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Digital Divides: E-literacy in Science Classrooms when Using Information Communication Technologies

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ABSTRACT *Terms such as computer assisted/ aided/ based/ managed and specific terms such as simulations, CDROMS, dataloggers, etc., were used to identify literature that helped to inform this article. References from this batch of preliminary literature were then used to identify further literature. As all the identified literature was not readily available, so the analysis is indicative rather than comprehensive. Nevertheless, analysis of the literature from the last five years (1999 - May 2004) provides a snapshot of an emerging digital divide that is more than a consequence of access to hardware and resource. Analysis suggests that e-learning environments are a fusion of constructivist strategies using tools informed by behaviourist and information-processing views of learning resulting in much routine and less innovative use of technologies in classroom practice. Analysis also suggests that students' perceived relevance of technology in formal and informal environments is creating two e-learning cultures (school and everyday). Analysis also shows that epistemological, conceptual and pedagogical values and beliefs (students' and teachers') are determining the effectiveness of e-learning technologies on learning outcomes.*

KEY WORDS: *e-learning, digital divide, relevance of technology, science teaching, e-literacy*

Introduction

Changing societal needs and rapid technological advances have seen calls to include and integrate technology in science classrooms in order to help students become more scientifically literate (Valanides & Angeli, 2002), more economically competitive, and more involved in their learning. The use of technology in science lessons is usually advocated in terms of learner control, proactive learning or increased student engagement and motivation. This article analyses literature reporting on the use of technology in science lessons. The article uses e-learning to encompass the use of educational computing, multimedia, information technology, telematics and information communication technology for learning science in schools. The literature documents investigations into the computer games culture and student interest (see for example, Prensky, 2004; Littlejohn, Suckling, Campbell, & McNicol, 1999; Kirriemuir, & McFarlane, 2004) and on the use of other forms of technology in science classrooms. Barton (2004) suggests digital collaborative technologies improve interaction. Trindale, Fiolhais, and Almeida,

(2002) suggest three-dimensional virtual environments help students with high spatial aptitude to acquire better understanding of particular concepts. The potential of dataloggers (See Newton, 2000; Rodrigues, 2002; Metcalf & Tinker, 2004), Emails (Van derMeij & Boersma, 2002), CDROMS, simulations (Jha, Widdowson, & Duffy, 2002), modelling (Angeli & Valanides, 2004a; Löhner, Van Jooligen, & Savelsbergh, 2003; Barab, Hay, Barnett, & Keating, 2000; Pallant & Tinker, 2004), Computer assisted learning (Watson, 2001), Integrated Learning Systems (Rogers, & Newton, 2001) and the Internet/web (Nachmias, Mioduser, & Shemla, 2000; Lawless & Brown, 2003) continue to be promoted.

Overall, dataloggers are promoted as able to reduce the monotony of repetitive, routine experiments, limit distracters, and allow for measurement within too fast or too slow experiments. Simulations side step issues of cost and ethics, and enable testing the impossible, and in some cases they remove the 'messiness' found in wet labs. The Internet increases access to global sources and reduces temporal and interaction constraints. Multimedia authoring caters to a wider variety of learning styles. So, the rhetoric has been well rehearsed.

Outside the school environment, we see a climate where students use mobile phones, chat rooms, and text messages. Indeed, it could be argued that cyberspace is reality for many students as they spend time searching the internet, text messaging on a mobile phone, and communicating with others in a chat room. It has been suggested that 70% of children play computer games each week (Facer, 2001), and the youth average about 10 000 hours playing video games, 10 000 hours using the mobile phone to talk, play games or use data, and have sent about 200 000 email messages (Prensky, 2004).

Analysis of the literature presented in this article leads to a suggestion that three aspects (a) relevance (formal and informal learning), (b) fusing learning theories, and (c) pedagogical, epistemological and conceptual change, beliefs and values appear to be fostering a digital divide.

Some Literature about Informal E-learning

Computer games take various forms: action games (characters move between platforms), adventure games (puzzles in a virtual world), fighting games (compete against computer controlled characters), puzzle games, role-playing games (adopt a role in a virtual environment), strategy games (adopt an historical role) and simulations (Kirriemuir & McFarlane, 2004).

Some games investigations focus on gender related issues (see for example, Kadijevich, 2000; Schott & Selwyn, 2000). Fewer girls than boys were interested in computers, and males showed a more positive attitude toward computers than females (Kadijevich, 2004). At primary school age, boys were interested in games and CDROMS, whereas girls were interested in writing and drawing (McEune, 2004). Boys had a wider range of uses for the technology, in comparison with girls (Taylor Nelson Sofres, 2001), though Crawford, Neve, Pearson and Somekh (1999) report that this difference may be socio-cultural and socio-economic dependent. Volman and van Eck (2001) report on a review of literature using Sutton's three constructs of access, processes of learning, and outcomes, to review recent literature in terms of gender differences. Ching et al. (2001) showed that girls initially concentrated mainly on organising and reporting and solving conflicts, whereas boys ignored the group process and concentrated on completing the task. Girls appeared to work more slowly because they spent time exchanging information. To a certain extent, though the discussion critiquing 'Lara Croft' (from the Tomb Raider Series) dwells on the female role model image rather than the nature of engagement or communication when this game is played (Kennedy, 2002), as Bryce and Rutter (2002) suggest, this may be due to investigations on content not the playing. In effect the focus on 'playing' in both formal and informal learning environments provides a great deal of insight into the need for tangible change in pedagogical, conceptual, and epistemological change in e-learning environments. Volman and van Eck (2001) suggest that there is no theoretical or methodological debate about gender and ICT in education. They suggest that the field has not developed theoretically or conceptually in the last decade. Schott and Selwyn (2000) also suggest that as technology becomes more common, these gender differences should disappear.

