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# *Scientific Literacy, E-Literacy and Illiteracy: The Interaction Between Two Pupils and One Simulation*

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ABSTRACT *This paper explores the influence of symbolic or representational learning materials on pupil engagement or learning outcomes, when 14-16 year old pupils use common types of science simulations. The project pilot phase involved three (15-16 year old) male pupils and a main phase involved twenty-one (14-15 year old) pupils. A retrospective accounts methodology (Clarke, 1998) presented pupils with a digital record of their 'think aloud' (Ericsson & Simon, 1984) behaviour with the simulation, and they were asked for retrospective comment. Pre- and post-surveys were also used. This interaction record for two boys is used to illustrate the findings. This record was chosen, because the boys spoke aloud throughout the period of engagement, which generated useful data for microanalysis. Findings suggest that pupils working with science simulations face a trans-disciplinary demand (computer competence, information processing skills, traditional language proficiency, and science understanding). In terms of traditional and subject literacy, pupils have to make sense of linguistically complex information when using common science simulations. They need to understand their subject, be confident and competent with the available technology, and possess language skills that enable them to establish links between the microscopic, macroscopic and symbolic components of science.*

KEY WORDS: *E-Literacy, Illiteracy, Scientific literacy, simulations.*

## Introduction

There is growing documentation on how computer-based technologies are impacting on communicative practices in school, and many are suggesting that this requires new understandings about literacy (Unsworth, 2001). Some (see Rodrigues, 2004) suggest that teachers need to use technologies as more than tools; they have to ensure that working with these technologies goes beyond simply locating and retrieving information. Users need to develop strategies that enable them to critically evaluate information and be able to work across semiotic systems in designing multimodal representations (Unsworth, 2001). It has been argued that literacy exists not only on a screen or on paper, but also in the practices that surround it and the situation in which literacy is carried out (Unsworth, 2001; Mackey, 2002). Lemke (1998) pointed out that science education, and scientific texts in particular, involve images (graphs, diagrams, etc) and written text, and that these components contribute differently to knowledge construction. Therefore, given the increasing push to use simulations in science, we need to understand how these different modalities separately and interactively help in the construction of meaning.

Many studies investigating changes in multimedia representation discuss the concept of working memory and cognitive load (Kester, Kirschner, & van Merriënboer, 2004; Kirriemuir & McFarlane, 2004), arguing that the nature of the representation (visual, text, aural, or various combinations) make significant cognitive demands on the user. For example, it has been posited that changing the presentation format in multimedia may reduce cognitive demand (Sweller, van Merriënboer, & Pass, 1998). Or to be more precise, as Mayer (2003) suggests, multimedia instructions are more effective, when aural and visual information is presented close together (the contiguity principle), and instructions are effective when verbal information is presented aurally rather than visually (the modality principle). However, Tabbers, Martens, and van Merriënboer, (2004) suggest that the reduction in cognitive load findings could also be explained by a reduction in visual search. In addition, the cognitive load argument finds itself in a quandary, because similarly demanding representations that are commonly found in computer games do not appear to generate cognitive overload.

Regardless of these cognitive load issues, the last two decades have seen an increase in the number of calls to include various forms of multimedia and computer-based technology in science education (see Rodrigues, 2004). Support for the integration of computer-based technology is guided by a belief that use will empower teachers and pupils, and result in enhanced learning outcomes (Leach & Moon, 2000; Loveless & Ellis, 2001). However, if digital literacy involves the ability to use computer-presented information in multiple formats from a wide range of sources (Glister, 1997), then informed use of multimedia in science will require digital literacy. Though the concept of digital literacy is still developing, the National Research Council: Committee on Information Technology Literacy (1999) considers digital literacy to be an ability to apply information technology in complex and sustained situations, and to understand the consequences of the action. Digital literacy in science education can therefore be viewed as the relationship between process/skills-based components and concept-based components that are particular to the science classroom. The process/skill-based component includes computer skills (technical computer related competence) and information processing skills (a competence that requires being able to recognize information need, retrieve, evaluate, use and disseminate information). The concept-based component includes traditional literacy (language competence) and subject literacy (science competence). A small-scale project involving 24 students from two schools was initiated in order to explore the influence of these components on the way students make sense of science.

