siting examples in everyday contexts, we believe that students will be more likely to select responses which match their own conceptions rather than choose one to reflect a statement learned in school but not necessarily believed.
Example 1

Kim takes a metal ruler and a wooden ruler from a pencil case. He announces that the metal one feels colder than the wooden one. What is your preferred explanation?

A. Metal conducts energy away from his hand more rapidly than wood.
B. Wood is a naturally warmer substance than metal.
C. The wooden ruler contains more heat than the metal ruler does.
D. Metals are better heat radiators than wood.
E. Cold flows more readily from a metal.

Example 2

Vic takes a couple of frosty-fruits (icy poles) from the freezer, where he had placed them the day before, and tells everyone that the wooden sticks are at a higher temperature than the ice part.

A. Deb says: “You’re right because wooden sticks don’t get as cold as ice does.”
B. Ian says: “You’re right because ice contains more cold than wood does.”
C. Ros says: “You’re wrong, they only feel different because the sticks contain more heat.”
D. Ann says: “You’re wrong, they are at the same temperature. Your skin is not a good thermometer.”

Which person do you most agree with?

A list of possible conceptions underlying the selection of various (incorrect) distracters is shown in Table 1. While students were expected to choose an answer which matched their personal beliefs, it was also anticipated that rote-learned statements, such as ‘heat rises’ or ‘evaporation causes cooling’ would also be selected as explanations whether appropriate or not.

Research Method

The trial test was administered to 478 Western Australian students in four consecutive year levels (see Table 2). It was also given to the two Year 13 classes (first year university) as a post-test to measure change following instruction in Thermodynamics. The results are shown in Tables 3 and 4 and the data is included in the histograms in Figure 1.
Table 2. Number of Participants in Test Trials.

<table>
<thead>
<tr>
<th>Student groups</th>
<th>Number of students</th>
<th>Number of schools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 10</td>
<td>163</td>
<td>5</td>
</tr>
<tr>
<td>Year 11</td>
<td>145</td>
<td>5</td>
</tr>
<tr>
<td>Year 12</td>
<td>122</td>
<td>7</td>
</tr>
<tr>
<td>Year 13 (university)</td>
<td>48</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>478</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Results of Students on the Trial Test.

<table>
<thead>
<tr>
<th>Year</th>
<th>N</th>
<th>Mean /32 (%)</th>
<th>Stdev (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>163</td>
<td>11.1 (35)</td>
<td>5.8 (18)</td>
</tr>
<tr>
<td>11</td>
<td>145</td>
<td>16.8 (53)</td>
<td>2.7 (8.4)</td>
</tr>
<tr>
<td>12</td>
<td>122</td>
<td>19.5 (61)</td>
<td>1.7 (5.3)</td>
</tr>
<tr>
<td>13</td>
<td>48</td>
<td>21.3 (67)</td>
<td>3.4 (11)</td>
</tr>
<tr>
<td>Total</td>
<td>478</td>
<td>16.0 (50)</td>
<td>5.7 (18)</td>
</tr>
</tbody>
</table>

Table 4: Posttest results for Year 13 population.

<table>
<thead>
<tr>
<th>Year</th>
<th>N</th>
<th>Mean /32 (%)</th>
<th>Stdev (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 posttest</td>
<td>47</td>
<td>24.5 (77)</td>
<td>3.5 (11)</td>
</tr>
</tbody>
</table>

The test reliability, determined using a simple split half correlation with Spearman-Brown correction, was found to be 0.81 (see discussion below).

Data Analysis and Discussion

The overall test mean of 16 (50%) and standard deviation of 5.7 (18%) were good indicators that the trial test was appropriate for the intended population of 15 to 18 year-olds. There was a clear difference between Year 10 students, generally from ‘more able’ classes, and Year 11 students who had studied the physics unit Heating and Cooling. Approximately half of the Year 11 and 12 students also study chemistry which has a small but significant thermodynamics (reaction kinetics) component taught either in Year 11 or Year 12.
The Year 13 population (two classes) had elected to study physics at the tertiary level and hence corresponds to a sub-group of a Year 12 cohort studying physics. The Year 13 group scored significantly higher than the Year 12 population (average 21.3 vs 19.6, \( p = 0.05 \)), with the difference being mostly in the scores of a small core of higher-achieving students. Apart from the high score end (scores \( \geq 25 \)), the distribution of the Year 13 population scores closely matches that of the Year 12 population probably reflecting the lack of formal tuition in thermodynamics between the testing times (mid-Year 12 and mid-Year 13).