Some Literature about E-learning in Science Classrooms

The novelty factor may have lessened as the last five years have seen an increase in the presence of technology in classrooms. For example, Coley, Cradler, and Engel (2000) reported that in 1984 there was a ratio of 125 students to a computer, and this has now dropped to a ratio of 10 students to a computer. There has also been an increase in resource levels in schools (McEune, 2004; Jaillet, 2004) but the benefit of technology use has not been consistently voiced (Cuban, 2001), and technology is not seen as reliable (Zhao, Pugh, Sheldon, & Byers, 2002). Indeed, Cuban, Kirkpatrick and Peck (2001) observed and interviewed a sample of teachers and students in high schools in Silicon Valley and found that access did not result in widespread teacher or student use. Nevertheless, access to a range of science relevant technologies and continuing professional development (see for example Becker, 2000 and Mulkeen, 2003) continues to increase. Consequently, there is literature on enhancing environments (see for example, Jaillet, 2004 and Rodrigues, 2000). Nevertheless, though many teachers have had continuing professional development, many are still not confident and continue to experience difficulty in developing integrated environments (Department for Education and Skills, 2001). So, the technologies continue not to be used or are under-utilised (Zhao, et al, 2002), and the slow integration of technology in teaching and learning by teachers (see Cuban 2001; Becker, 2000; Zhao & Cziko, 2001) continues to be reported. Zhao and Frank (2003) suggest that technology adoption is co-evolutionary; dependent upon perceived costs and social dynamics.

From a resource level perspective, there are several studies indicating that access has increased, but use may not have changed practice or increased in science classes. Two national surveys of Scottish schools (Stark, Simpson, Gray, & Payne, 2000) provided baseline data on the impact of learning initiatives on Scottish pupils' skills and knowledge. Pupils' knowledge of software applications in the final year of primary was marginally lower than their knowledge in the penultimate year of compulsory secondary schooling, and though around half the primary and two thirds of the secondary schools had an e-learning policy, only a minority reflected recent national initiatives. Cuban et al. (2001) also suggested that when teachers did use the technology, they tended to maintain rather than alter existing practice. Williams, Coles, Wilson, Richardson, and Tuson (2000) investigated Scottish teachers' needs for knowledge and skills in relation to effective use of various technologies. Teachers' levels of technology use, experience of technology training to date, and perceptions of technology knowledge and skills were explored. Teachers were motivated and interested. The focus for both primary and secondary teachers was word processing and use of the Internet was low. Neither cost nor lack of technical support was strong inhibiting factors. Williams et al. (2000) suggest that mathematics and science teachers displayed more negative attitudes and lower use of information communication technologies.

Smeets and Mooij (2001) reported on a study carried out in 25 technology rich primary and secondary schools in five European countries. Technology was used to facilitate traditional ways of teaching, and the majority of lessons involved technology as an add-on to a traditional learning environment (Smeets & Mooij, 2001). Most of the lessons had a behaviourist drill and practice approach, in essence pupils followed instructions. Only a minority of the 90 lessons observed were innovative, where the technology was integrated in pupil-centred learning (Smeets & Mooij, 2001).

Woodrow, Mayer-Smith, and Pedretti (2000) reported on a seven-year field based research programme of technology integration in secondary school science (grades 9-12) in the USA. Between 1992 and 1998, the participation rate in physics rose to 18%, while the rate for the Province was 13% for the same period. The increase in enrolment did not result in a decrease in achievement. The success rate in examinations was consistently higher than the Provincial norm. Changes in teachers' instructional styles were reported in the project schools (Woodrow, Mayer-Smith, & Pedretti, 2000). The project may have achieved its success by modifying the environment to take on board a more learner-centred approach.

In order to provide some structure to the analysis of the remaining literature that is reviewed for this article, the e-learning environment was perceived as being modified in three ways:

- modify the tool
- modify the strategy
- modify student behaviour

There is, of course, overlap between these areas. Nevertheless, analysis in terms of reporting on modifications in tool, strategy, or student behaviour provides a framework from which to view the bulk of the literature.

Modifying the Tool

Modifying an e-learning tool may mean adjusting representation or changing the capacity of the tool to persuade or inform. This section on the modification of tools, presents literature investigating differences between games and paper (Ko, 2002; Kirriemuir, & McFarlane, 2004; Lim, Byung Ro, Plucker, & Nowak, 2001); external representations in modelling (Löhner, Van Jooligen, & Savelsbergh, 2003); animations and narrative/text or extraneous information (Mayer, 2003; Mayer and Moreno, 2002); animation and text (Rodrigues, 2002); multiple representations (Wu, Krajcik, & Soloway, 2001); graphic and symbolic representation (Testa, Monroy, & Sassi, 2002; Metcalf & Tinker, 2004); virtual 3D environments (Trindale, Fiolhais, & Almeida, 2002); use of prompts (Davis & Linn, 2000); persuasion and graphical representation (Hargreaves, Shorrocks-Taylor, Swinnerton, Tait, & Threlfall, 2004; Murphy, Long, Holleran, & Esterly, 2003, Clark & Slotta, 2000); on learning outcomes.

