Transforming knowledge and learning through technologies and modalities:
Mapping Patterns of Practice in New Life Science Classrooms

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Abstract

In the first phase of this research a number of baseline classroom observations have been carried out in Queensland, New South Wales and South Australia. The teaching of NLS concepts and associated use of digital and multimodal representations were documented through the application of coding schemes. The results discussed in this paper include the initial baseline observations of NLS classrooms and our development of coding schemes to map out the patterns of practice in these classrooms. The two coding schemes developed for this study focus on 3 domains: (1) the kinds of knowledge offered in these classrooms and the cognitive work this knowledge involved; (2) the modalities through which this knowledge was presented, their function, and the presence or absence of multimodal ensembles and materials in classroom work; and (3) the tool systems used by teachers and students. This paper will discuss the initial phase of this research project where we have mapped patterns of practice in Australian senior high school NLS classroom settings using these coding frameworks. It will highlight that NLS topics are generally appended onto traditional content; that a number of modality ensembles are used in representing and communicating NLS concepts; that the modalities engaged depends on the type of knowledge represented and that the technologies available influence the kinds of representations and modalities selected by teachers. Phase II of the project will also be briefly outlined.

Introduction

The ‘New Life Sciences’ (NLS) is a rapidly and continually evolving meta-discipline comprising a collection of increasingly specialised areas of bioscience such as bioethics, biotechnology, immunology and genetic engineering. This new meta-discipline integrates the traditional disciplines of biology, chemistry and physics together with educational, commercial, industrial and social applications. Due to the rapid expansion of knowledge in this area there is a continually widening gap between research output and public understanding (Hurd, 2002; Sgard, 2005). The growing importance of the NLS demands a society of ‘NLS literates’. Therefore, appropriate integration of this new information into the science curriculum and representation of this knowledge in the science classroom is vital. As much of the new knowledge in the NLS requires the visualisation of complex phenomena, representation via modes other than language through the use of digital technologies is often necessary. Taken together, with the growth of information in the NLS come questions about (1) which modes of communication best represents what content, and (2) whether the impact of digital technologies on transforming knowledge in this area and its representation amount to changes in knowledge. These are the fundamental questions of this ARC Discovery project. This paper focuses on the first question.

The ever widening gap between scientific research output and public understanding has prompted reflection on the current state of science education. Gilbert (2008) stresses the issue of science education failing to keep up to date with scientific advancement.

As scientific enquiry into a particular field advances, the versions of the phenomena investigated become either ever closer to or ever more distant from the naturally occurring phenomena. However, science education rarely follows far down this path or, if it does it does so slowly (p. 8).

Gilbert’s view highlights a global concern in science education; the mismatch between its practice and what is happening in the scientific world itself (Goodrum, Hackling & Rennie, 2001; Nichols & Davies 2006, Sgard
2005; Tytler, 2007). This is particularly apparent in the area of the NLS. Given the scope of the NLS and technology information that science students will face in their lifetime, science education needs to provide opportunities to understand and make decisions about the application of these new technologies.

Considering the abundance of life science issues at the moment: stem cells, human cloning, genetically modified (GM) foods, the effect of planting GM crops on our environment; it has become essential to develop a scientifically literate general public that can engage with these issues. “There’s simply no other way that as a society we will be prepared to make informed decisions on a range of issues that will shape our future” (Shapiro, 2005). NLS-specific literacies, like other discipline-specific literacies “have their own characteristic language forms and hence entail distinctive literate practices” (Unsworth, 2002, p66). As NLS concepts are abstract and multilevel in nature (eg. “an organism is at the macro level; cells, chromosomes or DNA are at the micro/submicro level; and genotypes are at the symbolic level, Tsui & Treagust, 2006, p277), a variety of practices, symbols and representational systems are required to understand and communicate (construct NLS) knowledge, making the literacy demands high. Another characteristic of the NLS is the shifting and remaking of disciplinary boundaries. This also raises challenges for literacies as they are “shaped by disciplinary practices and histories” (Jewitt 2008, p247).