**Reliability**

Reliability for this test refers to the consistency with which it measures students conceptions about thermal phenomena. Factors affecting its reliability are likely to be its length, time allowed for completion, constancy of attitude of students, and distribution of items of variable difficulty. The reliability of 0.81 was considered acceptable but steps to improve this were planned for the revised test.

Teachers administering the trial test reported times taken varying from 15 to 50 minutes. Some students worked rapidly while others were more reflective. The importance which students ascribe to a task will affect the care with which they respond to questions. This test was not, at the time, directly related to the class work of any but the Year 13 students, and this factor may have resulted in a lack of 'fair effort' by some.

Thirty two written items place some demands on the concentration of readers and so the intention was to reduce to 25 or 26 items, which could reasonably be completed in
20 to 25 minutes. If students are able to maintain their level of concentration, one might expect a greater constancy of attitude, particularly towards the end of the test. Some of the test questions were too easy for the population tested. Since reliability can be improved if the variability of items is reduced, easy items would be deleted or modified. Items which discriminate poorly would be removed or modified. Some of the harder items would be more evenly distributed.

Validity

There is no simple procedure for determining the validity of a test. Test validity relates to the accuracy with which it measures what it is purporting to measure. This test must award a high score to students whose ideas about thermal physics approach those of 'experts' and a low score to those who believe or apply naïve or less well-developed ideas about a range of thermal concepts. The test was given to experienced lecturers in the Department of Applied Physics for feedback on the 'correctness' of the physics represented and the appropriateness of the 'right' answer.

Part B

Development of the final test

The data collected during the trial period was used to perform a standard item analysis on the questions. The data included index of discrimination (D), item difficulty and percent correct in each Year population (10 – 13). Index of discrimination facilitates differentiation between high and low achieving students. Highly discriminating items were considered important for this type of test. Item difficulty ranges from 0 % (hard) to 100% (easy). A moderately difficult test was considered necessary if it was to be suitable for both Year 11 and Year 13 populations.

Criteria used to construct the final test version were:

1. 25 - 26 questions so that the test can be completed within 25 minutes.
2. Four or five distracters per item, depending on possible alternative beliefs.
3. Item Difficulty of 30% – 60%.
4. Discrimination index of 0.4 – 0.8.

The changes made to trial test items, when compiling the final test, are shown in Table 5. About three-quarters of items in the revised test are essentially the same as those in the trial test. The test was again submitted to teaching faculty from Curtin University Department of Applied Physics for validation and comment. Their feedback enabled us to
ensure that all questions had one distracter providing the most acceptable ‘answer’, thermodynamically.

Table 5. Changes Made to Trial Test.

<table>
<thead>
<tr>
<th>Type of change made to trial test item</th>
<th>Number of affected questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unchanged</td>
<td>11</td>
</tr>
<tr>
<td>Minor changes (wording or question structure)</td>
<td>9</td>
</tr>
<tr>
<td>Change to one or more distracters</td>
<td>3</td>
</tr>
<tr>
<td>Major rewrite, amalgamation of questions</td>
<td>6</td>
</tr>
<tr>
<td>Item deletion</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 6. Links Between Questions and Alternative Conceptions in Revised Test

