Technologies and the representation of ideas[1]

Professor John G. Hedberg, School of Education, Macquarie University, Sydney, Australia
john.hedberg@mac.com

Introduction

There is a change afoot and it might prove a pivotal point for the world of digital education. Technologies are more focussed on what the user wishes to achieve as an outcome, pedagogies are less focussed upon integration of ICTs and more on the need for the technologies to represent the information and knowledge of the discipline. We are moving into a time where the technology can assist us to represent ideas in a variety of forms, to share resources and to assist with the creation of a new forms of representation. Additionally as we employ collaborative tools and access the Internet, we can co-construct representations of our understandings about the world.

Technologies and educational contexts

While many new options are possible in our digital world, we must be aware of the hype with which many enthusiasts have approached this topic. For example, Prensky (2001) has coined the terms ‘digital native’ and ‘digital immigrant’ and while such a classification has definite appeal distinguishing the skill levels of those who have spent their complete lives living within a digital world, it is largely unsupported with solid evidence. However, the popular culture still abounds with beliefs about the ability of our students to manipulate the digital world with dexterity and speed. Interestingly, in a study about Singapore students a few years ago, we found that this digital expertise was limited by the expediency of the learning task (Hedberg, Brudvik, Tui and Towndrow 2006). Often students might find digital resources using the many search engines, but they did not always spend the time to carefully identify the relevance of what they found for the task they had been set. While they presented their solutions to learning challenges, they did not always ensure that their answers were the best and the most appropriate to the desired goal.

Prior to the computer age, only the book had major impact on ways in which we shared information and then at least until the Gutenberg printing revolution, it had more selective influence especially when compared with the current digital technologies and their links to Internet resources. In education we are increasingly witnessing a growing emphasis on the need to support learners not only to acquire knowledge and information, but also to develop the resources and skills necessary to engage with social and technical change, and to continue learning throughout the rest of their lives. Bereiter and Scardamalia (2005) suggest the use of the term ‘dialogic literacy’ ‘as the ability to engage productively in discourse whose purpose is to generate new knowledge and understanding’ (p. 11), and they contrast it with ‘functional literacy’ which refers to the ability to comprehend and use traditional communication media to serve the purposes of everyday life. Dialogic literacy is thus a fundamental literacy for a knowledge society. As Bereiter and Scardamalia (2005) note:

> ‘In every kind of knowledge-based, progressive organization, new knowledge and new directions are forged through dialogue… The dialogue in Knowledge Age organizations is not principally concerned with narrative, exposition, argument, and persuasion (the stand-bys of traditional rhetoric) but with solving problems and developing new ideas…Higher-order Knowledge Age skills have to do with collaboration, initiative, communication, and creativity.’ (p. 16-18)

[1] Aspects of this paper have been presented in other forums e.g. Hedberg, J.G., van Bergen, P., Freebody, P., Nichols, K., van Rooy, V., Barton, G. and Chan, E., (2008).

This concept is not tied to any particular representational medium, so long as the medium is one through which learners can interactively build their knowledge. Increasingly the forms of communication employ a range of modal representations in multiplicity of hybrid forms of 'texts' (Manovich 2006) and through interaction learners must decode and construct meaningful artefacts to represent their understanding. Each learning task thus focuses on problems and challenges developed around authentic situations, and learners must learn to express themselves within the context of the discipline knowledge. Thus, language and literacy in the classroom have become a research focus within Science Education. Investigations into the multimodalities of teaching and learning science (Kress, Jewitt, Ogborn and Tsatsarelis 2001) show that, along with the written and spoken word, communication modalities at work include gesture, body language, eye contact and movement as well as a range of digitally-mediated forms. The learning context of today extends beyond the traditional forms of learners' collaboration which in the recent past did not go much beyond than printed text. Findings indicate that in the Science classroom speaking is not the dominant mode of communication; teachers and students construct knowledge about particular scientific themes, such as cells, as a result of an orchestration of a range of modes…each with specific representational and communicational affordances and provenances that contribute in particular ways to the multimodal ensemble (Jewitt and Scott 2002).