In order to develop knowledge and understanding of the NLS, the science curriculum needs to include a focus on them and how knowledge in the NLS is constructed in the classroom. Given that the NLS are themselves created, explored and/or represented via digital or multiple modes of communication, the teaching of such concepts is likely to require similar communications methods. It follows that an examination of how NLS knowledge is constructed in the classroom through the use of multiple modalities is essential in order to better understand how to teach NLS concepts effectively.

... how knowledge is represented, as well as the mode and the media chosen, is a crucial aspect of knowledge construction ... It follows, then, that to better understand learning and teaching in the multimodal environment of the contemporary classroom, it is essential to explore the ways in which representation in all modes feature in the classroom (Jewitt, 2008, pp. 241-242).

Based on this statement, Jewitt would recommend an exploration of how classroom representations of NLS concepts are constructed in all modes. Current research regarding teachers’ construction, reconstruction and representation of meaning in the science classroom indicates that students benefit from the appropriate application and integration of multiple modes of communication that include the use of digital technologies (Ainsworth, 2008; Jewitt 2008; Prain & Waldrip, 2008). Jewitt (2008) stresses the importance of digital technologies in the support of meaning making in the classroom and how it has the potential to transform knowledge and its representation “the multimodal facilities of digital technologies enable image, sound, and movement to enter the classroom in new and significant ways” (p247). The use of a range of modes and media to interpret, construct and reconstruct textual representations, collectively referred to as multiliteracy (as developed by the New London Group 1996) (also see Jewitt, 2008; Kress, 2000; Kress & Jewitt, 2001), has implications for science instruction and the function of literacy education in developing students’ understanding of complex scientific phenomena (Hilton, Nichols & Gitsaki, 2008).

Over the past two decades multimodal text analysis has advanced significantly (see for example Ainsworth 2008; Bezemer & Kress, 2008; Prain and Waldrip, 2008; Jewitt, 2008). There is now a need to move from a description of the structure and meaning-making potential of multimodal texts, to a detailed description of how teachers use those potentials in everyday educational settings. What is also needed is a close study of how it is that NLS and its curricular manifestations differently configure and put to work digital and multimodal textual experiences. More specifically, the questions posed for this analysis are:

1. What knowledge and cognitive processes are put to work in the NLS classroom?
2. What are the digital and semiotic resources that are employed in the teaching and learning of secondary school NLS?
3. How do these resources interact with each other in meaning making? As well as being the goals of this paper, these questions act as a platform for the development of interventions aimed at facilitating 'NLS-literate' capacities in learners.

This paper reports on the development of coding schemes for classroom interactions; and a preliminary description of the features of classroom practice in secondary school biology focusing particularly on the distribution of knowledge and multimodality and the interaction with digital and other technologies in the context of NLS.

**Methodology**

**Data collection**

In order to carry out this examination a number of baseline classroom observations were undertaken in Australian secondary schools. Table 1 shows the number of teachers, schools and lessons selected and videotaped for the project.

Table 1: Number of Participants and lessons in the study. NSW: New South Wales, QLD: Queensland, SA: South Australia.

<table>
<thead>
<tr>
<th></th>
<th>NSW</th>
<th>QLD</th>
<th>SA</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of schools</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>No of teachers</td>
<td>12</td>
<td>2</td>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>No of lessons</td>
<td>106</td>
<td>19</td>
<td>6</td>
<td>131</td>
</tr>
</tbody>
</table>

The lessons filmed spanned a unit of work in each school (approximately 6-10 lessons of a unit). Included in these lessons were introductory phases, explanatory and research lessons, and also a number of laboratory practicals. During the lesson observations field notes were taken. In addition to this data corpus, teachers were interviewed in a semi-structured manner and student work products were collected.

The analysis for this initial phase of the project focused on the classroom activity patterns where two aspects were considered (1) the kinds of knowledge that is presented in these classrooms and the cognitive activity this knowledge entails and (2) the modalities through which the knowledge types and cognitive activities are presented in the classroom. The coding categories were modified from previous coding schemes (Guo and Freebody, 2007; Luke et al., 2003).

The unit of analysis was the activity phase of the lesson within a unit of work. These phases included but were not limited to, introduction and review of previous work, question-answer discussion, demonstrations by the teacher followed by small group work carrying out a practical activity, and lesson summaries. It is these activity phases that were coded using the coding schemes.