Ko (2002) investigated the ability of 87 children, aged between 7-10 years, to make and use inferences in the context of computer games and to note how this differed between individuals. "Find the Flamingo" (O'Brien, 1985) uses "yes-no" answers and "if-then" statements. Children have to find the location of a flamingo hidden among 25 cards. The children were randomly assigned to either the computer group or board group who used a 5 x 5 grid. Ko (2000) found most of the 10-year olds made fewer moves than the 7-year olds. There were different play patterns between good problem solvers and the random guessers, and these existed right from the start of the games. Neither game media differences, nor gender differences were found. The children were more disposed to playing the game on the computer and reported high satisfaction regardless of accomplishment on the computer (Ko, 2000).

Many pupils consider games developed for the school system to be bogus, perhaps because educational games are repetitive, simplistic, poorly designed or have limited activities (Kirriemuir & McFarlane, 2004). This evolution in games and school cultures may result in the construction of a digital literacy divide. So, perhaps, instead of trying to replicate computer games for education, investigations could focus on understanding the games experience and this could help construct environments that support learning (Kirriemuir & McFarlane, 2004) and subsequently limit the development of a digital literacy divide. Lim et al. (2001) outlined 6 facets when constructing learning by web design projects: collaboration, location of content, publicity, visual design, and balance of learning content and design skills, and students' reasons for selecting a web design project. Lim et al. (2001) also say that designers must make information difficult to find, as students equate the challenge with enhanced learning.

Designing learning environments provides programmers and designers with various challenges, as e-learning environments allow various representation elements to be manipulated. Löhner, Van Jooligen and Savelsbergh (2003) investigated the effect of different external representations on the construction of computer models by comparing secondary school student pairs. Some had to use correct equations to make the model run, and others used a graphical representation and the model was built by qualitatively linking physics variables. Löhner et al (2003) suggest that the two representations created behaviours that suited diverse facets of the modelling process.

Mayer (2003) and Mayer, and Moreno (2002) suggested that students learn more effectively from multimedia when the explanation does not include any superfluous information. Students were learning about lightning by either reading a passage of text with illustrations, or reading text embellished with irrelevant information (such as how a footballer was struck by lightning). The addition of irrelevant information was detrimental to student understanding. Mayer and Moreno (2002) also suggest auditory information is better than visual on screen text, and they suggest that it is better to present animation and narration rather than animation, narration, and screen text. In the Mayer (2003) study, students were asked to generate useful solutions to new problems posed to them. Mayer (2003) suggests that meaningful learning was not paper or technology dependent.

The Rodrigues (2002) video-animation project tracked 11 male and 11 female students' engagement as they explored and used animation and video clips, with or without accompanying text, on the topics of dissolving, melting, and boiling. Students had choices of video clips of macroscopic events (e.g., ice melting) or animation clips of 3D molecular models of microscopic events (coloured balls to represent atoms). The computer programme logged students' choices and responses during computer use and students completed a one-page survey on exiting the programme. The tracks showed that 16 of the 22 students followed the prescribed sequential presentation route. The number of students viewing animations declined between selecting topic 1 and topic 2. Indeed 7 never selected the microscopic level animations. Fifteen students cited 'video and text' as the most helpful presentation type to understand the science concepts. There was an increase in the use of text explanations between selection of their first topic and second topic, but a decline from the second topic to the third. Students said they selected topics because they were interested in them, and selected presentation style because of perceived functionality and utility.

Wu, Krajcik, and Soloway (2001) reported on the use of a computer based visualisation tool (eChem) that over a period of 6 weeks allowed 71 eleventh-grade state school students used to build molecular models and view multiple representations (formulas, structures, and symbols) simultaneously. Wu, et al. (2001) reported a significant improvement in students' understandings of chemical representations. They also suggest that students engaged in discourse that enabled them to make links between visual and conceptual aspects of representations.

Testa, Monroy, and Sassi (2002) described the importance of graphic and symbolic representation when reporting on a project investigating secondary school students reading and interpreting documents containing images of real-time kinematics graphs. The study involved novice students and those with some experience of real-time experiments. Real time graphs produce 'background noise,' and users need to ignore this and ensure that details/irregularities are not seen as poor quality or malfunctioning apparatus (Testa et al., 2002). Graphs in textbooks are 'cleaned' of superfluous details/irregularities. As real time graphs display 'noise,' some novices found these graphs difficult to interpret. Student familiarity with main features of graphs was also an issue. Increasing student familiarity may help them understand experientially the difference between representations of experimental data and equation produced graphs.

