Chandra, Vinesh, Nutchey, David J., & Park, Ji Yong (2012) The complementary potential of multimedia and science demonstrations. In Shengquan, Yu (Ed.) *2nd International STEM in Education Conference*, 24-27 November 2012, Beijing, China.

Adding value to demonstrations in science through Web 2.0 technologies

Abstract

Science is often considered as one of the cornerstones of human advancement. Despite its importance in our society, science as a subject in schools appears to be losing ground. Lack of relevance, the nature of the curriculum and the pedagogical approach to teaching are some of the reasons which researchers believe are causing a “swing” away from science. This paper will argue for the effectiveness of simple science demonstrations as a feasible pedagogical option with a high task value and which has the potential to reengage and reinvigorate student interest in the subject. This paper describes a case study *(N = 25)* in which the *Integrative problem based learning model for science* was implemented in a year nine science class. The study was conducted at a secondary school in Australia. Teacher demonstrations were situated in classroom activities in a “Why is it so?” problem/question format. Qualitative data gathered from students demonstrated a number of benefits of this approach. This paper then explores ways in which Web 2.0 technologies could be incorporated to enhance the value of science demonstrations.

Keywords: Demonstrations, problem-based learning, science education, technologies, Web 2.0

Introduction

Science is often considered as one of the cornerstones of human advancement. Scientists such as Newton, Galileo, Darwin, Edison, and Einstein have impacted on the world in ways that have changed it forever. Despite the importance of science in our society, as a school subject, it appears to be losing ground. Some believe that, science “was in danger of becoming an optional snack in a smorgasbord of subjects” (Roberts, 2002, p. 13). The nature of the curriculum and the pedagogical approach to teaching the subject is disengaging students in learning to a point where even the more capable students are not opting to do the subject at higher levels. The actual picture of science is disappointing and the quality of teaching ranges from brilliant to appalling (Goodrum, Hackling, & Rennie, 2002). In schools there is a need for science teachers to find creative and effective teaching solutions which have the potential to re-elevate the importance of science as a subject in school. Simple science demonstrations have long been recognised as a feasible pedagogical option with a high task value (Eccles & Wigfield, 1995). This paper will explore the effectiveness of science demonstrations and then present an argument on how some of the Web 2.0 technologies could be used to add value to science demonstrations.

A cause and effect scenario in science education

This paper will focus on three key factors as possible causes for some of the effects observed in science classrooms. Firstly, a significant part of the science curriculum is not relevant to the needs, concerns, and personal experiences of many students (Gibbs & Fox, 1999; Goodrum et al., 2001). The science taught is often a "catalogue of discrete ideas, lacking in coherence or relevance" (Millar & Osborne, 1998, p. 2005). Secondly in countries such as Australia, the USA, and the UK, the curriculum appears to address the needs of a minority who may eventually pursue a science-related career, while the needs of the majority of the students are not met (Gibbs & Fox, 1999; Goodrum et al., 2001; Millar & Osborne, 1998; Wieman, 2007). Thirdly, the pedagogical approach to teaching the subject is perhaps compounding the problem. The teaching and learning of science is not always centred on enquiries and investigations that lead to the construction and testing of ideas that are connected to the natural world (Goodrum et al., 2001). Chalk and talk teaching, copying notes off the board and cookbook practical lessons dominate most lessons, which leads to a 'flat' curriculum. This is reflected in Goodrum et al.'s research (2001), in which 61% of high school respondents claimed to have written notes every lesson. One third of these respondents requested for more practical and hands-on activities. Research has shown the some of the traditional methods were not helping students' master basic concepts in the subject (Wieman, 2007) and as a consequence students probably lost interest.

Goodrum et al. (2001) observed that many students were unmotivated and as a consequence they did not engage in their learning. Such a response from students could not be wholly accounted for by the onset of adolescence (Millar and Osborne, 1998). Additionally, subject difficulty did not appear to be a plausible reason for the lack of enjoyment and engagement because science was "neither too easy nor too hard" (Goodrum, et al., 2001, p. 121). These findings suggest that if students are not tuned in with an activity, then they are less likely to engage in it. Goodrum et al., (2001) posited that this lack of engagement was due to the lack of connectedness of the curriculum to students' interests and the use of outdated pedagogical approaches.

To counter this disengagement, there should be a move away from teaching science to the elite toward teaching all students by encouraging curiosity, questioning, and facilitating collaborative learning (Goodrum et al., 2001). Science activities with high task value which are viewed positively by students need to be identified (Osborne, Simon, & Collins, 2003). For activities to be high in task value students should perceive them as interesting, enjoyable, important and useful to achieving a future goal (Eccles & Wigfield, 1995). While research has explored science education from different perspectives, it was "somewhat surprising that so little work has been done in the context of science classrooms to identify what are the nature and style of teaching and activities that engage students" (Osborne et al., 2003, p. 1074). Teacher demonstrations are common in teaching science, yet there appears to be little reported in the literature in terms of how they are done, their effectiveness in terms of the task value and so on. This was confirmed by a search in the ERIC database using the keywords "science", "demonstrations" and "secondary" in varying combinations.