Not only is collaboration key to this networked digital world, the form of discourse is also changing. Bereiter and Scardamalia (2005) also contrast the concept of dialogue with the concept of discussion:

> 'Discussion is aimed at settling differences, whereas dialogue is aimed at advancing beyond the participants' initial states of knowledge and belief…. Dialogue is purposeful, but it does not have a fixed goal. The goal evolves or emerges as the dialogue proceeds. Ability to sustain this open-ended yet goal-directed character would seem to be a hallmark of dialogic literacy.' (p. 12-13)

Also related to this distinction between discussion and dialogue they make a distinction between 'belief mode' and 'design mode' in how ideas are treated. 'In belief mode, the concern is with truth, evidence, and coherence. Rational argument is the preferred form of discourse in belief mode. In design mode, the concern is the usefulness and improvability of ideas' (p. 13).

The general argument being made is that we need to consider a range of ways in which we can represent our understandings and communicate them to others. In fact, our students are being asked to participate in collaborative open content systems, and to become familiar with notions of distributed creativity — especially where information, knowledge, and creative industries are accounting for an increasingly larger share of the economy in most Western nations. To be a meaningful participant in such a knowledge culture, students must acquire greater skills at assessing the reliability of information, which may come from multiple sources, some of which are governed by traditional gatekeepers, others of which must be crosschecked and vetted within a collective intelligence (Jenkins 2006). Contemporary creativity may no longer be focused towards creating original content, but is a practice of ripping, mixing and burning, where content is taken, appropriated, adapted, combined, and distributed in a way in which consumption of media and information becomes a productive act of remixing, transformations and creation of mash-ups of content from various sources.

Rethinking responses to technologies

Responding to teachers concerns about their use of technologies in the classroom, Vrasidas and Glass (2005) compiled several views about the task of preparing teachers to use technologies in the classroom, they found it easy to identify a number of significant obstacles to integration (Table 1), but their limited prescriptions for overcoming the obstacles suggest that it is not simply a matter of providing access to technologies. In fact, it requires successful experience in teaching with the technologies, and participating in a community that provides continuous support. In many higher education contexts some of these elements are missing. Certainly, many instructors have never used digital technologies as part of their own role as a learner, nor have they had training in, or previous experience of, teaching with digital technologies. Russell, Bebell and O'Dwyer (2005) also provide evidential support for the obstacles to digital technologies facing teachers in school contexts: while schools have invested in the technologies, teachers make little use of the technologies and students have limited access. However, they also point to the coarseness of the design and discussion, suggesting that teacher technology use is multifaceted and that to really address issues of technology use, it is important to collect multiple measures and realise that teachers value different technologies in different ways. The question still remains as we move into a time where the access to the technologies is less an issue, such as higher education, the challenge is how we begin to represent ideas and learning challenges in a world where 3D forms are becoming more readily available and the student of today is less concerned about presenting their ideas in traditional text.

Table 1: Obstacles to Integrating ICT in the Classroom (Vrasidas and Glass 2005, p. 8)

- The conservative nature of the traditional culture of schooling and classroom instruction.
- Teachers' resistance to changing their traditional teaching approaches.
- Lack of time for teachers to learn how to use and integrate ICT in their teaching.
- Lack of technology infrastructure.
- Lack of specific technologies that address the specific needs of teachers and students.
- Lack of ongoing support.
- Lack of released time and incentives for teacher innovators.
- Incompatibility of traditional teaching with the constructivist framework fostered by ICT.
- Need for teachers to unlearn traditional teaching beliefs and practices.
- Need to prepare teachers to integrate ICT by integrating ICT in teacher preparation programs.
- Need for policy, curriculum, and assessment reform.

So how should we select digital technologies to make a major difference in most teaching and learning contexts, when most of the instances are not radical shifts in approach? To suggest a possible answer to this question, Clayton Christensen (1997) proposed the idea of disruptive technologies. He claimed that a disruptive innovation or technology is one that eventually takes over the existing dominant technology in the market, despite the fact that the disruptive technology is both radically different from the leading technology and that it often initially performs less successfully than the leading technology according to existing measures of performance but over time the functionality or the attributes of the new way of doing things replace the older technologies. Here an obvious recent example is the demise of film as the medium for home photography. Over many decades acetate film provided the record of family and other real world experiences. Then towards the end of last century we had a potentially disruptive technology in the Polaroid film process. Visual records were now viewable almost immediately and several important uses were found for this technology. However, as the recording processes moved from analogue to digital mechanisms, suddenly the storage of images in a visually recognisable form was no longer required; they could be deconstructed, manipulated and retrieved at will through digital technologies. The digital images could also be transmitted with high quality and reconstructed to the same quality. Thus digital photographic technologies became disruptive technologies and replaced most forms of photographic film.