Metcalf and Tinker (2004) reported on the use of two middle school curriculum units using probes that interface with hand held computers in Australia and the USA. They suggest that the software helped students confront misconceptions and determine the relationship between the physical phenomena and modelling/graphical representation. Trindale, Fiolhais, and Almeida, (2002) created a virtual environment (virtual water) for final year high school students and first year University students to study phases of matter, phase transitions, and atomic orbital. The students did not have a strong background in physics and chemistry but had high spatial aptitudes (reasoning and comprehension abilities), as determined by using a test similar to the test for logical thinking. Only some parameters (interactivity, navigation and 3D perception) were shown to be relevant (Trindale et al., 2002).

Bakas and Mikropoulos (2003) designed an environment using a 3D interactive virtual environment based on the results of an empirical study involving 102 secondary school students. They suggest students were positive and modified their misconceptions of the day and night cycle and change of seasons. They suggest that virtual environments for earth science and planetary phenomena can help pupils better understand the planetary system. Their research also shows that the children created more scientifically acceptable models, perhaps because the students could mentally act on the relations they have with representations of the world.

Hargreaves, Shorrocks-Taylor, Swinnerton, Tait, and Threlfall (2004) study on mathematics learning, considered icons, symbols and graphical representation, models that are also found in science lessons. The Hargreaves et al. (2004) study of matched samples of 260, ten-year-old pupils' performance on a 16-item pencil and paper test against a 16-item computer test conducted a month later, suggests that student performance scores were better on computer tests. Though Hargreaves et al. (2004) suggest computer assessment may have limited the way in which the question could be answered and may not allow for unanticipated approaches. Although this article is concerned with e-learning in school science, Murphy, Long, Holleran and Esterly (2003) investigating the issue of persuasion in a tertiary e-learning environment, suggest that the medium, and hence representation, does not have a significant impact. Murphy et al. (2003) compared online computerised texts with traditional paper texts. They were also interested in to what extent students' reactions to the features of the text were influenced by the medium. Murphy et al. (2003) suggest that simple computerised texts do not enhance learning (change knowledge or beliefs) more than paper based texts, and the level of navigation skill had little influence on the extent to which students were persuaded by what they read.

Clark and Slotta (2000) explored how source authority and media enhancement affect students' interpretation of evidence in a culturally diverse high school. They involved eight classes of second year high school students (15 year olds) who represented a culturally diverse population. Each class was assigned one of two fictitious scientists (a university professor and dinosaur enthusiast/newsletter writer) presenting information for competing theories on the cause of dinosaur extinction. Clark and Slotta (2000) suggest that no overall media effect was noticed. However, a gender analysis showed that boys tended to label evidence more frequently as most important if it had an accompanying dinosaur/action image (for example, a dinosaur eating an animal). There was no overall effect of authority on preference rating of evidence by the whole group, gender, or reading ability. However, though the students discriminated according to authority level, and deemed the professor to have more training than the newsletter writer, they did not use this information when evaluating the evidence they reviewed. The higher authority source may be more knowledgeable, indeed more credible, but, for the students, it had no significant influence on their preferred theory. In effect, the researchers suggest that the students placed no more confidence in statements from scientists than when it was anonymous, and this suggests that they give equal credence to any material, regardless of the writer. Students' personal beliefs affected their faith in the authority source rather than the authority affecting their personal beliefs.

Hoadley and Linn, (2000) contrasted historical debate and narrative text to assess the impact of an asynchronous discussion on the notion of light. For four weeks, six classes of 30 eighth-grade students were taught by the same teacher, who was assigned to 15 discussion groups. Students studied science everyday and 16 computers were available. The researchers suggest that discussion succeeded in helping students when comments were introduced in the discussion and when they enact a historical debate, rather than follow a narrative. Students were also seen to learn more when they revisited the discussion on different days, but there was no correlation between the number of comments read or contributed (Hoadley & Linn, 2000). The number of times the students expressed the most scientific aspect- that light is composed of colour- rose by a very small number (from 13 of the 234 in the pre-test to 27 of the 206 in the post-test). But, it should be noted students used the same explanation for more situations (Hoadley & Linn, 2000).

This brief snapshot of the literature on modifying the tool provides no conclusive evidence to suggest that representation has any significant influence on learning outcome, though it was seen to result in different behaviours. The issue of navigation and representation, and, in particular, the notion of cognitive overload will be discussed in the section on student behaviour.

Modifying Strategies

Analysis of the literature on strategies was classified by considering the articles in terms of reporting on:

- Problem-based learning (Huppert & Lazarowitz, 2002; Renkl, Atkinson, & Grobe, 2004).
- Collaboration and Communication (Oosterwegel, Littleton, & Light, 2004; Windschitl, 2001; Koivusaari, 2002, 2004).
- Other socio-constructive strategies (Seng Chee Tan, 2000; Pallant & Tinker, 2004).

Although there is a significant volume of literature reporting on problem based learning, computer assisted learning (CAL), simulations, and web-based learning at the tertiary level (See for example, Kim & Astion, 2000; Jha, Widdowson, & Duffy, 2002), in primary and secondary education, simulations, some of which involve problem solving, are reported more widely. At the secondary level, some computer simulations require students to assign variables to an experiment and make decisions as they advance. This is a form of problem-based learning.

