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Science learning via multimedia portal resources: The Scottish case

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Abstract

Scotland's rich heritage in the field of science and engineering and recent curricular developments led to major investment in education to equip pupils with improved scientific knowledge and skills. However, due to its abstract and conceptual nature, learning science can be challenging. Literature supports the role of multimedia technology in addressing the difficulties associated with science learning. This paper reports on a two-phase investigation that explored the impact of multimedia resources situated in a national e-learning portal to (1) assist generalist and specialist science teachers' teaching practices and (2) stimulate pupils' interest, encourage engagement and improve overall science learning experiences. Our research also investigated how portal resources facilitated and/or acted as barriers for teaching and learning. Findings from our research affirm that multimedia technology has transformed science learning; with these resources accessible through a national portal, radically different learning experiences ensued. These findings raise serious implications for teacher education and professional development in ensuring that teachers acquire sound science content and pedagogical knowledge as well as practical strategies for utilising technology-rich environments, as this is likely to become the norm. Harnessing the fullest potential that information and communication technology, multimedia and e-learning portals can offer starts by addressing these challenges.

Introduction

There exists a widespread barrier associated with learning science—it can be difficult to learn! Johnstone (1991) asserts the conceptual nature of science as a major stumbling block to learners because of its theoretical components and also due to the inherent tendency of many scientific concepts to lend themselves to complex explanations. Although the conceptual nature of science cannot be changed, it has been extensively recognised that multimedia technology can have a critical role in addressing this barrier and enhancing pupils' learning experiences in science (Barton, 2004a; Thoman & Jolls, 2004). For example, Zheng, Yang, Garcia and McCadden (2008) found that high school pupils who were taught genetics using multimedia had improved knowledge retention and comprehension compared with those who received traditional lectures. Work by Shieh (2012) reports very favourable improvements in motivation and engagement with physics, whereas Lou, Lin, Shih and Tseng (2012) note improved effectiveness in the teaching of chemistry when multimedia technology was employed. Recent technological developments have also paved the way for the evolution of e-learning portals to assist learning and teaching.

Practitioner Notes

What is already known about this topic

- Recent technological developments have contributed to the evolution of pedagogical designs aimed at harnessing information and communication technology (ICT) for better instructional learning. The enormous potential of ICT for technology-enhanced learning is recognised; nevertheless, constant development also demands constant re-evaluation of the technological resources that best support effective learning and pedagogies.
- Learning portals are increasingly used in education and initially serve as a repository of information; a platform for sharing information and collaborative activities; and a mechanism for promoting independent learning to their learning communities. Scotland plays a significant role as it leads in having the world's first national e-learning portal for education. However, there are very few studies on e-learning portal usage, especially within UK.
- It has been suggested that multimedia resources could address the challenges associated with learning science (due to the conceptual nature of the subject being a major stumbling block), increase pupils' motivation and subsequent understanding of scientific ideas and concepts and promote learning autonomy.

What this paper adds

- The paper reports on an investigation into effective usage of multimedia portal resources and assesses their impact in assisting teachers with lesson preparation and delivery. Differences between generalist and specialist science teachers as well as between less- and more-experienced teachers are explored.
- The paper also endorses the generic role of video and multimedia technology as important tools in learning contexts for improving pupils' overall learning experiences, especially in challenging subjects such as science.
- The paper provides knowledge related to e-learning portal usage, particularly the facilitators, barriers and issues encountered by the users of multimedia portal resources followed by reflection on the implications in order to encourage maximum usage and impact. The role of the portal resources not only encourages the promotion of independent or self-regulated learning but also the development of a new learning culture where pupils simultaneously, collaboratively and interactively learn with others located in different regions, made possible by common access to portal resources.

Implications for practice and/or policy

- The differing impact of multimedia resources on generalists and subject specialists mandates support to facilitate pedagogically sound and innovative use of technology and in satisfying pupils' need for autonomous learning.
- Technological advances, like portals, promote a "pedagogical shift" and a radically different learning culture. This has major implications for the provision via Initial Teacher Education and Continuing Professional Development to ensure that teachers respond, utilise and maximise usage of emerging technologies.
- It is acknowledged that the potential offered by continuous developments in ICT is enormous. However, in fully harnessing this potential, university educators at the national level play a significant role in ensuring that they take into account and respond to the changing, developing needs of learners and teachers brought about by technology-rich learning environments and/or a new learning culture.