In the search for a digital pedagogical equivalent, it would seem that, so far, no such disruptive innovation has replaced our traditional pedagogies. However, consider the interactive whiteboard, which has made substantive inroads into the classroom in recent years, and in particular, the primary school classroom. Interactive whiteboards have provided several opportunities to include current data and resources in the classroom as required and to provide access to other classroom and linked resources and objects that in a wired world might challenge the role of traditional textbooks (Hedberg and Freebody 2007). Indeed the growth of e-learning pedagogies has enabled the curriculum of the educational institution to be more efficiently recorded and transmitted to learners in many different contexts. The representations that are made available through such technologies are sharable representations of concepts, many employing animation and interaction to enable the ideas to be built up and more quickly understood compared with verbal descriptions. Today students, who still meet in formal classes, will ask for many aspects of their course to be provided online and digitally so they can access the resources while managing a complex work and study schedule. Early in the use of e-learning technologies in higher education, there was student resistance to employing any online elements, but more recently in her survey of the technology universities, Alexander (2005) found that students valued:

1. access to information — knowing you could pre-read, or catch up;
2. asking questions — asking 'dumb' questions without embarrassment, and 'seeing' what other questions people were asking;
3. benchmarking and comparing — comparing your interpretations and products with others and understanding assessment demands and rubrics; and
4. time and place flexibility — being able to juggle work, family and study, reducing long commuting times and maximising the time spent on each activity and at what place that time would be spent.

Technologies and new sciences

In a current project, we are exploring how well teachers preparing Year 12 students for their examinations and future tertiary studies, understand the use of the digital options to represent and communicate ideas and concepts in what might be called the New Life Sciences (NLS)[2]. The project illustrates the melange of discipline, digital technologies and the changes in fundamental pedagogical processes through which students come to understand the discipline. The project began with the argument that the 'New Life Sciences', a collection of increasingly specialised areas of neuroscience, biochemistry, genetics and other bioscience fields; has required, in recent years, emerging digital technologies and other technological innovations to support the empirical exploration and simulation of phenomena that were formerly too small, large, slow or fast to be easily studied and taught – concepts such as the chromosome, the cell, the galaxy, etc. The technologies have begun to reshape and accelerate the emergence of entire fields of study based on these phenomena. Also in the NLS much new knowledge is produced and disseminated via digital technologies, and much is represented in symbolic forms other than, or in conjunction with language.

The project's task is to understand and to incorporate more pervasively the significance of digital technologies as sites for learning and for displays of the mastery of knowledge, in multi-modal and open-textured task domains. Not only the incidence of NLS concepts within Science classrooms is being documented as part of this project, but also the relationship between the emerging paradigm of NLS and its empirical and educational reliance on digital technologies. This implicates two issues – those multimodal ways of knowing and representing most readily afforded by digital technologies, and the additional affordance of open-ended, extended experimental, exploratory investigations. Theorisations of teaching and learning that draw on cognitive and interactional analyses, and the empirical bases they rest on, do not currently address these issues well. Further, such considerations put pressures on education systems (especially syllabus developers, technical supports, assessment practices, teacher-education programs, schools as well as teachers) to provide learners with new

2 See ARC Discovery Grant — DP0772550 Freebody; Hedberg; Nichols; and Van Rooy. *Transforming the technologies and modalities of learning: The case of the New Life Sciences in secondary schooling* (2007-2009).

kinds of educational experiences. The study responds to these rapid and mutually-reinforcing developments through the design of a research program aimed at a better theorisation of teaching and representation NLS concepts within Year 12 Science classrooms.

The project is in the first phase where a number of baseline classroom observations have been carried out in Queensland and New South Wales. The teaching of NLS concepts and associated use of digital and multimodal representations were coded through the application of coding schemes. The results to this point include the initial baseline observations of NLS classrooms and our development of coding schemes to map out the patterns of practice in these classrooms. Two coding schemes have been developed for this study focus on three 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.

Recently a revised version of the traditional Bloom's taxonomy has been devised 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). This framework has been re-worked for teacher observations. The scheme 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.

Technologies and multimodalities

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. Despite the various classifications of these modes, these forms include such categories 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 our study 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, and worksheets, and the semiotic resources employed. This coding scheme has been used to provide a detailed description of how teachers and students use multimodal texts in NLS classrooms.