## Methodology

The project involved two phases. The first phase piloted the technique with three male students (aged 15-16 years). A retrospective accounts methodology (Clarke, 1998) involving 'thinking aloud' (Ericsson & Simon, 1984) was used to access students' thinking. The 'thinking aloud' strategy has been used in cognitive psychology research, and is often used to explore pupils' problem-solving strategies; however, recent times have seen this strategy used to explore pupil-computer interactions (Crowther, Keller, & Waddoups, 2004). Digital records documenting students' 'at-the time' behaviour and actions were collected and then replayed to them. The students were asked to explain their actions during this informal, semi-structured retrospective interview. In addition, the students completed pre and post surveys. The main phase involved 21 volunteers (male and female students aged 14-15 years) from another school. These students worked in pairs (apart from one group of three). The paired approach was an attempt to reduce students' viewing this task as a test, and it was felt that pair working may encourage more 'thinking aloud' as students conversed. Digital records were collected and then replayed during the semi structured interviews. The transcripts found in this paper have been coded to render the students some degree of anonymity.

Analysis of one record is reported in this paper. It was chosen because the two male students were talking aloud throughout the whole period of engagement, and their digital record therefore provides useful data for microanalysis. This digital record and transcript was made available to a team of four comprising the principal investigator, a language specialist, a science specialist, and a technology specialist. Using a modified version of Clarke's (1998) complementary accounts methodology approach, the insights provided by these four perspectives inform the discussion in this paper.

This article reflects on the engagement with a simulation that required students to make sense of multiple format information. Figure 1 provides a screenshot of the simulation under discussion. It is a commonly found type of science simulation.

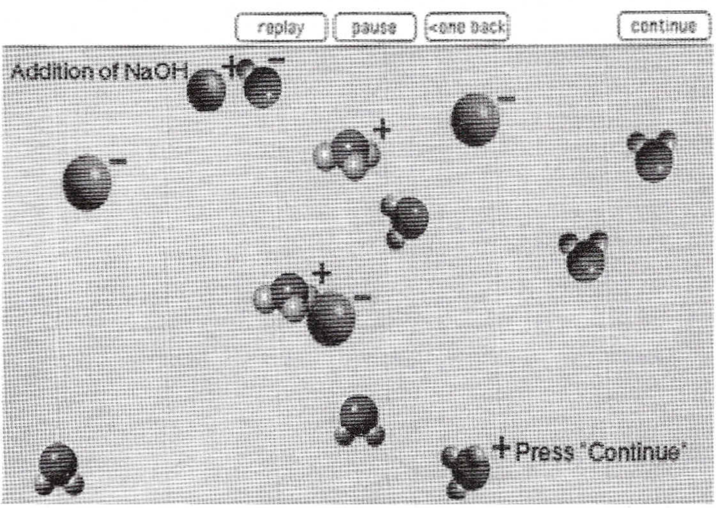


*Figure 1. A screenshot to a Simulation*

The simulation used in this project is freely available on the following website, http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/animationsindex.htm. It is typical of many commercially available science education simulations. The website provided tutorial worksheets, but these were not used, as the intention was to gain an insight into the digital literacy demands made by the simulation and not the support documentation.

The pupils described in this paper use a simulation representing the reaction between sodium hydroxide and hydrochloric acid, on a microscopic level. The simulation shows a series of tab instructions on the top edge of the simulation, some text, some icons and some symbols on screen. If the simulation is allowed to run its course, the icons and symbols move erratically and collide sometimes, and occasionally new text appears on screen. This text either provides direction regarding continued use of the simulation or information relevant to making sense of the science.

## Findings

The digital recordings of the pupils working together with the simulation suggest that they are familiar with working together. For example, they complete each other's sentences:

*Sam* *They are like (pause). Right. So.. basically, we have got all these wee…*
*Jim* *Things…*
*Sam* *Negatives. Neutrons and …..*
*Jim* *Charge things…*
*Sam* *Protons and …*
*Jim* *Neutrons…*
*Sam* *Electrons and protons and..*
*Jim* *Neutrons*

Transcript 1. Excerpt from Pupil Engagement Recording

Their discussions are purposeful. Their register also suggests that they are comfortable working together and the change in register whenever they reach a conclusion suggests that they are confident.