Arguably, situating multimedia science resources in a national e-learning portal heightens flexibility of use, communication, information-sharing and collaboration. However, such technological advances likewise raise vital pedagogically focused questions.

This paper examines how multimedia-rich science resources, situated in a secure portal, impact on pupils' experiences of learning science. Our research draws evidence from an online survey combined with interviews and focus groups with teachers and pupils from selected Scottish case study schools. Knowledge of the research outcomes is important to the decision makers in evaluating the perceived utility of these technology-enhanced learning resources and facilities. Our findings raise critical pedagogical issues for science teachers that influence learning, especially the promotion of learning autonomy; after all, "science learning goes beyond this acquisition and application of knowledge: it encompasses an understanding of scientific method; an ability to *do* science. . . ." (Pearce & Nott, 2003, p 1).

Background

ICT and science learning in Scotland

In Scotland, Devlin (2009) stresses that the interest in science, medicine and technology has strong historical roots. A rich heritage in the field of science, medicine and engineering in which a number of scientists, eg, Alexander Fleming, James Black, James Watt and Thomas Telford played a major role, was impressed on pupils. However, it is the renewed global interest in the importance of science, engineering and technology from Australia (Batterham, 2000 cited in Watters & Diezmann, 2003), USA (see Fischer, 2011) through to the European context (European Commission, 2007), which coincides with the recent Scottish curricular developments (Scottish Executive, 2004) that brought science back to centre stage. This resulted in the Scottish Government increasing investment in science education to give pupils the opportunity to develop better science skills and knowledge. A strategy called "Science and Engineering 21—Action plan for Education for the 21st century" (Scottish Government, 2009) included pioneering the development of new high quality multimedia science resources designed to enhance educational experiences, which would be accessible through "Glow"—the Scottish e-learning portal. It is important to stress that the content of these resources were designed to match specifically the new Curriculum for Excellence (CfE) (Scottish Executive, 2004).

Enhancing science learning via multimedia technology

The rationale behind the utility of multimedia technology in science learning is based upon numerous studies for which usage of multimedia resources greatly enhanced teaching and pupils' learning experience and improved subject comprehension (Barton, 2004b; Lou *et al*, 2012; Shieh, 2012; Zheng *et al*, 2008). Because science is both theoretical and practical, Wellington (2004, p 88) argues the usefulness of ICT and multimedia in both the "thinking" and "practical" aspects of science. Furthermore, not only does multimedia help address the challenges in science lessons, it also instils a sense of wonder in pupils resulting in improved motivation and better real-life connections (Thoman & Jolls, 2004; Watters & Diezmann, 2003) and helps overcome pupils' misperceptions of science, eg, its relevance being restricted to pupils wanting to pursue science-based professions.

This should not really come as a surprise, as a symbiotic relationship between information and communications technology (ICT) and learning and teaching pedagogy is widely acknowledged (Andersson, 2006) especially in science (Barton, 2004b). There is continuous evolution of the pedagogical designs aimed at harnessing ICT for better instructional learning (Andersson, 2006), taking into account the advent of the Internet and better access to technologies (Davidson & Elliot, 2007). In the midst of all this, Watters and Diezmann (2003) contend that effective science learning is dependent upon teachers' pedagogical knowledge of science leading to effective

learning and teaching practices. Science delivery using technologies necessitates openness to utilising these resources and readiness to embrace the accompanying "pedagogical shifts" (Barton, 2004a, p 38). A challenge for science teachers is not simply access to good quality multimedia resources, which fit well with the content of the curriculum, but finding resources that improve their content knowledge and increase their teaching confidence and effectiveness. Sound science learning instils in pupils enthusiasm for further learning and develops scientific literacy and critical thinking in pursuit of learning autonomy. This conforms to Fenstermacher's (1986) notion (cited in Watters & Diezmann, 2003, p 4), which states "the central role of teaching is to enable the child to become a learner."