<table>
<thead>
<tr>
<th>Question number</th>
<th>Possible alternative conceptions (see Table 1)</th>
<th>Question number</th>
<th>Possible alternative conceptions (see Table 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>24, 28</td>
<td>14</td>
<td>9, 13, 15</td>
</tr>
<tr>
<td>2</td>
<td>13, 20, 29</td>
<td>15</td>
<td>3, 5, 7</td>
</tr>
<tr>
<td>3</td>
<td>20, 21</td>
<td>16</td>
<td>9, 18, 23, 24, 25</td>
</tr>
<tr>
<td>4</td>
<td>33</td>
<td>17</td>
<td>20, 31</td>
</tr>
<tr>
<td>5</td>
<td>10, 11, 15</td>
<td>18</td>
<td>3, 8, 9, 23</td>
</tr>
<tr>
<td>6</td>
<td>20, 30</td>
<td>19</td>
<td>11, 20, 30</td>
</tr>
<tr>
<td>7</td>
<td>11, 24</td>
<td>20</td>
<td>17, 25, 23</td>
</tr>
<tr>
<td>8</td>
<td>5, 19</td>
<td>21</td>
<td>1, 18, 23</td>
</tr>
<tr>
<td>9</td>
<td>8, 9, 10, 13, 20, 24, 25</td>
<td>22</td>
<td>1, 2, 18</td>
</tr>
<tr>
<td>10</td>
<td>3, 18</td>
<td>23</td>
<td>3, 31</td>
</tr>
<tr>
<td>11</td>
<td>4, 5, 6, 12, 29</td>
<td>24</td>
<td>8, 9, 24</td>
</tr>
<tr>
<td>12</td>
<td>1, 34</td>
<td>25</td>
<td>4, 12, 14</td>
</tr>
<tr>
<td>13</td>
<td>1, 2, 3, 18, 19</td>
<td>26</td>
<td>21, 22, 31</td>
</tr>
</tbody>
</table>

Use of the Final Test

The revised test (Appendix 1) is available to the physics teaching community for:
1. use as either a pretest/posttest instrument;
2. assessing alternative conceptions in a class at any point during instruction; or
3. planning instruction or remediation as required.

The test will be made available on the Curtin University of Technology Department of Applied Physics Website for interactive use by students. The site will contain information for teachers about conditions of use of the test. Students’ results will be automatically emailed to the teacher’s nominated email address as well as being recorded by the Curtin Physics Education Research and Development Group for future test analysis.
References


TEST OF THERMAL PHYSICS CONCEPTUAL UNDERSTANDING

This questionnaire is about your understandings about temperature, heating and cooling.
To help you visualise each situation, think of a group of friends in a well-equipped canteen or common room. Imagine that they are an observant and inquisitive lot who are interested in understanding common phenomena. They also explain their ideas to one another.

For each question, choose the answer that is closest to your understanding. 
**Record all answers on special answer sheet.** Colour the circles using 2B pencil or blue or black biro. Do not mark outside the circles. Be careful to mark the alternative you want to. Some questions have four alternatives and some have five.

1. What is the most likely temperature of iceblocks stored in a refrigerator’s freezer compartment?
   a) -10 °C
   b) 0 °C
   c) 5 °C
   d) 10 °C

2. Ken takes six iceblocks from the freezer and puts four of them into a glass of water. He leaves two on the bench-top. He stirs and stirs until the iceblocks are much smaller and have stopped melting. What is the most likely temperature of the water at this stage?
   a) -10 °C
   b) 0 °C
   c) 4 °C
   d) 10 °C

3. The iceblocks Ken dropped on the bench-top have half-melted and are lying in a puddle of water. What is the most likely temperature of these iceblocks?
   a) -10 °C
   b) 0 °C
   c) 4 °C
   d) 10 °C

4. On the stove is a kettle full of water. The water has started to boil vigorously. The most likely temperature of the water is about:
   a) 70 °C
   b) 90 °C
   c) 100 °C
   d) 110 °C

5. Five minutes later, the water in the kettle is still boiling. The most likely temperature of the water now id about:
   a) 80 °C
   b) 100 °C
   c) 110 °C
   d) 120 °C
6. What do you think is the temperature of the steam above the boiling water in the kettle?
   a) 80 °C
   b) 100 °C
   c) 110 °C
   d) 120 °C

7. Next to the kettle is a saucepan containing a boiling sugar/water solution. What is the most likely temperature of this solution?
   a) 70 °C
   b) 90 °C
   c) 100 °C
   d) 110 °C