In studying the use of multiple semiotic modes in Science and Science education, Lemke (2002) as explained why Science and Science teaching are necessarily multimodal: Different meaning-making resources have different strengths and weaknesses. Important here is the distinction Lemke drew between 'typological' and 'topological' meaning-making: '[a]ll semiotic resources, whether verbal language, mathematics, or visual representation, combine two basic principles for making meaning: meaning by kind and meaning by degree' Lemke (2002). Each semiotic resource is optimally organized around a certain type of meaning-making:

> 'Language, as a typologically oriented semiotic resource, is unsurpassed as a tool for the formulation of difference and relationship, for the making of categorical distinctions. It is much poorer … in resources for formulating degree, quantity, gradation, continuous change, continuous co-variation, non-integer ratios, varying proportionality, complex topological relations of relative nearness or connectedness, or nonlinear relationships and dynamical emergence.' (Lemke 1998, p. 87, 92)

Mathematics, visual representation, and gesture, for example, have evolved chiefly to help people make these latter, topological meanings, but, as Lemke (2002) pointed out, studying and producing scientific knowledge calls for both qualitative/categorical and quantitative reasoning practices. These developments are cultural, and, as the conclusions of studies in a number of countries have indicated, teachers need to come to terms with them rapidly, reshaping their understandings and practices, in the main without much theoretical or empirical guidance. With the growth of information in the NLS come questions about which modes of communication best represents what content, and whether changes in the representation of knowledge amount to changes in knowledge? National school Science curricular objectives emphasise the transmission of scientific knowledge and the training of scientific ways of communicating ('talking and writing like a scientist'), and then changes in the communicational environment will be crucial, most evidently in NLS.

Table 2. Summary of research on multimodal education in school

Modality	Participants	Results
Graphs and tables	Middle school students (12 yrs)	Students poor proficiency with graphs and tables
Images in astronomy	University students	Students' image interpretation not adequate
Graphs	Year 7, 8 and 10 students	Students have difficulty with image and text and did not perform well on graphic interpretation
Real-time graphs, pictures, animations	Students (12-18 yrs) and Science teachers	Students have difficulty Teachers are largely insensitive to students' difficulties
Graphs	University students and scientists	Students interpret graphs differently from scientists
Laboratory software	University Anatomy and Physiology students	Students have difficulty interpreting images without verbal narration
Primary and Secondary Science text	272 Secondary biology students from 4 schools (all studying the same topic)	Students reading primary text have better inquiry skills Students reading secondary text show better comprehension

[drawing largely on Baram-Tsabari and Yarden (2005); Bowen, Roth and McGinn (1999); Bowen and Roth (2002); Dawson, Skinner and Zeitlin (2003); and Peña and Quílez (2001)]

Comparatively little research has focused explicitly on interventions in pedagogical processes aimed at improving learning in multimodal settings. Some researchers (e.g., Cope and Kalantzis 2000; Pintó 2002) have described the difficulties students have in interpreting and constructing multimodal ensembles. Some of these findings are summarised in Table 2. Other researchers (e.g., Unsworth 2001) have set out to explore and improve the classroom practicalities associated with multimodal learning. One of the general conclusions from current research is that, while multimodal text analysis has advanced significantly over the last fifteen years (see Emmison and Smith 2000; Jewitt and Kress 2003; van Leeuwen and Jewitt 2001), there is now a need to move from descriptions of the structure and meaning-making potentials of multimodal texts toward a detailed description of how teachers and students actually use them and how they might use their potentials in everyday educational settings.

So the argument is that to appreciate, theoretically and practically, the ways in which literacy (in its broadest sense) can be 'maintained' through the learning experience is to engage its reconfiguration, pedagogically and cognitively, through encounters with: i) discipline-specific ways of representing knowledge; and ii) the technologies that make those representations possible in the use, transformation and production of that knowledge. Digital literacy derives its complexity as a field of practice and study from the practitioner's need to understand information in multiple formats and the skills of deciphering, among other things, images, sounds and text. (Gilster 1997; Lanham 1995; Lynch 1998).

Technologies and learning tasks

A further dimension of learning activities in science classrooms relates to the degree of structure and 'definiteness' of bodies of knowledge and tasks. Here it is important to draw the distinction between Stipulative and Open-textured knowledge and tasks. (In some traditions of research and theory, this is referred to variously, as, for example, 'well- versus ill-structured' or 'open versus closed' domains.) This distinction has been discussed (by Jonassen 1997) in these terms: Stipulative problems are those that are constrained, with convergent solutions that engage the application of a limited number of rules and principles, and with well-defined parameters, right answers and right ways to them; Open-textured problems entail potentially multiple solutions and solution pathways, fewer set parameters that are less manipulable, and uncertainties about which concepts, rules, sequences, and principles may be necessary for the solution, how these issues may be organised, and which solution is best for the particular task at hand.