Access to resources via a national portal

e-Learning portals are one of the most recent technological developments together with the formation of networked learning environments, digital learning environments and course management systems (eg, Moodle, The Sakai Project). The key elements characterising portals are (1) gateways to information, (2) user-centric and community-based and (3) providing multiple services to the community (Singh, 2006 cited in Pynoo *et al*, 2012, p 1308). e-Learning portals consolidate multiple intranets with a single log-on feature enabling access to a resource repository; this offers new possibilities, providing educationists, teachers and pupils with a platform for collaboration and information-sharing. Examples are eLearningeuropa.info—a portal initiative by the European Commission on new learning processes and educational uses of technology (see http://www.elearningeuropa.info/en/home) and other national e-learning portals valued by policymakers (Pynoo *et al*, 2011):

- ***KlasCement portal***, Belgium <http://www.klascement.net (or.be/.nl)>,
- ***National Educational Portal***, Kenya <http://www.elimuportal.net/>,
- ***Kennisnet***, Holland <http://www.kennisnet.nl/>, and
- ***Glow***, Scotland <https://secure.glowscotland.org.uk/login/login.htm>.

Scotland leads in having the world's first national portal for education called "Glow," which was launched in 2007. Glow is an innovative venture aimed at making learning experiences and opportunities more accessible to around 54 000 teachers and 750 000 pupils, enabling more sophisticated communication, working and learning together where networking and exchanges of information and resources operate within a secure online environment. Glow is a major facility that "serves as a self-sufficient resource, complete with e-mail capabilities, discussion groups, instant messaging, and teaching materials" (Clery, 2009, p 60). All key stakeholders are interconnected in Glow, providing uniform access to resources and features, eg, web-conferencing (Glow Meet), text-based chat (Glow Chat), instant messaging (Glow Messenger), email (Glow Mail), an integrated virtual learning environment for creation and sharing of teaching resources (Glow Learn) and other optional sub-sites.

Glow contains resources tailored to support different areas of the curriculum. Glow Science is a suite of 500 online videos and support materials for teaching levels P6-S3 (ages 8–14), which are specifically matched to the identified science topics within CfE. Menus are easy to negotiate and can be accessed in school and remotely. Videos are produced to a good standard and contain high quality animations. Clear science content is often combined with humour in order to engage pupils in either highly theoretical or otherwise "dry" topics. A film on digestion called "Burps and Farts" demonstrates the passage of food through the digestive system, whereas "How to Make a Human" video features the "chemical recipe" required to create a person! In the physics menu, "Magnets" is an excellent 3-minute film showing how magnets are used in magnetic resonance imaging scanning, and thus, demonstrating real life application of science concepts. For any given topic, there are a variety of films affording personal learning and choice for pupils—a key component of the CfE. Taken together, Glow Science resources serve to match exactly the topics

and pupils' levels and resolve the previously recurrent problems, ie, cost and licensing issues that accompany usage of these technologies.

Research questions

At the core of this study are the analyses of the questions: how do portal multimedia-rich resources, with moving images, music and animation set in a context familiar to children and young people, contribute towards (1) generalist and specialist teachers' teaching practices and (2) pupils' engagement and understanding of science? Additionally, we investigated general perceptions and problems that users encountered in accessing the resources in order to understand the facilitators, barriers and other "portal use behaviour" (Pynoo *et al*, 2011). In this study, whereas generalist teachers refer to those whose undergraduate degree is in education and who teach all curricular subjects including science, specialists are teachers whose degree is in science and teach only science in secondary schools.

Methodology

Research design, participants and procedures

Our research necessitated a mixed-methods approach where broader quantitative elements from the wider teacher survey complemented more in-depth qualitative insights from the 10 case study schools. Data of various forms were generated from a combination of an online questionnaire survey, individual interviews, focus groups and observation. Table 1 outlines the research methods, the sample and the rationale for the methods employed.