Huppert and Lazarowitz (2002) report on a problem-based learning activity using 'The Growth Curve of Microorganisms' computer simulation with 181 tenth-grade biology students from 5 Israeli classes. They investigated the simulation's impact on academic achievement and science process skills in relation to cognitive stages. Students exhibited complex reasoning (Huppert & Lazarowitz, 2002). Concrete and transition operational students in the experimental group demonstrated higher academic achievements than those in the control group, and lower cognitive stage students improved their academic achievement by mastery of measurement, communication, interpretation, and experimental design skills. Simulations made the problem concrete by displaying the process or presenting outcomes immediately and visually (Huppert & Lazarowitz, 2002).

Renkl, Atkinson, and Grobe (2004) reported on the transition from learning from worked examples to problem solving. Findings from one of the Renkl et al. (2004) experiments suggest that faded steps do not influence learning outcomes, but fading is associated with fewer unproductive learning events. However, Davis and Linn (2000), as reported later in this article, suggested that some prompts encouraged complacency and some became distractors.

Zandvliet and Fraser (2004) studied 1040 students in 81 senior high schools in Australia and Canada, but focused more on the ergonomics of e-learning environments. They report on student-centred approaches, involving problem solving, and show teachers taking on facilitator roles. The relationship of social interaction in shaping learning environments has been reported (Littleton & Light, 1999) though some research evidence suggests that girls are opting not to participate in e-learning related activities (reported in Oosterwegel et al., 2004). There is some evidence to suggest that students in most schools undertake 'exercises' that do not encourage extended deliberative discussion, so simulations tend not to be well utilised for social interaction. Indeed, McCormick (2004) suggests that much of the technologies used for assessment purposes do not promote assessment for learning, but focus on summative assessment. McCormick (2004) suggests that perhaps the fields of ICT and assessment have been independently brisk, but the development of e-learning for assessment has not kept pace with current views and theories.

The prominence of group work and shared computer access led Windschitl (2001) to investigate the influence of assertiveness on pair dynamics and conceptual change. Windschitl's (2001) studied 90 students in a public suburban middle school life science class, examining the relationship between academic assertiveness in the students' and their partners' conceptual change when a cardiovascular simulation was used. Three teachers of various subjects, who worked regularly with the students, rated student assertiveness and students rated their self-efficacy. Partners were randomly assigned and given a week to become familiar with the technology. In the second week, they were asked to resolve cases dealing with a hypothetical cardiovascular health problem. Teacher ratings of individuals' assertiveness were not significant predictors, but the assertiveness ratings of individuals' partners was a significant negative predictor of the individual's conceptual change score (Windschitl, 2001). Assertive pairs were more likely to discuss relationships in the simulated environment and suggest 'what if' scenarios. Less assertive partners adopted a stepwise approach to the task, and did not explain why or how phenomena occurred in the simulated environment (Windschitl, 2001).

Koivusaari (2002) explored the nature of pupil interaction within the same age range and across different ages when working with computers. Koivusaari (2002) reported that students expressed opinions more openly, asked for more orientation and showed more positive reactions during 'horizontal' interactions. Students were also less inhibited when the teacher was not part of the dialogic community.

Social constructivism advocates the importance of dialogue and networking in the construction of knowledge, one form of networking knowledge is the use of concept maps. The effects of incorporating concept mapping into a computer-assisted learning scheme for an 'O' level organic chemistry syllabus in Singapore was reported by Seng Chee Tan (2000). The 91 high school students were randomly assigned to three groups and they had four days to use the simulation. The partial map group (who had to construct maps at the review stage of each topic) performed significantly better on the chemistry cognitive test and, not surprisingly, better than the menu group on the concept mapping test. The partial map student group were better on higher-level questions (application level), but were not as proficient when addressing lower level questions (knowledge and comprehension).

Mistler-Jackson and Butler Songer (2000) reported on the Kids as Global Scientist project that used online communication and imagery to study atmospheric science. The case study involving a sixth-grade class and an over an 8-week intervention indicates that students found the learning environment an enjoyable way to learn about their own science questions. Mistler-Jackson and Butler Songer (2000) suggest that careful tele-collaboration, participation in authentic questions and time for in-depth investigation are important contributors to student achievement and self efficacy.

Pallant and Tinker (2004) report on eight classrooms of middle and high school students using molecular dynamics hypermodels in the area of phases of matter. They suggest that middle and high school students can acquire robust mental models through guided exploration using molecular models and that these students hold fewer misconceptions. Interactive molecular dynamic representations and guided activities are useful provided that: there is a balance between open-ended and direct instruction; there are numerous links between the macroscopic and microscopic; and that the core computational models appear in several contexts.

Modifying Student Behaviour

The final body of literature reviewed for this article documents investigations that report on student behaviour in an e-learning environment. There is debate on the demand placed on students in terms of working memory and cognitive load (Angeli & Valanides, 2004b; Kester, Kirschner, & van Merrienboer, 2004; Morena, 2004; Kirriemuir & McFarlane, 2004), and discussion regarding student mindful engagement (Kozma, 2003; Linn, 2000; Buckley, 2000; Rodrigues, 2003; Orion, Dubowski, & Dodick, 2000; Hoffman, Wu, Krajcik, & Soloway, 2003).