Traditionally Science has been regarded as operating with strict, definition-based concepts that have determinate and generally abstract meanings, compared to some other subject areas that tend to operate with more open-textured concepts, in which the key categories, their attributes, and evaluations of their efficacy and moral value are subject to multiple interpretations. Traditional Science can be characterised as presenting students with a set of convergent goals, in which quasi-algorithmic, linear sequences of procedures lead toward a verifiable position (a 'right answer'); other subjects and disciplines generally present students, in their school tasks, with a cyclic, non-linear movements of procedures toward a broader base of multiple accounts, leading perhaps to a provisional, bounded position (a 'warrantable or defensible' interpretation or point of view). Digital technologies have been found to play a positive role in fostering the cognitive flexibility required of ill-structured problem-solvers (Spiro, Feltovich, Jacobson and Coulson 1992; Wiesenmayer and Koul 1998) and in enabling the sharing of information and discussion about the factors relating to contextualised problems (Jonassen and Hyug 2001).

This contrast – between closed versus open-textured information and task domains – itself interacts with the multi-modal and on-line perspectives available through the engagement of digital technologies. The sources of knowledge with which students may deal in such an environment are compacted in time and space, available online for immediate multiple access and use. Saye and Brush's (2002) recommendation of a learning environment whose core foundations and values are consistent psychologically, pedagogically, technologically, culturally, and pragmatically becomes crucial in the NLS, where much of the learning activity is exploratory and experimental (Barab, Young and Wang 1999). The issue for teachers concerns the potentially negative consequences, specifically in NLS, of the use of pedagogies that may be well suited to the traditional teaching of the disciplines and epistemologies but that may simply not afford NLS knowledge, as it is embodied in modalities and tasks, and afforded via certain technologies.

Outcomes observed in classrooms

This study has to this time observed 12 teachers in NSW and Queensland high schools each teaching classes of 12 to 22 students. They have been chosen to represent good Science pedagogy and address issues such as:

- public and private schools;
- differing levels of teacher experience, school resources, and student backgrounds; and

- differing curriculums: QLD is flexible and process-oriented; NSW is prescribed and focuses on content and skills

The approach has been to undertake video recordings of classroom activities over a unit of work, that normally includes about six to ten lessons. Units include those with both high and low potential for New Life Science content. Additional data sources include: interviews with teachers regarding their practice; samples of student work; and lessons analysed into phases and coded according to the coding schemes for modalities and conceptual/cognitive demands.

From the early result in this study, our qualitative analyses reveal three emerging trends: (1) Highly specialised NLS concepts did not typically form the central aspect/s of units of material taught in the classroom, but did nonetheless influence the material that is taught within many units (2) NLS content influenced how teachers represented concepts in the classroom, and (3) There were individual differences amongst schools and teachers in the extent to which both NLS concepts were integrated and digital and multimodal resources were employed. Whilst these findings are currently limited to qualitative analyses, note in addition that we expect, from preliminary investigations, that multivariate statistical analyses of the knowledge and modality will provide an interesting quantitative overview of how teachers structure each lesson; matching and supplementing our qualitative analyses of the interaction of these components with NLS content.

First, it emerged that highly specialised or 'pure' NLS content (e.g. proteomics, genomics) was not regularly taught as the central aspect of a unit of work in any of the classrooms, despite the relative degree of freedom in selecting topics afforded to the some teachers. It may be that students do not yet possess sufficient knowledge of basic biology concepts that underpin these highly specialised sub-disciplines. Consistent with this possibility, NLS-related concepts and sub-topics, necessary for the future understanding of more highly specialised NLS units of work, were often taught.