8. Lee takes two cups of water at 40 °C and mixes them with one cup of water at 10 °C. What is the most likely temperature of the mixture?
   a) 20 °C
   b) 25 °C
   c) 30 °C
   d) 50 °C

9. Sam takes a can of coke and a plastic bottle of coke from the refrigerator, where they have been overnight. He quickly puts a thermometer in the coke in the can. The temperature is 7 °C. What is/are the most likely temperature(s) of the plastic bottle and coke it holds?
   a) They are both less than 7 °C
   b) They are both equal to 7 °C
   c) They are both greater than 7 °C
   d) The coke is at 7 °C but the bottle is greater than 7 °C
   e) It depends on the amount of coke and/or the size of the bottle.

10. A few minutes later, Ned picks up the coke can and then tells everyone that the bench top underneath it feels colder than the rest of the bench.
    a) Jon says: "The cold has been transferred from the coke to the bench."
    b) Rob says: "The can has prevented the air in the room from warming the bench."
    c) Sue says: "Heat has been transferred from the bench to the coke."
    d) Eli says: "The can causes heat beneath the can to move away through the bench-top."
    Whose explanation do you think is best?

11. Pam asks one group of friends: "If I put 100g of ice at 0 °C and 100g of water at 0 °C into a freezer, which one will eventually lose the greatest amount of heat?
    a) Cat says: "The 100g of ice."
    b) Ben says: "The 100g of water."
    c) Nic says: "Neither, because they don't contain any heat."
    d) Mat says: "Neither because they both contain the same amount of heat."
    e) Jed says: "There's no answer, because you can't get water at 0 °C."
    Which of her friends do you most agree with?

12. Mel is boiling water in a saucepan on the stovetop. What do you think is in the bubbles that form in the boiling water? Mostly:
    a) Air
    b) Heat
    c) Oxygen and hydrogen gas
    d) Water vapour
    e) There's nothing in the bubbles
After cooking some eggs in the boiling water, Mel cools the eggs by putting them into a bowl of cold water. How do they cool?
a) Temperature is transferred from the eggs to the water  
b) Cold moves from the water into the eggs  
c) Particles of heat flow from the eggs to the water.  
d) Energy is transferred from the eggs to the water

13. Jan announces that she does not like sitting on the metal chairs in the room because “they are colder than the plastic ones”.  
a) Jim agrees and says: “They are colder because metal is naturally colder than plastic.”  
b) Kip says: “They are not colder, they are at the same temperature.”  
c) Lou says: “They are not colder, the metal ones just feel colder because they are heavier.”  
d) Mai says: “They are colder because metal has less heat to lose than plastic.”
Who do you think is right?

14. A group is listening to the weather forecast on a radio. They hear: “… tonight it will be a chilly 5°C, colder than the 10°C it was last night…”  
a) Jen says: “That means it will be twice as cold tonight as it was last night.”  
b) Ali says: “That’s not right. 5°C is not twice as cold as 10°C.”  
c) Raj says: “It’s partly right, but she should have said that 10°C is twice as warm as 5°C.”  
d) Guy says: “It’s partly right, but she should have said that 5°C is half as cold as 10°C.
Whose statement do you most agree with?

15. Kim takes a metal ruler and a wooden ruler from his pencil case. He announces that the metal one feels colder than the wooden one.
What is your preferred explanation?
a) Metal conducts energy away from his hand more rapidly than wood.  
b) Wood is a naturally warmer substance than metal.  
c) The wooden ruler contains more heat than the metal ruler.  
d) Metals are better heat radiators than wood.  
e) Cold flows more readily from a metal.