### Technology

The two male pupils will be referred to in this paper as Jim and Sam. They were asked to rate their experience level and comfort level for several applications, using a scale of 1-4. where the ratings indicated the following::

| Experience level (E) | Comfort level (C) |
|---|---|
| 1= a lot of experience | 1= very comfortable |
| 2= some experience | 2= moderately comfortable |
| 3=a little experience | 3= would need some help to feel comfortable |
| 4 = no experience | 4 would need lots of help to feel comfortable |

Table 1 documents their self-rating, their experience rating (E) value is presented first, and then their comfort level (C) rating.

*Table 1*
*Comfort and Experience with Various Technologies.*

| Activities using technology | Jim | | Sam | |
|---|---|---|---|---|
| | Experience | Comfort | Experience | Comfort |
| Word processing | 1 | 1 | 1 | 1 |
| Databases | 2 | 2 | 3 | 3 |
| Presentation software/Powerpoint | 2 | 2 | 1 | 1 |
| Computer games | 1 | 1 | 1 | 1 |
| Internet search engines | 1 | 1 | 1 | 1 |
| Simulations | 3 | 3 | 3 | 2 |
| Desktop publishing | 3 | 3 | 3 | 3 |

Jim (aged 14) and Sam (aged 15) felt they were very or moderately comfortable with word processing and playing computer games, but not very or moderately comfortable using simulations. These experience and comfort ratings are of interest for two reasons. First, it would appear that these two pupils do not equate computer games with simulations, and second, their Internet use does not predominantly involve simulations. These two pupils were part of the project sample of 24. Overall, 16 of the 24 pupils felt that they had lots of experience of word processors, 17/24 said they had lots of experience of computer games, and 17/24 said they had lots of experience of the internet, but only 4 said they had lots of experience with simulations.

The simulation is neither as complex nor as vivid as that found in the average computer game. In essence, information is presented through dialogue boxes and two-dimensional dynamic icons, with a pale blue screen background. Yet, in general the dialogue between Jim and Sam suggests that they are engaged when using the simulation.

From a technology literacy perspective, although the visual media is not as sophisticated as that encountered in many computer games, the need to pay attention to detail is significant. The tab buttons provide access to the technology component of the simulation, i.e., the need to replay, or revisit the animation is managed by using these tab buttons. In addition, the introduction of labelled icons, albeit fleetingly in some cases, provides some clues to help make sense of the science. The text boxes provide access to key words and useful instruction. These on screen text boxes help situate the animation in terms of the science.

The labels that accompany the icons are in some cases fleeting, while others remain permanently on screen. For example, the spheres representing NaOH are initially introduced with that label. Likewise, the sphere representing Cl- is also labelled. However, on dissociation, the Na+ is reduced to being represented as a sphere with '+'. Likewise, the Cl- ion is reduced to being represented as a sphere with a '-' alongside. These subliminal clues resulted in the pupils associating the simulation with atomic charge (protons, neutrons, and electrons). The initial text box that signalled the simulation as a neutralisation experiment between acid and alkali was on screen at the start, and while it was accessible whenever the pupils replayed the simulation, it was not 'on screen' to the same extent as the spheres with positive or negative symbols. In addition, the text boxes with information relevant to science rather than activity instruction may have been better presented through a sound track.

**Linguistics**

Language is considered a crucial element in the understanding of learning through negotiated meaning (Holliday & Hessian, 1980) and indeed in the wider mechanism of thought (Vygotsky, 1934/1987). The boys' language can be interpreted in terms of pedagogical 'moves,' such as 'structuring' 'soliciting' 'responding,' and 'reacting' (Sinclair & Coulthard, 1975). Structuring is where the learning situation is established, soliciting usually takes the form of a question or request, reacting involves modification and shaping of moves, and responding tends to be represented as interactive conversations. In addition to interpreting talk in terms of pedagogical moves, systemic functional linguistics can be used to help describe the dimensions of the interaction (Christie & Unsworth, 2000) in terms of the 'Field' (what happens in that situation), 'Tenor' (the personal – power relations) and 'Mode' (the part that language plays in learning and securing relationships).