Second, it has emerged that NLS content influences how teachers represent concepts in the classroom. Visual-graphical images and visualisation techniques used in the NLS together with digital technologies have transformed the kinds of resources teachers and students have available to them. Indeed, some concepts can only be represented effectively using these technologies for example dynamic visual-graphical animations modelling complex processes. Investigation into the kinds of modalities used across phases, lessons, and units of work revealed that although technologies were used for a variety of topics, they were used to a greater extent when representing NLS content than other content. To this point we have found that where the main cognitive activity is understanding or analysing conceptual or procedural knowledge, much of the semiotic load is carried by multiple, complementary representations supported by verbal explanation. Where the main activity is applying procedural knowledge, material-operational meaning-making predominates but this is increasingly being supplemented by interactive computer simulations. In some cases for example where cutting edge experimentation may not be possible in schools, application is substituted by digital simulations. In fact, the more highly specialised or technical the knowledge, the greater the need for mathematical or discipline-specific symbolic representation, and the more complex the concepts the more it requires knowledge of discipline-specific representations.

Importantly, only some modalities depend on teacher and on lesson content. In particular, dynamic, non-verbal, visual-graphical digital representation of material was often more sophisticated and detailed when used to teach NLS and related concepts: many teachers used *Microsoft PowerPoint* presentations in place of the traditional 'talk and chalk' across topics, but were more likely to also show pictures and diagrams, animations, and the like when considering NLS-related material; that is, move beyond a written language-verbal representation to also include dynamic visual-graphical representations. Similarly, various interactive internet sites and digital worksheets based on these sites were used by teachers as a tool for consolidating previously learnt NLS-related information either at the end of a lesson or prior to beginning the next one. In contrast, effective teaching appeared to include monologic and dialogic verbal commentary irrespective of NLS content or of other modalities employed.

It should also be noted that the interaction of advanced technology and NLS content was not limited to digital materials, but also included the material-operational modality: one private school class used a variety of expensive and advanced equipment, including protein electrophoresis equipment to instruct students in the electrophoresis procedure. Such equipment enables the topic to be effectively taught, and its availability was therefore instrumental in determining the focus and direction of the unit.

Third, despite some trends towards what we would consider ‘best practice’, in which emerging digital technologies allow the teaching of various NLS concepts previously unable to be taught in a high-school classroom, there remained a wide variation in both focus on NLS topics and the use of digital technologies and multimodality in the observed classrooms.

One explanation for this finding is that teachers were in some instances restrained by resources. For example, at one public school a projector was available for projecting to the class computer images such as *PowerPoint* slides, but was stored on a trolley and shared between classes, needed to be booked, and teachers often wasted significant amounts of class time struggling to connect the projector to their computers and project the images they wished their class to see. In contrast, all private schools and some public schools had in-built projection systems. Similarly, many schools had wireless Internet available and utilised the Internet well, yet the number of laptops per student differed between schools, and in many cases the wireless Internet connection intermittently dropped out.

A second explanation is related to the teachers themselves. We intentionally selected teachers representing a range of schools, locations and teaching experience. Given the lack of teacher professional development and training in this area, it is likely that teachers bring to their classroom different levels of technological experience and competence. This then implicates the modalities that teacher is likely to use in their representation of knowledge and, by inference, the potential for innovative use of digital technologies in the NLS.

Implications

While there are positive instances of effective digital and multimodal representation of NLS concepts in the classroom, there are also significant individual differences amongst schools and teachers. These observational findings are an important preliminary step in enhancing teacher supervisory and facilitator skills to manage the design, set-up, testing and analysis of classroom teaching and laboratory projects in cutting edge science. Teachers need some assistance in managing NLS content and representations employing digital technologies. The next stage is to separate out, as much as is practicable, the changes due to enhanced use of multi-modalities from those associated with an enhanced understanding of the paradigmatic-integrative nature of the NLS.

This research example offers practitioners evidence that digital technologies integrating written and dynamic visual-graphical representations are in many cases being used to represent NLS concepts, but not necessarily entire NLS units, in the classroom. Evidence of ‘best practice’ also emerges: it is apparent that effective teaching of NLS concepts is aided in particular by the appropriate use of digital technologies for non-verbal modelling and demonstration, together with verbal framing and explanation of supporting concepts. These findings have implications in three key areas: curriculum development, classroom practice and the development of effective multimodal representation of NLS topics in the classroom.