16. Amy took two glass bottles containing water at 20°C and wrapped them in towelling face-washers. One of the face-washers was wet and the other was dry. 20 minutes later, she measured the water temperature in each. The water in the bottle with the wet face-washer was 18°C, the water in the bottle with the dry face-washer was 22°C. The most likely room temperature during this ‘experiment’ was
a) 26°C  
b) 21°C  
c) 20°C  
d) 18°C

17. Dan simultaneously picks up two cartons of choc-milk, a cold one from the refrigerator and a warm one that has been sitting on the bench-top for some time. Why do you think the carton from the refrigerator feels colder than the one from the bench-top?
Compared with the warm carton, the cold carton ---
a) contains more cold.  
b) contains less heat.  
c) is a poorer heat conductor.  
d) conducts heat more rapidly from Dan’s hand.  
e) conducts cold more rapidly to Dan’s hand.
18. Ron reckons his Mum cooks kangaroo tail soup in a pressure cooker because it cooks faster than in a normal saucepan but doesn’t know why. [Pressure cookers have a sealed lid so that the pressure inside rises well above atmospheric pressure.] Why does the food cook faster?
   a) Emi says: “It’s because the pressure causes water to boil at 110°C.”
   b) Col says: “It’s because the high pressure generates extra heat.”
   c) Fay says: “It’s not the pressure that’s important, it’s because the steam is at a higher temperature than the boiling soup.”
   d) Tom says: “It’s because pressure cookers spread the heat more evenly through the food.”
Which person do you most agree with?

19. Pat reckons her Dad cooks cakes on the top shelf inside the electric oven because it is hotter at the top than at the bottom.
   a) Pam says that it’s hotter at the top because heat rises.
   b) Sam says that it is hotter because metal trays concentrate the heat.
   c) Ray says it is hotter at the top because the hotter the air the less dense it is.
   d) Tim disagrees with them all and says that it’s not possible to be hotter at the top.
Which person do you think is right?

20. Bev is reading a multiple-choice question from a text book: “Sweating cools you down because the sweat lying on your skin:
   a) wets the surface, and wet surfaces draw more heat out than dry surfaces.
   b) drains heat from the pores and spreads it out over the surface of the skin.
   c) is the same temperature as your skin but is evaporating and so is carrying heat away.
   d) is slightly cooler than your skin because of evaporation and so heat is transferred from your skin to the sweat.
Which answer would you tell her to select?

21. Zac has a small jar of ball bearings with him. He shakes the jar continuously for about ten minutes. What can you say about the temperature of the ball bearings in the jar?
   a) The temperature will increase because energy is being transferred to the ball bearings.
   b) The temperature will increase because heat is passing from his arm to the ball bearings.
   c) The temperature will not change because no heat is being added or removed.
   d) The temperature will decrease because air in the jar acts like wind and cools the ball bearings.

22. Why do we wear jumpers in cold weather?
   a) To keep cold out.
   b) To generate heat.
   c) To prevent heat loss.
   d) All three of the above reasons are correct.

23. Vic takes some frosty-fruits (icy poles) from the freezer, where he had placed them the day before, and tells everyone that the wooden sticks are at a higher temperature than the ice part.
   a) Deb says: “You’re right because the wooden sticks don’t get as cold as ice does.”
   b) Ian says: “You’re right because ice contains more cold than wood does.”
   c) Ros says: “You’re wrong, they only feel different because the sticks contain more heat.”
   d) Ann says: “I think they are at the same temperature. Your skin does not measure temperature well.”
Which person do you most agree with?
24. Gay is describing a TV segment she saw the night before: “I saw physicists make superconductor magnets, which were at a temperature of -260 °C.”
   a) Joe doubts this: “You must have made a mistake. You can’t have a temperature as low as that.”
   b) Kay disagrees: “Yes you can. There’s no limit on the lowest temperature.”
   c) Leo is not sure: “There is a lowest limit, but I think its about -500 °C.”
   d) Gay believes she is right: “I think the magnet was near the lowest temperature possible.”
   Who do you think is right?

25. Four students were discussing the dumb things they did as kids. The following conversation was heard: Ami: “I used to wrap my dolls in blankets but could never understand why they didn’t warm up.”
   a) Nic replied: “It’s because the blankets you used were probably poor insulators.”
   b) Lyn replied: “It’s because the blankets you used were probably poor conductors.”
   c) Jay replied: “It’s because the dolls were made of material which did not hold heat well.”
   d) Kev replied: “It’s because the dolls were made of material which took a long time to warm up.”
   e) Joy replied: “You’re all wrong.”
   Who do you agree with?
   THE END