Analysis of the register, while the two pupils were using the simulation, suggests that the Tenor is equitable. The two boys share ideas, their pedagogical moves show equitable turn taking in structuring, soliciting, responding, and reacting. The Field that evolves shows the two boys making progress with respect to technical competence in managing the simulation. Their dialogue suggests that they hold similar views with respect to understanding the simulation, but this element of Mode will be considered in more detail in the following section on science.

The boys' register also suggests that they are confident with their interpretation of the simulation, though their soliciting and responding statements suggest they are still trying to make sense of particular elements. Although Sam's register suggests more confidence, Jim is more active in and this suggests that Jim is more involved in structuring. He directs Sam's attention and puts forward ideas for consideration, while Sam tends to accept challenges to his thinking, but, in general, they negotiate activity direction.

| | |
|---|---|
| *Sam* | *Very interesting.* |
| *Jim* | *Wait, did all those minuses just become like neutral or something?* |
| *Sam* | *I have no idea.* |
| *Jim.* | *Watch.* |
| *Sam* | *See, like right at the start* |
| *Jim* | *Look at that positive, right.* |
| *Sam* | *See if it changes into a green one or something* |
| *Jim* | *See watch these ones coming in (points to screen)* |
| *Sam* | *That just lost it's minus.* |
| *Jim* | *Aye, It got a plus from there.* |

Transcript 2. Excerpt from Pupil Engagement Recording

Although the text on screen was limited, the pupils paid scant attention to key information that needed to be read. Having read the text box, the pupils were then required to translate and transform this language into the language of science in terms of icons and symbols. Consequently, the pupils interpreted the word 'neutralization' in terms of the reaction between protons and electrons rather than the reaction between an acid and an alkali.

**Science**

The survey data shows their familiarity with areas of chemistry as it is indicated in Table 2.

*Table 2*
*Comfort and Experience with Various Chemistry Topics*

| Chemistry topic | Jim | | Sam | |
|---|---|---|---|---|
| | Experience | Comfort | Experience | Comfort |
| Atoms and Molecules | 2,2 | | 2 | 2 |
| Balancing equations | 2,2 | | 2 | 2 |
| Acids reacting with alkalis | 2,2 | | 1 | 2 |
| Titration experiments | 3,3 | | 3 | 3 |
| Reactions of metals | 2,2 | | 2 | 2 |
| Conductivity of Solutions | 2,2 | | 1 | 1 |
| Dissolving | 2,2 | | 2 | 2 |

Analysis in terms of 'Mode' also helps in the analysis of the pupils' understanding of the science concepts they encounter. The simulation involved the use of every day language, science terminology, science symbols, and iconic representations. For example, the introductory screen contained a text box that included everyday language and science terminology (such as neutralization), it also contained tab buttons with text instructions (such as continue), and it contained colored spheres intended to represent molecules and ions, and symbols to identify these molecules and ions.

There is a notable difference in the two pupils' science literacy.

*Sam* *You have to replay it. (Reads the text box, aloud) The following is a representation of a neutralisation when NaOH is added to aqueous H C i*
*Jim* *H. C. L.*
*Sam* *Are you sure that is an L?*

Transcript 3. Excerpt from Pupil Engagement Recording

Analysis of the transcript and the post use narrative account, suggests that Jim was able to interpret various sources made available through the simulation. He initially shared Sam's interpretation of the simulation, but his post-use narrative account suggests that he was also reserving judgment and considering whether the simulation represented ions, whereas Sam was still interpreting the simulation from the atomic model perspective.

*Interviewer* *What was becoming neutral?*
*Sam* *The protons.*
*Jim* *And the minus ones.*
*Sam* *Electrons.*
*Interviewer* *Ok. So, what are the green things then?*
*Sam* *Neutrons. I mean electrons.*
*Interviewer* *Ok. If I told you that this is....*
*Jim* *Ions.*
*Interviewer* *Yeah. Would that make any difference?*
*Jim* *Yes, because they are like charged things.*
*Sam* *Are ions like when...*
*Jim* *Charged particles.*

Transcript 4. Excerpt from Post Use Narrative.

