Unlocking the potential of multimodal representation (MMR) to foster dialogue that promotes learning in science, 2010

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Science employs multimodal representation as a set of cultural tools that facilitate the ‘doing’, knowing and understanding of science. The use of MMRs in science has evolved over time to reflect the nature of science. Research has highlighted the need to ‘unlock the potential’ of effective language use to support enhanced student learning. How do we approach this challenge? Multimodal representation requires far more than control over the conventions of language, it requires the ability to combine and use MMRs appropriately and flexibly in a variety of contexts. This is the first chapter in the story of how students use MMRs. The story begins towards the end of school life for a group of students, but generates questions that point to the need for dialogue between teachers at all levels of students’ schooling. It provides some tentative suggestions for the kinds of things that teachers could do to enhance learning through MMR.

Language in its many modes (oral, written, visual) is fundamental to all human activity. It is the system used to share knowledge, understandings, ideas, and beliefs and undertake any other human activity. Sometimes the message is clear, such as the widely understood visual message of a ‘no smoking’ sign (Figure 1). At other times meaning can be much less clear, for example antiquities.
such as Stonehenge. Interpretations of these artefacts are often fraught with conjecture and controversy. The problem being that we do not have the cultural understandings to interpret such things as we do not understand the symbolism of the ‘language’ that is used because we can only use a mixture of evidence and imagination to understand the people who created such things. This adds weight to the notion of language being a set of cultural tools. The nature and form of language use is determined by the context and purpose for such language use (Halliday, 1985) and relies on the people using language having common cultural knowledge and understandings. Literacy is the ability to apply language flexibly and appropriately in a wide variety of contexts which culturally defined. Academic disciplines have their own distinct cultures and unique ways of using language to enhance and further learning. Children from their earliest learning experiences need to know that all language is not the same and that language is used in special and distinctive ways by people working in disciplines such as science or history or mathematics.

Multimodal representation (MMR) is here defined as the individual modes (written, graphical, oral, mathematical and kinaesthetic) of language and forms (graphs, tables, paragraphs, diagrams, dialogue, etc) that are used in a variety of combinations to present, represent and re-represent science data, ideas, knowledge and concepts, and that support and enhance the pursuit of science. Scientists must find ways of representing complex things in ways that still maintain the integrity of the original referent (the thing they are studying), whilst facilitating the study of the key elements required to answer the question that is being considered. Sometimes, to do this effectively, scientists need to use a variety of representations and may need to transform information or data from one form to another, hence, over time the use multimodal representation has evolved in science.

Scientific literacy is the ability to combine language, knowledge and conceptual understandings flexibly and in a variety of contexts as an initiate of the culture and nature of science. Science uses multiple modes of representation for providing instruction, exploring ideas and communicating. Often MMR (multimodal representation) is used in scientific investigations to translate the results of activity (e.g. experiments) and observations into data which can then be compared and contrasted with existing scientific knowledge and conceptual understandings, so that new knowledge can be built (Latour, 1999). As such, a robust understanding and ability to use MMR effectively may be seen as crucial to the development of scientific literacy. International and national research (Goodrum, Hackling, & Rennie, 2001; Goodrum & Rennie, 2007; Organisation for Economic Co-operation and
Development, 2009; Tytler, 2007; Yore & Treagust, 2006) and the draft Australian Science curriculum (Australian Curriculum Assessment and Reporting Authority, 2010a, 2010b) emphasise the import of the development of scientific literacy as a fundamental outcome of science education for all students. Once achieved, it will mean that as tomorrow’s citizens and workers, students will be better equipped to make informed decisions about changes and issues related to advances in science and technology. This paper will explore how science learning can provide opportunities for a group of upper school students to continue developing their scientific literacy through the use of MMR. It will explore some of the things teachers can do to embed effective content area literacy into a regular upper school science program. It is also suggested that some of these things could be added to primary science learning so that students are well-prepared for the things they need to do in high school science.