**Coding classroom activities**

Once lesson observations were carried out the researchers saw the need to code the lessons in regard to pedagogical approach by the teacher. As such two coding frameworks were developed. The two coding frameworks were used to map patterns of practice by each teacher in their own particular context.

**Coding the modalities in use: The modalities framework**

To teach and learn science effectively, teachers and students need to grasp diverse representations of scientific concepts and processes, translate and transfer them, and comprehend how to orchestrate modality ensembles to represent scientific knowledge (Ainsworth, 1999; Jewitt, 2008; Kress, 2007; Lemke, 2005).
Although there are a number of classifications of these modes, some forms include categories such as: verbal (written, spoken), mathematical/symbolic, visual/graphical (pictorial, diagrammatic), gestural/kinaesthetic or material/operational representations of the same concept or process. The modalities coding framework devised for this study (Table 2) allows researchers to record not just the modalities used and their functions, but further, the representational forms (static or dynamic), the particular tool systems used by the teachers and students including textbooks, PowerPoint presentations, worksheets and the semiotic resources employed. The coding framework has been developed based on previous work (Kress, 2007; Lemke, 2005; Unsworth, 2001). This coding scheme was used to provide a detailed description of how teachers and students use multimodal texts in NLS classrooms and how NLS and its curricular applications in Australian schools blend and utilise multimodal textual experiences.

Table 2: The modalities coding scheme including examples that were coded in the observed lessons.

<table>
<thead>
<tr>
<th>MODALITY</th>
<th>REPRESENTATIONAL FORMS Static</th>
<th>Dynamic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Language/verbal Eg. speech, writing</td>
<td>Teacher shows students handout on greenhouse effect</td>
<td>Teacher discusses notion of clinical tests</td>
</tr>
<tr>
<td>Mathematical-symbolic</td>
<td>Teacher draws symbols for Haemagglutinin Inhibition test on board</td>
<td>Simulation for protein synthesis</td>
</tr>
<tr>
<td>Visual-graphical Eg. diagram, graph, image</td>
<td>Teacher points to diagram of a cell</td>
<td>Teacher has provided students web simulation of running an electrophoresis gel</td>
</tr>
<tr>
<td>Gestural-kinaesthetic</td>
<td>Not applicable</td>
<td>Teacher gestures the process of cell division</td>
</tr>
<tr>
<td>Material-operational Eg. use of specific tools, materials</td>
<td>Students use microscope to investigate onion skin</td>
<td>Teacher explains procedure and materials for preparing protein gel and use of micropipettes</td>
</tr>
</tbody>
</table>

Coding knowledge: The knowledge/cognitive dimensions framework

Recently a revised version of Bloom’s taxonomy has been developed to consider learning that covers both the kind of knowledge to be learned (factual, conceptual, procedural and metacognitive) and the cognitive processes used to learn this knowledge (remembering, understanding, applying, evaluating and creating) (Anderson & Krathwohl, 2001). This framework has been re-worked for teacher observations. The scheme, shown in Table 3, provides descriptions of teacher behaviour that depict the interaction of the cognitive and knowledge dimensions to allow the researchers to view and record what kind of knowledge was being deployed by the teacher as well as what was being done with that knowledge in each phase of the lesson.

Table 3: The knowledge and cognitive domains coding scheme and examples observed in Queensland, NSW and other NLS classrooms. Blank cells indicate an absence of available examples from observed classroom activities.
Results: Patterns of practice

NLS observed:
The teaching of NLS was observed in both NSW and QLD schools. The units in NSW that included NLS concepts such as DNA and protein synthesis, point mutations leading to disease and genetic engineering techniques were in core prescribed senior Biology syllabus units referred to as “Blueprint for Life” and “Search for Better Health”. Queensland Biology and Science 21 syllabus elective units observed included Biotechnology, Proteomics (the study of genetics that focuses on all the proteins expressed by the genome), Epidemiology (the study of the causes, distribution and control of disease in populations) and Virology (the study of viruses and viral diseases) addressing topics such as DNA isolation, DNA and Protein electrophoresis and characterising viral subtypes.