To return to the concept of dialogic literacy, teachers and learners will need several new digital technology skills. In assessing the students' ability to work with digital representations they need to demonstrate:

1. *Dialogic literacy through social annotation — Mashup* — collating resources and selecting the most appropriate for the task. Kuiper, Volman and Terwel (2005) analysed the demands that the use of the Web as an information resource in education makes on the support and supervision of students' learning processes. The authors concluded that students need support in searching on the Web as well as in developing information literacy. Sending students to the Internet to do their own inquiry does not guarantee meaningful learning. Hedberg and Brudvik (2005) in a study on students' online inquiry behaviour in lower middle-school science and history classrooms found that most of the students spent lots of time searching for irrelevant information, and using the information by merely copying and pasting what was closest to a 'correct answer'.
2. *Dialogic literacy — Organising knowledge in a folksonomy*. An emerging aspect of software is the way that formal taxonomies and knowledge structures are giving way to 'folksonomies'. Instead of a scholarly designed taxonomy, a folksonomy - a collection of tags defined by people in the community of interest - emerges spontaneously from members of the community. Simply by applying tags that make sense, using tools that allow commonly applied tags to float to the surface, this provides the basis for sharing digital resources in any form and providing links independent of formally classified systems.

A bombardment of student 'voices' can be hard to manage in the digital worlds that we are currently inhabiting. It has illustrated the increasingly varied ways in which we can use the new tools to construct artefacts and communications that are no longer limited to the traditional texts but rather require new modalities of representation.

References

Alexander, S. (2005) E-Learning: blended directions. Paper presented to the E-agenda Conference, Singapore, May 2005.

Barab, S.A., Young, M.F. and Wang, J. (1999) The effects of navigational and generative activities in hypertext learning on problem solving and comprehension. *International Journal of Instructional Media*, **26**(3), 283–309.

Baram-Tsabari, A. and Yarden, A. (2005) Text genre as a factor in the formation of scientific literacy. *Journal of Research in Science Teaching*, **42**, 402–428.

Bereiter, C. and Scardamalia, M. (2005) *Technology and Literacies: From Print Literacy to Dialogic Literacy*. Retrieved March 20, 2007, from University of Toronto, Ontario Institute for Studies in Education Web site: http://www1.oise.utoronto.ca/projects/impactonpolicy/pdfs/ bereiter_edited_Feb_20_04.pdf.

Bowen, G.M. and Roth, W-M. (2002) Why students may not learn to interpret scientific inscriptions. *Research in Science Education*, **32**, 303–327.

Bowen, G.M., Roth, W-M., and McGinn, M.K. (1999) Interpretations of graphs by university biology students and practicing scientists: toward a social practice view of scientific representation practices. *Journal of Research in Science Teaching*, **36**, 1020–1043.

Christensen, C.M. (1997) *The Innovator's Dilemma*, Cambridge, MA: Harvard Business School Press.

Cope, B. and Kalantzis, M. (2000) *Multiliteracies: Literacy learning and the design of social futures*. London: Routledge.

Dawson, M.E., Skinner, S. and Zeitlin, A. (2003) Rules of engagement: proceed with caution when integrating multimedia learning tools into existing course formats. *Electronic Journal of Science Education,* **7**.

Emmison, M. and Smith, P. (2000) *Researching the Visual*. London: Sage.

Gilster, P. (1997) *Digital literacy*. New York: Wiley.

Hedberg, J.G. and Freebody, K. (2007) *Towards a disruptive pedagogy: Classroom practices that combine interactive whiteboards with TLF digital content*. Melbourne: Le@rning Federation. Retrieved August 15, 2007 from http://www.thelearningfederation.edu.au/tlf2/showMe.asp?nodeID=891.

Hedberg, J.G. and Brudvik, O.C. (2005) Visual representations for Students' learning processes in Internet Tasks. *Proceedings of the World Conference in Educational Multimedia 2005,* Montreal, Canada.

Hedberg, J.G., van Bergen, P., Freebody, P., Nichols' K., van Rooy, V., Barton, G. and Chan,' E. (2008) Transforming through Technologies the Modalities of Learning: New Life Sciences in Secondary Schooling. In J. Luca and E.R.

Weippl (Eds) *Proceedings of ED-MEDIA 2008 World Conference On Educational Multimedia, Hypermedia & Telecommunications*. (6322–6330). Chesapeake, VA: Association for the Advancement of Computing in Education. Published by Association for the Advancement of Computing in Education (AACE), P.O. Box 1545, Chesapeake, VA 23327-1545. ISBN: 1-880094-65-7.

Hedberg, J., Brudvik, O.C., Tiu, A. and Towndrown, P.A. (2006) Lower High-school Students' Approaches to Finding, Evaluating and Using Web Resources in History and Science Tasks: Technical report on the first-year study. Research Report RRS 06-004. Centre for Research in Pedagogy and Practice. National Institute of Education. Singapore.