Latour (1999) describes how scientists employ such representations. A rainforest ecosystem is transformed through a variety of representations designed to assist and augment the systematic collection of data that will be used to shed light on an identified problem. Data collected using such representations are done in such a way that they can be traced back and forth between the original referent and the various representations. Such data can be taken back to the university with confidence that further analysis will accurately represent the situation in the forest. If students are to maximise their learning in science, they need to gain control and understanding of how MMR is used in science. The following presents a brief sketch through the work of real scientists. Figure 2 represents a conceptualisation of a few of the transformations used by scientists as they collected data on an expedition to the Boa Vista forest. Scientists have come to the area because the rainforest suddenly stops and there is a drastic change in vegetation. There is no apparent reason for this phenomenon and the scientists plan to look at things like geological, pedological and other factors that may be the cause of this anomaly. The left hand side of the diagram shows the way the physical location and the plants found in the area are transformed into forms and representations that maintain the essence of the original referent by examining them and representing them in great detail. For example, plant specimens are collected and processed for transportation to the
laboratory but a further transformation occurs as their details, descriptions and locations are noted. At the final stage once the samples are taken back to the university they are placed in a shelves that are organised using a scientific taxonomy. At each transformation all attempts are made to ensure that the representation refers back to the original reference creating a ‘circular reference.’ (Latour, 1999 p.24). This means that even when the data that is collected and taken back to the university, a scientist who has not been part of the expedition will be able to make sense of what has been collected and be able to analyse the materials and relate them to the original research questions. In the work of practicing scientists the process of presenting, representing and re-presenting science is employed for its capacity to transform and deepen the knowledge it contains with each multimodal representational “pass” (Tytler, 2007 p.35). Students need to learn how scientists use MMR and how it can be used to deepen understanding. MMR is not a series of random acts but a deliberate system used for exploring, storing and transmitting items of scientific interest. The teachers involved in the
initial stages of this research orchestrated opportunities for students to work with MMR. As an observer who had worked with science teachers to improve literacy, these teachers provided a new perspective on how such relationships and roles should work and the depth of knowledge that can be attained.

The City School Chicken Massacre is an investigation that was done by the Stage 1 Integrated Science students as part of a unit on forensic science. The investigation was designed to find out about what happens when bodies of chickens are left to decay under different conditions. This investigation provided students with the opportunity to think about, do and represent science in a realistic situation to find the answer to an important question – one that is important if you are interested in forensic science. The discussion that is provided is a composite of the actions of the two classes involved. It provides some pointers about ways we can get children of all ages to learn more from their science experiences.

One of the aims of the teachers was to get their students to ‘stand in the shoes’ of a forensic scientist. They knew from experience, that many of the students drew their prior knowledge from programs such as NCIS which generally glossed over the scientific evidence and the conceptual understandings that underpin the practice of forensic science. They also knew from experience that students will just ‘do’ science without making the connections to how and why. The teachers had students watch footage of real forensic scientists who not only demonstrated their craft but also ‘talked aloud’ about how and why they were doing what they were doing. The teachers used this representation to help students make connections between the activity of forensic science and the underpinning science concepts and processes. Students were challenged to compare their TV experiences to those of a real forensic scientist. They watched as these practitioners articulated their actions and emphasised the need to collect data and evidence using representations that would allow the reconstruction of the crime scene at a late date; much in the same way that the Boa Vista scientists collected their data.

These teachers work in classes with a very high proportion of students who are ESL/ESD (English as a Second Language / English as a Second Dialect) learners. Many of the students are new learners of English who have only been learning for a few years. Research indicates that it takes new English learners up to seven years to develop CALP (Cognitive Academic Language Proficiency) (Cummins, 2008) which enables them to participate in school learning at their level. These teachers face the challenge of teaching such students in upper school Stage 1 Integrated Science, with some students only having basic literacy skills equivalent to children in years 1 – 3. What is remarkable is that such students, when given rich opportunities to notice, learn and use MMR in science, can develop deep knowledge and conceptual understandings. In terms of basic literacy they may be on a par with much younger students but they are able to engage in quite complex science learning using MMR. Perhaps, a similar approach might benefit younger students who do not ‘get’ the basics straight away?

The literacy wars have seen approaches bounce between top-down meaning based approaches to bottom-up skill based approaches with every conceivable approach in between these two extremes.
With the attention and debate that the literacy wars have been given, it is hardly surprising that content area teacher think that teaching literacy means teaching children to read and write. Whilst literacy basics are fundamental to learning, students also need to be supported to gain control over the distinctive discipline literacies too. In high school science classes, clearly science teachers are the best people to address this need. However, primary students need to be introduced to content area language use in parallel with mastering the basics so they are at least aware of the different ways that language is used in the different discipline areas. For native speakers many elements of language use are unspoken or unconscious, for students who are not native speakers or who do not come from a rich language background, this can be problematic.

The activities associated with the various units of study in these Year 11 Integrated science classes are very ‘hands on’ with teachers foregrounding much of students’ learning through MMR by using observation, activity and oral discussion. This provides students with the experiences they need to explore the topic through various MMRs. Oral language allows students to observe primary data, talk about their ideas and plan ways of using MMRs during their investigations.

During the Forensic science unit the students undertook a number of activities designed to expand their working knowledge of forensic science from one based on what they watched on CSI to one with strong scientific underpinnings. They learnt about fingerprint evidence; the collection of other forensic evidence including how to interpret blood spatter patterns. The City School Chicken Massacre was an ongoing investigation for students to see how the carcasses of 3 chickens decomposed over time. The correct and appropriate use of science language and vocabulary is always at the fore. The chicken investigation provides an indication of the learning that can occur through such hands on activity.