The way that NLS knowledge is constructed in the classroom has implications on both curriculum and pedagogical levels. It is evident that NLS areas were not the focus of the curriculum but rather offered as highly specialised topics appended to generally traditional science content (see Figure 1). One example being where the NLS topic transgenics (the genetic modification of an organism to contain genetic material from another organism) was appended onto the traditional topic of genetics without appropriate connections of content and concepts being made. This reflects the comments made by teachers that the emergence of NLS
as a meta-discipline has not been systematically matched with teacher professional learning or education programs.

![Diagram of traditional curriculum with NLS appended](image)

**Figure 1:** A diagrammatic depiction of traditional curriculum with NLS appended

*Relationships between knowledge, cognitive processes and modalities:*

An examination of the classroom activity patterns using the coding schemes revealed a number of patterns between cognitive activities engaged and modalities employed (Table 4). For example, when the main activity is reviewing factual knowledge, such as a question and answer session in a class about a previously learnt topic, the modality most commonly employed is verbal language. As the teacher starts to move progressively higher in the knowledge and cognitive levels however, modalities ensemble are required to support the cognitive approach to knowledge construction. For example, a teacher draws a diagram or writes a word on the board to explain a concept further or to complement the use of verbal language. A teacher may also use multiple representations to explain the same topic or reinforce certain knowledges. One example observed was where the teacher used a diagrammatic representation of a procedure used to produce a transgenic species while also showing a 2D still image of green fluorescent mice (a transgenic species) and an animation on the process of splicing DNA and inserting a gene (taken from a species of jelly fish) that codes for green fluorescent protein into a bacterial plasmid. In this example a range of modalities complement each other in representing and communicating the NLS process of transgenics in the classroom. This example is one of the most complex multimodal configurations that we observed and represents best practice for “the move of semiotic material from one mode to another” (Bezemer & Kress 2008, p176) also known as transduction.

<table>
<thead>
<tr>
<th>Cognitive activity</th>
<th>Modality(ies) employed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recalling factual knowledge</td>
<td>Verbal language</td>
</tr>
<tr>
<td>Understanding/applying conceptual knowledge</td>
<td>Multiple representations with ICTs</td>
</tr>
<tr>
<td></td>
<td>Supported by verbal language/gesture</td>
</tr>
<tr>
<td>Understanding/applying procedural knowledge</td>
<td>Multiple modalities with reliance on material operational meaning making &amp; mathematical/symbolic representations</td>
</tr>
<tr>
<td></td>
<td>Supported by verbal language</td>
</tr>
<tr>
<td></td>
<td>Supplemented with ICTs</td>
</tr>
</tbody>
</table>

Table 4: Observed relationships between cognitive activities and modalities employed in constructing NLS concepts.
The type of NLS knowledge also influenced the modalities employed by teachers. For example, where the main activity was constructing procedural knowledge, material-operational meaning making predominated. For example, a lesson on protein electrophoresis used authentic electrophoretic chambers. The teacher also demonstrated the use of these materials prior to students using them in a laboratory practical. In the same lesson, the teacher demonstrated the procedure using the chambers, micropipettes and authentic protein samples from animal muscle. Where access to technologies was more prominent, procedural knowledge was often reinforced through the use of computer-based simulations (in this example students carried out virtual electrophoresis activities following the practical experience (see http://learn.genetics.utah.edu/content/labs/gel/). A different teacher comments on the rationale for reinforcing knowledge through the use of virtual experimentation.

“They will do gel electrophoresis, they will do DNA extraction, they will insert a fluorescent gene from jelly fish so they are going to do hands-on stuff. The beauty of being able to use ICTs beforehand is that they can do some of this stuff online first in little integrated activities where they can interact with them and then do it in real life. We are also having a lecture from the Children’s Medical Research Institute about gene therapy and cloning and so on.....Again for them to be able to look through and see what these techniques are (using ICTs), what the processes are that are involved and be familiar with them... the lecture will make more sense when they have it” (CSIRO visit – 28/08/08).

Where practical activities were the key learning experiences for complex NLS concepts (eg. bacterial transformation) students claimed that the use of advanced visualisation technologies (eg. animations, simulations, 3D images) supplemented and reinforced understanding because they allowed them to visualise the process at a molecular level not observable by the naked eye. In regards to carrying out a bacterial transformation in a test tube as compared to viewing PowerPoint pictures of the process, a student comments;

“When we looked at the pictures they made more sense... you can’t see anything, when you have it in a test tube you can’t see anything... it is more clear in a picture.... The pictures look better - you could visually see how it works” (Teacher interview: 29/08/08).