Kester, Kirschner and van Merrienboer (2004) studied 88 third year high school students (aged about 14) who participated in an investigation into behaviour and transfer. A simulation programme (Crocodile Physics) has 10 practice trouble shooting tasks for faulty circuits, followed by 10 test tasks. Kester et al. (2004) reported that despite the apparent optimal information presentation format, there were no significant effects noticed on the effectiveness of instruction. Kester et al. (2004) also suggest that although the right information was provided at the right time, simultaneously manipulating the circuit, mentally integrating the information, and judging the information on its own merit may have been too demanding.

Morena (2004) reported on two studies investigating guided feedback that involved discovery learning environments and explanatory feedback (EF) and identical materials using corrective feedback (CF). In both studies, the EF group produced higher transfer scores, rated the computer game as more helpful, and gave comparable interest and motivation ratings than the CF group. Both Mayer and Moreno (2002), and Mayer (2003) suggest that their results are consistent with core tenets of cognitive load theory. Cognitive load theory suggests that working memory can only process a few aspects at any one time. Consequently, it is posited that students learn more deeply when their working memories are not overloaded. Computer games' demands do not seem to result in similar overload (Kirriemuir & McFarlane, 2004), but this may be due to computer games being intrinsically motivational learning tools (Bryce & Rutter, 2002).

Kozma (2003) examined differences between chemists' and students' representational skills and the way they draw on these skills. Kozma posited that experts develop connections across a range of representations (equations, molecular animations, video segments, and real time graphs). Experts use various representations in conversation, because they are proficient at moving between these representations (Kozma, 2003). In contrast, most students have difficulty in swapping representations and many fail to connect representations to phenomena represented. Kozma (2003) also suggests that student discourse is different in a wet lab and a computer modelling lab. In a wet lab, they talk about chemical substances, procedures and equipment. In the modelling lab, talk is on molecular structures and students make few references to substances and phenomena.

In the Linn (2000) paper, models are considered to be patterns, templates, views, ideas, theories, and visualisations. Linn (2000) reports on Knowledge Integration Environment (KIE) activities designed to promote lifelong science learning and based on 'constructivist' tenets. One tenet advocates building on existing student knowledge, another advocates making thinking visible by modelling the process of knowledge integration, and a third draws attention to collective knowledge and peer learning. Under "The Knowledge Integration Environment (KIE)" umbrella, Davis and Linn, (2000) report on which sorts of prompts led students to reflect, while Bell and Linn, (2000) reported on the importance of being able to argue both sides of a question.

Davis and Linn, (2000) investigated the characteristic of prompts and tried to determine whether reflection prompts promoted knowledge integration for eighth-grade students working on science projects. The Davis and Bell (2000) study involved different students from two different semesters. Their findings suggest that similar prompts elicited a diverse range of responses from students. The findings also suggested that students who indicated they understood everything performed significantly worse on the final project than other students. The Davis and Bell (2000) report also suggests that prompts can influence student learning. For example, activity prompts help students to complete activities, but may not help them develop understanding and integrate their understandings.

Bell and Linn (2000) reported on the use of Sensemaker, as part of a two week debate process. They question the degree of conceptual change as a consequence of the project, and also discuss the sorts of arguments students constructed. Students used more warrants than descriptions for their arguments, so students were trying to tether the evidence to the debate through scientific conjecture (Bell & Linn, 2000). Students have more integrated and inclusive ideas about light when they prepared responses for both sides of a question rather than prepare for only one side (Bell & Linn, 2000). However, it should be noted that the Bell and Linn (2000) findings rest on correlations that are low, so the effect is not strong. It should also be noted that the students also had difficulty in creating new conceptual frames/categories for their evidence. Though the addition of scaffolds did result in more autonomous behaviour.

Buckley's (2000) microanalysis of one student's interaction with model-building, 'Science for Living: The Circulatory System' (SFL), prototype interactive multimedia resource, documents intentional model building. Within the project, many of the other students still had fragmented and sometimes inaccurate knowledge.

However one student (not the most able, nor eager, but who liked working alone) scored quite highly in the preconceptions test score, the unit test, and the video quiz at the end of the year. Her model was more detailed and integrated than her peers. Buckley (2000) suggested that the student had a goal-orientated disposition and also a highly constructive approach to engagement with the science-for-living information. Buckley (2000) posited that the student was conducting thought experiments; posing questions, seeking information, and reasoning with that information. In contract, some of her peers saw the task as describing behaviour rather than explaining behaviour, and others simply used it to source images for their projects. Buckley (2000) suggests that students outperformed their control group on the structure and process, as well as the easier types of reasoning (from cause to effect) items. Motivation and learning were also influenced by students' beliefs about learning and the milieu in which students learn.

Rodrigues (2003) reported on pupil disposition, autonomy, and effective use of dataloggers and CDROMS. One class of 14-15 year old female students were given an award winning Periodic CDROM and given free choice for 20 minutes, twice a week. On the first screen, the students ignored the 'periodic table' and 'elements' buttons and opted for the 'quiz', they then ignored the '5 minute' and '90 second' quiz options and selected the 'sudden death' option. They engaged in dialogue with their peers to compare their scores. There was no real development in their understanding of the chemistry of the periodic table. Students navigated a safe and repeatable route, and did not have a favourable disposition toward risk taking and inquiry.