All registered teachers within the Glow community (including users and potential users of Glow Science) were invited to complete an online questionnaire containing 26 closed questions (eg, multiple choice, Likert scale, dichotomous), with a few requiring open responses. Word was spread through electronic newsletters, science forums, emails and relevant websites. Due to the open invitation and the "snowballing" technique employed, the number of teachers invited remains unknown. The questionnaire was situated in the portal (1) to encourage respondents to view the resources prior to completing the questionnaire and (2) to ensure that *only* teachers teaching in Scotland could access it. The questionnaire data provided the mechanism to contact case study schools containing active users and to obtain their consent for the next phase. Criteria

Table 1: Data collection methods

Method	*Rationale*	*Sample*
Questionnaire survey (scoping phase)	To obtain a profile of Glow Science users and potential users; general views on the resources	Online questionnaire completed by 120 Scottish teachers
Individual interviews (case study phase)	To explore teachers' experiences of Glow Science resources; impact on their competence and confidence	In-depth interviews with five generalist (primary school teachers who teach all subjects) and three specialist (secondary school teachers who only teach science) teachers
Focus groups (case study phase)	To investigate pupils' experiences of Glow Science resources; impact on their enjoyment, engagement and understanding of science	Eight informal discussions with five groups of primary pupils and three groups of secondary pupils
Observations (case study phase)	To observe teachers' and pupils' actual use of Glow Science resources; suitability of the learning environment and effectiveness of the e-learning portal as a platform for delivery	Two case-study schools consisting of primary and secondary schools

Table 2: Case study school participants

Case study school	*Teacher* (n = *8*)	*Pupil* (n = *65*)
Amethyst Primary School	Less experienced generalist	6 boys, 4 girls—P7
Jade Primary School	More experienced generalist	5 boys, 3 girls—P5
Onyx Primary School	Less experienced generalist	5 boys, 5 girls—P6 and P7
Opal Primary School	More experienced generalist	2 boys, 3 girls—P4 to P7
Pearl Primary School	More experienced generalist	2 boys, 7 girls—P7
Garnet Junior High School	More experienced generalist/specialist	2 boys, 4 girls—S3/S4
Emerald High School	More experienced specialist	2 boys, 7 girls—S3
Topaz Academy	More experienced specialist	2 boys, 6 girls—S1 and S2

Table 3: Users' perceived impact of Glow Science resources on teaching (n = *57*)

	Great influence (%)	*Some influence (%)*	*No influence (%)*
Ability to deliver	19 (33)	36 (63)	2 (4)
Increased confidence	14 (25)	29 (52)	13 (23)
Increased creativity/innovation	24 (42)	28 (49)	5 (9)

used in the purposive case study selection included (1) school's geographical location, (2) generalist/specialist teachers and (3) more/less experienced teachers (see Table 2). In the case study phase, we investigated teachers' and pupils' experiences of multimedia resources and portal usage focusing on the resources' impact and portal-related pedagogical issues.

Questionnaires were data cleansed, numerically coded and analysed using PASW Statistics 18 (IBM Company, Portsmouth, UK). Having generated mostly categorical data, data processing involved basic and cumulative frequency counts and percentages and multidimensional chi-square tests for cross-tabulating data to ascertain tests of differences between groups (ie, less-experienced/more-experienced, generalists/specialists). All textual data were analysed thematically using NVivo (QSR International Pty Ltd, Warrington, UK) to address the research questions while remaining sensitive to emerging issues. Approval for this study was granted by the Ethics Committee, College of Social Sciences, University of Glasgow.

Initial results: questionnaire survey

Perceptions, facilitators and barriers

The questionnaire survey was undertaken when the multimedia portal resources had not been extensively promoted to teachers. Yet the reported feedback from survey respondents ($n = 120$) was generally positive with 98% remarking that the quality of the videos was very good (65%) or good (33%). There was broad agreement concerning the resources' capacity to support science (97%) and Health and Wellbeing (78%). Based on the survey findings, the most critical issues preventing usage were (1) lack of time to access portal resources (58%), (2) lack of school IT infrastructure (35%) and (3) film-loading delays due to bandwidth issues (32%).

Impact on teaching practice and pupil learning

When the impact of the multimedia resources was examined, users ($n = 57$) suggested that these resources contributed towards teachers' ability to deliver and be more creative and confident in teaching (see Table 3). Further 2*3 chi-square analyses demonstrated differences in the impact made by the multimedia resources on generalist and specialist teachers. Within the generalist cohort, 62% rated the resources as having a "great influence" on their ability to deliver science compared with 38% from the specialist cohort. Using an exact significance test for Pearson's chi-square, a difference between teacher category and ability to deliver science when using the

Table 4: Perceived impact of Glow Science resources on pupil learning (n = *120)*