Jenkins, H. (2006) *Confronting the Challenges of Participatory Culture: Media Education for the 21st Century. Building the Field of Digital Media and Learning.* Retrieved March 20, 2007, from The Macarthur Foundation, Building the Field of Digital Media and Learning Web site: http://www.digitallearning.macfound.org/atf/cf/%7B7E45C7E0-A3E0-4B89-AC9C-E807E1B0AE4E%7D/JENKINS_WHITE_PAPER.PDF.

Jewitt, C. and Kress, G. (Eds) (2003) *Multimodal Literacies*. New York: Peter Lang.

Jewitt, C. and Scott, P. (2002) Meaning Making in science classrooms: a joint perspective drawing on multimodal and sociocultural theoretical approaches. *Language, action and communication in science education symposium*, ISCRAT, 2002.

Jonassen, D.H., and Hyug, I. (2001) Communication patterns in computer mediated versus face-to-face group problem solving. *Educational Technology Research and Development*, **49**(1), 35–51.

Jonassen, D.H. (1997) Instructional design models for well-structured and ill-structured problem-solving learning outcomes. *Educational Technology Research and Development*, **45**, 65–95.

Kress, G., Jewitt, C., Ogborn, J. and Tsatsarelis, C. (2001). *Multimodal Teaching and Learning: The Rhetorics of the Science Classroom*. London: Continuum.

Kuiper, E., Volman, M. and Terwel, J. (2005) The Web as an Information Resource in K-12 Education: Strategies for Supporting Students in Searching and Processing Information. *Review of Educational Research*, **75**(3), 285–328.

Lanham, R.A. (1995) Digital literacy. *Scientific American*, **272**(3), 160–161.

Lemke, J.L. (1998) Multiplying meaning: Visual and verbal semiotics in scientific text. In J.R. Martin and R. Veel (Eds), *Reading Science: Critical and Functional Perspectives on Discourses of Science.* London: Routledge, 87–113.

Lemke, J. L. (2002) Teaching all the languages of Science: words, symbols, images, and actions. In M. Benlloch, *La educacion en ciencias*. Barcelona: Paidos. 159–186.

Lynch, C. (1998) Information Literacy and information technology literacy: New components in the curriculum for a digital culture. Committee on Information Technology Literacy. Retrieved October 8 2004 from http://staff.cni.org/~clifford/papers/cni-info-it-lit.html.

Manovich, L. (2006) *Remixing and Remixability*. Retrieved March 25 2007, from http://www.manovich.net/.

Peña, B.M. and Quílez, M.J.G. (2001) The importance of images in astronomy education. *International Journal of Science Education*, **23**, 1125–1135.

Pintó, R. (2002) Introduction to the Science Teacher Training in an Information Society (STTIS). project. *International Journal of Science Education*, **24**(3), 227–234.

Prensky, M. (2001) Digital Natives, Digital Immigrants. *On the Horizon*, **9**(5). Retrieved February 3 2007, from http://www.marcprensky.com/writing/default.asp.

Russell, M., Bebell, D., and O'Dwyer, L.M. (2005) Tracking the arc of new teachers technology use. In C. Vrasidas, and G.V. Glass, (Eds). *Preparing teachers to teach with technology*. (45–63). Greenwich, CT: Information Age publishing.

Saye, J.W. and Brush, T. (2002) Scaffolding critical reasoning about History and social issues in multimedia-supported learning environments. *Educational Technology Research and Development*, **50**, 77–96.

Spiro, R.J., Feltovich, P.J., Jacobson, M.J. and Coulson, R.L. (1992) Cognitive flexibility, constructivism, and hypertext: Random access instruction for advanced knowledge acquisition in ill-structured domains. In T.M. Duffy and D.H. Jonassen (Eds), *Constructivism and the technology of instruction: A conversation.* Hillsdale, NJ: Lawrence Erlbaum.

Unsworth, L. (2001) *Teaching Multiliteracies across the Curriculum: Changing Contexts of Text and Image in Classroom, Practice*. Buckingham: Open University Press.

van Leeuwen, T. and Jewitt, C. (eds) (2001) *Handbook of Visual Analysis.* London: Sage.

Vrasidas, C. and Glass, G.V. (Eds) (2005) *Preparing teachers to teach with technology*. Greenwich, CT: Information Age publishing.

Wiesenmayer, R.L. and Koul, R. (1998) Integrating internet resources in the Science classroom. *Journal of Science Education and Technology*, **7**, 271–7.