The impact of the play element was also noted by Orion, Dubowski, and Dodick (2000). They reported on 32 secondary school students using multimedia authoring for an earthquake topic. To create their presentations, the students had to develop computer skills. Unfortunately, the focus on design issues diminished their consideration of subject matter (Orion et al., 2000). Students with low academic motivation recycled existing understanding of geology without investigating further or exploring related areas (physics). No noticeable increase in their knowledge understanding was observed (Orion et al., 2000). The 'play' element of the authoring software distracted students from the learning process. These Israeli students were accustomed to submitting written papers and believed that essay length equated with good grades (Orion et al., 2000). The students wanted to include lots of information, but recognised that too much text on a multimedia presentation was not aesthetic, so they enhanced their presentations through special effects, dramatic narration, background music, and pictures (Orion et al., 2000). There was some evidence that authoring encouraged students to reflect and reorganise information gathered.

Edleson (2001) reported on the development of an e-learning earth science inquiry unit. And assumed students learn content and process data more effectively than a traditional approach. Hoffman, Wu, Krajcik, and Soloway (2003) reported on eight student pairs (4 girls and 12 boys) from two science classes completing four online inquiry units over 9 months. Students did not explore, did not evaluate resources, tended to seek answers, and used the web naively. The development of an online research engine Artemis meant that students were encouraged to focus on the content, evaluating it and synthesising information rather than scanning the web for appropriate sites. The Hoffman et al. (2003) study also showed that 18% of the inquiries involved inaccurate understandings. Potential benefit from access to online resources is not automatic. Extensive support and teacher assistance is required.

Hakkarainen (2003) studied 10- and 11-year-old children working collaboratively in a computer supported classroom. Hakkarainen (2003) suggests that students were able to provide meaningful intuitive explanations about biological phenomena and they were able to engage in constructive peer interaction that resulted in them moving toward scientifically acceptable explanations. Songer, Lee, and Kam (2002) investigated the barriers to technology rich science education classes. Their earlier research had suggested that students and teachers in low-income areas often used computer-based technology and hardware for repetitive tasks instead of deploying them for use with higher-order thinking, problem solving, or creative tasks. Songer et al. (2002) described the implementation of an eight-week technology-rich, inquiry-focused weather programme, Kids as Global Scientists: Weather, with 6 urban Detroit sixth-grade teachers and nineteen of their classrooms. Of these six teachers, five taught in a public neighbourhood middle schools and one taught at a math and science magnet middle school. Data was collected through student pre and post content assessments, classroom observation forms, and post teacher interviews. Songer et al. (2002) found that despite efforts like the Kids as Global Scientists: Weather project, a digital divide persisted in many urban areas and the technology did not overcome urban classroom barriers (such as inadequate resource and time, high teacher and student mobility, poor training with ICT, poor internet connectivity) to inquiry pedagogy. The Songer et al. (2002) study also highlighted the significant role of the teachers' beliefs in implementing change. These were deemed to be key, if any reform in pedagogy was to be expected, and, furthermore, if teachers believed in the use of technology and a given approach, then student benefits were noted.

Discussion

Simulations, whiteboards, CAL, spreadsheets, modelling, word-processing, dataloggers, multimedia authoring, integrated learning systems, CDROMS, and the Internet are reported as having the potential to promote understanding of science concepts and skills in schools. The drudgery of routine, monotonous practical work can be lessened through the use of dataloggers, and simulations can circumvent issues of ethics and cost, while encouraging investigations of imaginary and hypothetical ideas. The Internet can widen access, and modelling may foster relationships between concrete, symbolic, and abstract facets of the same concept. It has often been suggested that access to hardware and the variety of technologies listed previously, may result in the creation of a digital divide. However, the research now shows that the last decade has seen significant investment in hardware, technologies, and increased access, but this does not mean that the issue of a digital divide has been addressed. The research findings suggest the digital divide may well be evolving, as a consequence of the following:

- E-learning environments that have developed as a fusion of constructivist strategies using tools informed by behaviourist and information processing views of learning.
- Two e-learning cultures (school and everyday) developing.
- Epistemological, pedagogical and conceptual beliefs and values that have scope to influence learning behaviour and outcomes in an e-learning environment.

Fusion of Constructivist Strategies and Behaviourist/Information Processing Tools

Reigeluth (2003) has already suggested that e-learning theoretical perspectives have developed from both educational and technological theories. There is a junction in e-learning environments where tools developed with a transmission view of learning are used to promote a knowledge construction view of learning by being used within social constructivist strategies.

Most of the technological tools increase sensory input (provide more or detailed information) or enhance data coding options, or opportunities to characterise data (Dillon, 2004), and this is part of the information processing rhetoric. The technology is also underpinned by a behaviourist view, as there is usually some sequential arrangement of material, pre-packaged, and arranged for student consumption. In effect, the technology is supposed to help students do things with greater efficiency and effectiveness in the classroom, by adding value to routine interactions. A socio-constructivist view of learning tries to identify the individual's existing knowledge to help them assimilate/accommodate information.