	Great influence (%)	*Some influence (%)*	*No influence (%)*
Increase engagement	63 (53)	53 (45)	3 (3)
Improve understanding	66 (56)	48 (41)	4 (3)
Increase enjoyment	83 (72)	29 (25)	4 (3)

resources was found: (χ^2 [2, 50] = 9.787, exact $p = 0.006$). Similarly, 75% from the generalist cohort claimed that the resources had a "great influence" on raising their confidence whereas only 25% from the specialist cohort made such an assertion. Using Pearson's chi-square, a difference between teacher category and confidence raised with the use of the resources was found: (χ^2 [2, 49] = 12.480, exact $p = 0.002$). In terms of the impact of the resources on teacher creativity, 50% from generalist and 50% from specialist cohorts viewed the resources as having a "great influence" on creativity as shown by Pearson's chi-square test: (χ^2 [2, 50] = 14.735, exact $p = 0.000$). Moreover, 72% of users and potential users endorsed the view that the resources contributed to pupils' learning enjoyment (see Table 4). Over half acknowledged their "great influence" on improving pupils' understanding of science lessons (56%) and increasing level of engagement (53%).

Main results: case study interviews, focus groups and observations

Perceptions, facilitators and barriers

All the case study schools affirmed the effectiveness of the multimedia technology for teaching science, with one school asserting that portal resources were integral to daily learning, not just in science. Because of these multimedia resources' distinct features: eye-catching, clear, relevant, with an inviting layout, they were regarded as "a super resource for Scottish schools" (Specialist, Emerald HS; Generalist, Jade PS), which "pull the kids in" (Amethyst PS). A Garnet Junior HS teacher described the resources as "aimed at the teenage mind—short, sharp, high impact, keep[ing] them interested." The appealing blend of moving images and "catchy" music set in familiar contexts enhanced learning: "video is a really powerful teaching aid . . . If you use the heart, for example, you can look [at] a photograph . . . but it's not as powerful as . . . seeing a heart pumping" (Opal, PS). According to primary and secondary pupils, the videos made complex information easily comprehensible because it was not communicated in "big words." Three teachers articulated the value of learning from videos regardless of pupil ability or learning preferences; the language was pitched at pupils, benefiting even those with additional support needs.

Notably, because these videos are located in a secure portal, it contributed to users' trust; teachers were confident that pupils accessed age-appropriate learning resources, and thus monitoring and control were unnecessary. Nevertheless, concerns that Glow Science was an "excellent" but "hidden" resource were expressed, because of navigation issues within the portal. Teachers raised the issue of the "timeout factor," ie, being restricted to a 25-minute window of inactivity caused inconvenience during teaching preparation and delivery.

Impact on teaching practice

Three more-experienced teachers (with 11 to 30 years' experience) whose teaching confidence had grown over many years, regarded multimedia resources as "an extra tool" generating "a fresh view" of science (Specialist, Emerald HS; Topaz Academy). Multimedia were considered extremely helpful by two generalist teachers (with less than 5 years' experience) who contended that this technology greatly assists non-specialists lacking teaching experience or familiarity with in-depth scientific matters: "I was always a bit worried about teaching [science] . . . the videos themselves and all the teachers' additional resources . . . supported my teaching . . . [increasing my confidence] tenfold" (Generalist, Amethyst PS).

Five teachers from both categories asserted that the resources promoted interdisciplinary learning, endorsed by CfE. In this connection, the resources were instrumental in enriching such activities as designing posters, reinforcing terminology learning through diagram completion, developing games and crosswords, presenting at the assembly and engaging in individual/collaborative research.

Impact on pupil learning

Upper primary and secondary pupils confirmed that relevance, language accessibility and the multimedia elements of the resources resulted in increased excitement, interest and independent learning, enabling pupils to "remember [concepts] really easily" (Boy, Pearl PS). "It helped you visualise things . . . I'm not good at just words . . . since I saw the diagrams, I found it easier to understand" (Girl, Jade PS). "Because everyone learns in a different way and you've got a person speaking and it's also visual and there's text, . . . it suits the majority of people in the class" (Girl, Garnet Junior HS).