Where advanced visualisation technologies were used to make meaning, this was often complemented by the use of gesture that took on a pointing or indicating function. Other modality ensembles included the use of gesture that often supplemented verbal language. Gestural movements were more pronounced when teachers were leading discussion with students (see Figure 2) and during role plays modelling complex processes such as immunity and viral transmission.

![Figure 2: Teacher A gestures the movement of chromosomes to either pole of the cell during meiosis in a discussion of genetic inheritance of disease.](image)
Additional examples of employed modality ensembles involved the use of mathematical-symbolic representations supported by verbal explanations. This usually occurred when the construction of complex NLS concepts required knowledge of discipline-specific representations. One such example includes a teacher explanation of the Haemagglutinin inhibition test for characterising viral subtypes where a verbal explanation of the procedure was complemented by an equation using signs and symbols that showed how the presence of antibodies to the type 2 viral Haemagglutinin protein prevented red blood cell clumping (see Figure 3).

Figure 3: A type 2 virus in the presence of an antibody to this viral type will prevent clumping of red blood cells.

The technologies available in the classroom also influenced the kinds of representations and modalities selected by teachers. Where a variety of technologies were available there was a perceived and greater reliance on modality ensembles and a diversity of representations used. Modes such as texts, diagrams, animations, images, lab equipment all featured here. Conversely, where there was a lack of available digital technologies there tended to be a greater reliance on verbal and written language and 2D static visual representations.

Conclusion

In summary, it was observed that NLS content was generally appended onto traditional science curriculum in the classroom. Teachers made it clear that there were a number of limitations on them to teach NLS effectively including lack of access to digital technologies, restriction of curriculum and professional development. This was evident in many teacher interviews. Multiple coding frameworks were used to map employed modalities to knowledge and cognitive processes in several lessons across 11 school science units where NLS were featured. Emerging findings demonstrate:

- NLS content is usually not the focus of the biology curriculum but rather is appended onto traditional content
- Best practice is evident with a number of modality ensembles used in representing and communicating NLS concepts
- The modalities engaged depends on the type of knowledge represented and
- Digital and other technologies available in the classroom influence the kinds of representations and modalities selected.
Compared to how traditional Biology syllabus content is taught, construction of NLS knowledge in the classroom requires a greater reliance on the modeling of complex phenomena (e.g., role plays on immunity, virtual activities on electrophoresis and practical activities demonstrating viral transmission), the use of advanced visualization technologies (e.g., animations on cloning, simulations on genetic modification) and the use of mathematical/symbolic representations (e.g., to represent complex structures such as DNA and complex processes as the Haemagglutinin inhibition test to characterize viral subtypes). Clearly, the impact of digital technologies on transforming knowledge and its representation in the NLS, is having an effect on how Biology is taught in classrooms today.

The findings of this study also reveal a relationship between cognitive and knowledge processes with certain modalities in representing and communicating NLS concepts in the classroom. The modality of verbal language is commonly used when a teacher is recalling factual knowledge. As the teacher moves progressively to higher levels in the cognitive and knowledge domains, multiple modalities are employed. Understanding and applying procedural knowledge, for example, often requires the use of an ensemble of modalities including verbal language, gestures, material-operational and mathematical/symbolic representations.

The following phase in the research is an intervention phase whereby teachers will participate in an intensive process to co-develop a set of practices with researchers that aim to develop pedagogical and assessment routines in the classroom and the laboratory. These will focus on both the productive use of technologies and modalities in the classroom as well as teachers’ and students’ understandings on NLS with a view to increase student outcomes in regard to knowledge and application of NLS concepts in their learning.

Our research has serious implications for developing teachers’ pedagogy in the area of NLS. In many educational jurisdictions there has been a new emphasis on curriculum to include NLS topics. However, there has not been the same level of attention given to professional development or extensive training programs for teachers to teach NLS effectively. This phase of the project is essential for the design, development and implementation of multimodal interventions with teachers so that an improvement in practice is likely.

References