In an e-learning environment the information is provided by information processing and behaviourist influenced technologies, which are employed within socio-constructivist strategies and are trying to enable the construction of personal knowledge, through social engagement. In essence, e-learning environments appear to be simply moulding themselves to fit in with existing pedagogy rather than shaping or revolutionising the pedagogy. A digital divide will arise between those that develop e-literacy skills in science by using technologies to do more than the routine, and by taking more innovative approaches, and those that use technology to continue to do what they currently do without technology. Cuban, Kirkpatrick and Peck (2001) suggest that now is the time for organised reform initiatives, schools as organisations must change.

Two E-learning Cultures (School and Everyday)

The 1970s and 1980s saw gender research reported on the importance of students perceiving the relevance of science. The science, technology, and society movement also highlighted the student's existence in two cultures: school science and informal science. Differences in student engagement in formal and informal e-learning environments has now also begun to emerge. This may also be cultivating a gender informed digital divide. The importance of relevance in science education is now heard in literature documenting student engagement and e-learning. Students are differentiating between games for leisure and school purposes and technology for leisure and education.

Many students use text messaging, chat rooms, and mobile phones to keep in contact with family and friends. They are also targeted by marketing executives who have identified students as having discretionary income that could be spent on various technologies and media gadgets. Not surprisingly, therefore, most of our students expect to be actively involved in their learning, yet our school system continues to promote a passive teaching environment. Many students have been conditioned to have their activity directed in a classroom environment, and to expect them to take ownership for mindful activity will require reconditioning. Fortunately, some students are not waiting for schools to help them become e-literate, some are developing avatars, participating in chat rooms, purchasing MP3s, and jumping into the digital environment with sufficient intuition and self-confidence to help them make progress without formal support. Unfortunately, not all students are in this position. Consequently, a digital divide, between students who are taking the risks in their informal environment, and those who are waiting for the challenge to present itself in their formal environment, is gradually being created. It is possible that many formal e-learning environments are perceived by students to have no connection with their social, personal, professional, or civic lives, while technology in their informal lives are seen to be relevant, authentic, and of real value to their social, personal, professional, and civic lives.

Epistemological, Pedagogical and Conceptual Beliefs and Values Influence Learning Outcomes and Behaviours in an E-learning Environment

Songer, Lee, and Kam (2002) suggest that teacher beliefs in implementing change were crucial in determining any reform in pedagogy. To what extent e-learning brings about epistemological as well as conceptual change is a critical question. If student and teacher epistemology has bearing on their goals and approach to a task, then epistemological change as well as conceptual change will be required for an e-learning environment to provide an effective and efficient host for learning. The extent of commitment and purpose appears to be determined by students' perception of required outcomes. Very few students have been encouraged toward risk taking and inquiry in science learning, so it is not surprising to find that most students opt for routine, predictable routes in science classrooms, regardless of the opportunities to consider alternatives. Though they all still appear to enjoy working with the technology. The technology has become simply another delivery mechanism for many students.

The teachers' role is vital in the integration of e-learning. Many are still looking for ways to help them secure this integration. Creating opportunities for students to engage comprehensively requires knowledge of students' alternative concepts and strategies to encourage them to reflect on their thinking. Teachers working in a truly e-learning environment face a trans-disciplinary demand. They need to know about their subject, be technically confident and competent, and develop a pedagogy that is cognisant of e-learning, media, and popular culture and education theory. They have to determine how to integrate e-learning and how to help students to make connections and interpret the science. Intellectual capabilities have been defined as "one's ability to apply information technology in complex and sustained situations and to understand the consequences of doing so." (National Research Council: Committee on Information Technology Literacy, 1999). For many students, these capabilities will be the "life skills" needed for the future, yet, in science education, most students use various technologies in complex situations, but for many the merit of doing so lies in demonstrating their competence for accreditation purposes. Having conditioned students to perform in classrooms, many students have ascertained the rules and have learnt to perform as directed, but as Levin (1999) reported, performance in tests does not link with workforce productivity.

Summary

The digital divide used to be discussed in terms of access to hardware and resources. To some extent, over the last decade many nations have actively sought to address this divide by providing finance and incentives. Now, the review of the literature suggests that the digital divide is actually evolving in terms of e-literacy and this is being influenced by three features:

- Routine use and innovative use of technologies in classroom practice.
- Student perceived relevance of technology in formal and informal environments
- Epistemological, conceptual and pedagogical values and beliefs determining behaviour and learning outcomes in e-learning environments.

The importance of e-literacy skills is critical in this digital age. For the most part, the development of e-literacy in science lessons appears to be incidental. Students and teachers need to use the available technology to do more than simply provide increased amounts of better presented data. It can be argued that to a certain extent students are being groomed to succeed in yesterday's society instead of preparing for tomorrow's world, because we have not changed the way we do what we do, instead we have modified some of the tools that we use. In science education, globalization, technology driven pace of change, advances in society, and the accelerating volume of knowledge generated, warrants a shift in our focus. We need to move toward the development of e-literacy for a digital age. If we want students to participate in civic and cultural affairs, contribute to economic productivity and take responsibility for personal decision-making, then e-learning science classroom practice will have to change.

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