Primary and secondary pupils claimed that their understanding of the subject had increased because of these resources. A boy from Pearl PS remarked "I didn't really like science before but when we started using them . . . I could understand it much better." The context in which the topics were set was equally vital: "The video shows . . . a normal, daily situation . . . you can relate to it" (Girl, Emerald HS). Pupils stressed that the multimedia element was behind the appealing presentation, which in turn, aided their understanding and increased their level of engagement and capacity to understand science lessons. Their endorsement of the effectiveness of these multimedia resources was strongly conveyed through their unanimous recommendation to create similar materials for every subject.

Discussion

Our study endorses the generic role of video and multimedia technology as important tools contributing to improved teaching and learning within science (Barton, 2004a). Glow Science videos are excellent quality, designed with learners in mind and effective resources in their own right. Teachers and pupils validate the quality, suitability and effectiveness of the videos for instruction and learning with some arguing that videos play a more important role than books (Goldman, Pea, Barron & Derry, 2007)—a strong and explicit endorsement of multimedia technology. The added value of situating the resources in a portal facilitates the creation of innovative learning environments with educational opportunities for multiple-class learning, thus, advancing not only a "pedagogical shift" (Barton, 2004a) but a radically different learning culture. As a case in point, a Glow Meet conference in Glasgow called "Blood, Bile and Body Bits," involved a large number of primary and secondary classes and was a glimpse of future mainstream learning—one in which urban pupils learn interactively with pupils from remote islands using the same materials via technology-enhanced learning environments.

Whereas Watters and Diezmann (2003) argue the significance of teachers' content knowledge, pedagogical knowledge and confidence when employing multimedia technology for effective science teaching, other studies claim that it might also depend upon teachers' capacity to handle technology-rich teaching environments (see Clarebout & Elen, 2000 and Nordstrom, 2000 cited in Andersson, 2006). In this connection, Barton (2004a, p 28) suggests that science teachers first need to become "convinced of the educational benefits" of computer-aided pedagogy and realise that the "educational benefits" far outweigh potential problems.

Our study suggests that the impact of technological resources is influenced by teachers' differing levels of science and pedagogical knowledge that affects their confidence. The "added value" that multimedia offer is widely recognised, but it is never intended as a replacement for teachers (Wellington, 2004) nor seen as a panacea for a lack of content and pedagogical knowledge that

characterises some science teaching. Teachers' knowledge of content and pedagogy remains pivotal for critically selecting resources using the "fitness for purpose" principle (Barton, 2004a) to maximise teaching effectiveness that technology facilitates. Furthermore, scientific knowledge is maintained to be co-created and enhanced through pupils' discussions with teachers (Barton, 2004a). Despite multimedia resources' proving to be a powerful resource for teachers, over-reliance on them could be highlighting a crisis in science teaching arising from a major deficiency during teacher education (Watters & Diezmann, 2003). Teaching provision via Initial Teacher Education (ITE) and Continuing Professional Development (CPD) needs to concentrate on improving subject content and pedagogic quality but equally, on promulgating practical strategies for handling technology-rich environments in the age of fast-paced technological advances.

In developing pupils' learning autonomy, multimedia offer new and distinct learning possibilities. Likewise, pupils' acquisition of critical thinking skills—manifestation of effective and deep learning—remains important for reflection, evaluation and increased comprehension of information delivered by multimedia technology (see also Pearce & Nott, 2003). Teachers' pursuit of content knowledge, sound pedagogy and critical judgment is expected to help them harness technological benefits more strategically as opposed to subtle dependence arising from their perceived or real teaching inadequacy. This is indeed critical, and arguably teachers should, by example, foster learning autonomy in pupils.

Conclusions

Technology can be a double-edged sword. It is recognised that technology-enhanced environments generate excitement because of the enormous potential offered by continuing technology diffusion in transforming science learning (Barton, 2004b). Moreover, using a portal addresses practical issues relevant to access, trust, cost and licensing concerns. Nevertheless, it poses numerous challenges in relation to (1) radically different educational experiences, and even the creation of a new learning culture, (2) urgent development of teachers' robust science content knowledge, pedagogically sound knowledge, and innovative usage of science technology during ITE and CPD, and (3) astute guidance from teachers as pupils increasingly use technological advances in autonomous learning. In sum, harnessing the utmost potential and impact of ICT, multimedia and e-learning portals starts by raising awareness and addressing these challenges.

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