### Information Processing Skills

Though the dialogue suggests that the two boys are working well together, analysis of the transcript and the retrospective narrative suggest that they are attending to different elements of the simulation. Hence, their 'Mode' (the part that language plays in learning and securing relationships) is different. For example, in the following clip, Jim identifies the introduction of something (italicized in the transcript), and though Sam continues to describe the activity of the other spheres, Jim's transcript suggests he is more observant with respect to the finer detail of the simulation, and hence paying more attention to a variety of symbols and text.

| | |
|---|---|
| *Sam* | *They are really hitting off the walls and each other and stuff. It's quite mental...press continue.* |
| *Jim* | *Something is added.* |
| *Sam* | *They are like hitting each other, greens and reds and purples. Some of them are pluses. Oh the green ones are minuses.* |
| *Jim* | *Purple ones are pluses.* |
| *Sam* | *And the red ones are in-between, so I'm guessing that the green, the red ones are, ok now this is weird the green ones are obviously neutrons.* |
| *Jim* | *No they're minus.* |
| *Sam* | *Electrons, that's what I mean. Electrons are the minus ones.* |
| *Jim* | *NaOH is added.* |

Transcript 5. Excerpt from Pupil Engagement Recording

## Discussion

Students working in an e-science learning environment face a trans-disciplinary demand. The influence of computer competence, information processing skills, traditional language proficiency, and science understanding levels in e-science learning environments should not be underestimated. In terms of traditional and subject literacy, pupils have to make sense of linguistically complex information, in effect use higher order information processing skills, when using common science simulations. They need to understand their subject, be confident and competent with respect to using the available technology, and have language skills that enable them to establish links between the microscopic, macroscopic, and symbolic components of science.

Of course, the context in which the simulation is deployed will have a significant impact on the way it is used. However, the intention of this project was to investigate the trans-disciplinary demand pupils faced when they used commonly found simulations. It could be argued that the insight provided by using a small group does not lend itself to generalisations with respect to trans-disciplinary demands. Indeed, it could be argued that the findings could be specific to the boys described in this paper. However, it should be noted that the pupils' talk as presented in this paper was representative of the project cohort. Further illustrations of pupil talk can be found in Rodrigues (2007), where individual differences among the pupils using a variety of simulations are used to illustrate the e-literacy skills and demands. Exploring the use of the simulation in a classroom context, with the teacher providing support, would not have enabled us to investigate the demands made by the simulation, as the teachers' strategies in deploying the simulation would have influenced pupils' engagement. In addition, the rhetoric surrounding the use of technology in science often alludes to it providing an opportunity for independent learning and student ownership of the learning process.

The fact that reports (see for example, Smeets & Mooij, 2001; Zhao &Cziko, 2001) continue to signal that practice involving the use of various technologies has not changed significantly, also suggests the development of digital literacy in e-science education environments is most likely incidental. Digital literacy needs to be taught more explicitly, if the available technology is to do more than simply provide increased amounts of better-presented data.

Recommendations for designers

- Although the pupils in this project were interested and engaged with the simulation, it was lacklustre in terms of presentation in comparison with computer games. The gap in sophistication and presentation between computer games and educational software needs to be addressed.
- Review how pupils will interpret the on going presence or removal of particular symbols or icons. Include checks that pupils need to complete to ensure that they have made the associations intended by the designer.
- Consider establishing explicit links between visual text and symbols or icons.
- Use a variety of media to support pupils' understanding. Include oral narratives and keep text information related to science on screen.

Recommendations for users

- The pupils need to be taught to read screens for informing and for learning. They need to be taught how to retrieve information from any given screen shot.
- If the pupils had not mis-identified sodium hydroxide, they may well have reconsidered their interpretation of the simulation. They need to be taught to verify and confirm their interpretation of key information before they reach firm conclusions.
- They need to be taught information processing skills.

Just as many have long argued that teacher discourse needs to be unambiguous, relevant and coherent, so now, science simulations also need to ensure that they are unambiguous, relevant and coherent from the user's perspective.

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