The teachers have a strong focus on language and supporting students to move from using their everyday language to science language. For example, students were scaffolded as they moved from using the everyday phrase ‘the study of insects’, to the term ‘entomology.’ This was done through introducing the term through a video recording with the teacher highlighting the term which was followed up with discussion during which the teacher encouraged the students to use and consolidate their scientific language. Oral language is an important mode of language used in MMR in that it can be used to explore and familiarise students with new discipline content and language without overtaxing the cognitive load (Mayer, 2005). Our brains can only hold a small amount of new material in working memory, so for students who are learning a new language or who have difficulties in the native language, oral language provides an excellent medium for introducing new content from whence it can be stored in long term memory. Material accessed from long term memory does not place any extra cognitive load on the learner, hence the importance of utilising prior knowledge. In this case, the teachers use oral language to ‘frontload’ student knowledge so they have more cognitive space to deal with ongoing learning demands. Over subsequent days the students continually use the new language including the written form. One of the teachers indicated that most students internalise new vocabulary that is introduced in this way in the context of their learning in about 3 – 5 days.
During this investigation, students collected a variety of data including: insect samples; visual observations and the weights of the carcasses were measured weekly. Students used a variety of ways to explore record and discuss their work. Insect samples were preserved and students re-represented them in sketches that highlighted their forms. These were matched against existing taxonomies that helped the students accurately identify each species. Also, students were able to observe the life cycle of some insects from egg to fly. These activities provided students with real life experiences of the application of important scientific concepts and as such added to their scientific literacy. The focus was firmly on the science but the teachers encouraged the use of oral language that had students discussing and explaining their understandings not only of the content but of the various representations they had used and how these were links in the chain of evidence as was done by the scientists working on a different question in the Boa Vista Forest. By the time students came to write about the investigation they had a good grasp of the key science content and their findings.

Students collected data on the change in weights of the chickens over a number of weeks and from these, graphs were created. According to Wallace and Hand (2007) many students may construct tables and graphs, but often fail to refer to them when writing the conclusions for an investigation. It was pleasing to see that at least some of these students did and when questioned others had clearly looked at the tables and graphs and understood what they said, but didn’t think they needed to include such information in their writing. Ainsworth (1999) notes the difficulties that students have moving between the different forms of language used in science. One would imagine that after almost 10 years of school science this would be automatic for most students, but clearly it isn’t. Whilst many of the students in this study did not have the advantage of ten years of school science, teachers indicated that they found that Year 12 TEE students do have problems in this area.

There is a clear indication that something is going wrong. Many primary teachers lack confidence in teaching science and programs such as Primary Connections are going a long way towards solving this issue. However, just as high school content area teachers should pay attention to some of the simple basics of language such as correct spelling and grammar, it may be that primary teachers also need to prepare students for science by helping them make connections between the words of science and the ways language is used in science. Programs such as Primary Connections which use an inquiry based approach to science that incorporates Bybee’s 5Es model (Bybee et al., 2006) provide teachers with science activity that encourages exploration of not only the content of science (the ‘what?’) but also the ‘why?’ and the ‘how?’ of science.

Further research will be undertaken to ascertain effective ways of introducing students to the unique language of science and its uses. The way that vocabulary was introduced by these teachers certainly has promise with students being able to internalise new vocabulary quite effectively. More work needs to be done on examining ways of helping students use MMR s to their greatest effect. Efforts are needed to help students focus on the connections between all of the different representations that are used in science and how they all contribute to exploring the key scientific ideas and concepts under
consideration. To do this we need to teach critical scientific literacy where language, thinking and science are unified.

Previous work with high school science teachers had indicated that the vast majority did not believe they should ‘do literacy.’ This echoes the sentiments of the International Reading Association’s Position Statement on adolescent literacy:

High school teachers often feel a great responsibility to impart knowledge about subjects such as science ... in which they are expert. This focus on subject matter is supported by the typical organization of high schools with the faculty assigned to separate departments and the day divided among separate subjects. Many teachers come to believe that teaching students how to effectively read and write is not their responsibility. Without intending to do so, they might send subtle messages that adolescents’ continued growth in reading and writing is incidental. (Moore, Bean, Birdyshaw, & Rycik, 1999 p.4)

In primary schools, the focus for many decades has been on students acquiring basic reading and writing skills and in recent years the NAPLAN tests for years 3, 5, 7 and 9 have put the focus directly on the assessment of such skills with only minimal attention being paid to the literacies of the content areas. The question here concerns what is understood by the requirement ‘to effectively teach students to read and write’ (Moore, et al., 1999 p.4). Perhaps, content area teachers are viewing this as their being expected to teach students how to read and write as opposed to teaching them how to use their literacy for learning in the content area. Much literacy support in across the curriculum in high schools has been generic in nature and does focus on the acquisition and remediation of such early skills, a bottom up approach. Thus it is not surprising that content area teachers may have the view that this is not their job. It isn’t. However, much can be done to motivate and engage students and deepen their learning when content area teachers help students to notice and learn how to use language – MMR and the individual modes and forms of language- that is exclusive to science.
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