A case for Demonstrations in science classrooms

More than thirty years ago Professor Julius Sumner Miller's science demonstration series "Why is it so?" featured on Australian Television. He posed one science question every day in a national newspaper. Miller believed that such an approach stirred up imagination, created interest, aroused curiosity, enlivened spirit and made the audience question and think (*Professor Julius Sumner who?*, 2004). Anderson, one of Miller's assistants wrote (Miller, 1988):

> *It gives me great pleasure and satisfaction to hear captains of industry, students, men, women and children say, "It was the Professor who gave me this idea" or "It was the Professor and his demonstrations that made me interested in the real world around me – I now look and see.* (p. 10)

Interesting demonstrations in science classes can effectively introduce topics, problems, concepts, investigations and research questions. According to Lynch and Zenchak (2002), hands on activities in science may initially engage students but many were inappropriately structured. Consequently, they did not enhance exploration and conceptual understanding. Some of the cookbook type practical lessons mentioned in Goodrum et al.'s (2001) report fall in this category. Lynch and Zenchak (2002) believed that demonstration experiments were one of ways in which both these desirable outcomes (exploration and conceptual understanding) could be achieved.

Demonstrations also have the potential to promote problem solving and help students develop higher order thinking skills such as analysis, characterisation, evaluations and synthesis (Meyer, Schmidt, Nozawa, & Panee, 2003). However, teachers have to implement a process that would facilitate students' thinking and questioning (Kelter, 1994). In order to achieve this, teachers should frame nurturing questions that lead progressively to "explanations and underlying concepts" (Meyer et.al., 2003, p. 432). Demonstrations enable teachers to model cognitive strategies and a teacher who thinks aloud and "invites students to observe how he or she deals with perplexity" encourages them to "follow along and participate in problem solving" (Meyer et.al., 2003, p. 432). Engaging students, monitoring their thinking and providing feedback are also considered to be essential to the success of lessons (Wieman, 2007).

Web 2.0 technologies

It is widely acknowledged that digital technologies have enabled young learners to satisfy their curiosity on their own (Brown, 2006). Experience with such tools makes them more independent and sets them up on the right path for lifelong learning. But for this to occur, we need to "re-conceptualise parts of our education system and at the same time find ways to reinforce learning outside of formal schooling. Luckily, successful models of teaching and learning already exist that we emulate and build on" (Brown, 2006, p. 18). As a successful model, the high task value of demonstrations in science has been known for some time (Eccles & Wigfield, 1995).

The Internet is now creating new opportunities to enhance this value even further by taking the learning outside formal schooling (Brown, 2006). The world of Web 2.0 is wired, connected, interactive, and evolutionary. Our users are no longer information consumers but they are contributors and co-creators of information. Web 2.0 applications enable users to: (i) use (webpages) and publish content (youtube); (ii) subscribe to information (e.g., RSS feeds); (iii) participate in social spaces (e.g., wikis and blogs), and (iv) access resources through a range of platforms (other than desktop computers). Options such as these have created new opportunities to build on successful teaching models such as demonstrations in science lessons.

Research Framework

In this study, teacher demonstrations were applied in a classroom using a modified version of the *Problem-based Learning* (PBL) framework. The demonstrations were used to initiate the learning process and were consistent with the belief that “the starting point for learning should be a problem, query or a puzzle that the learner wishes to solve” (Boud, 1985, p. 13). Barrows and Tamblyn (1980) described PBL as the learning which occurred in the process understanding or resolving a problem. This approach is used in tertiary education especially in specialist fields where significant problems could be aligned with real life situations. It is also believed to support “conditions that influence effective adult learning” (Boud & Feletti, 1997, p.19). However, as suggested by Boud (1985); the principal idea behind such an approach is to start the learner with a problem, query or puzzle. With clearly thought out problems which the learner may wish to solve, such an approach could be effectively applied in any learning environment and in a variety of formats.

In a high school environment, and especially in junior classes where time allocated for teaching science can be a limiting variable, assigning extended problem solving tasks to students can be an issue (Goodrum et al., 2001). However, this does not prevent the teacher from using PBL creatively. In this research, teacher initiated demonstrations formed the basis of initiating the learning and thinking process. An effective teacher demonstration varies the pedagogy and shifts it away from chalk and talk teaching and cookbook type practical lessons.

In this investigation, science demonstrations were integrated in classroom activities. Students were asked to explain their observations. Their explanations were in response to a problem/question. An *Integrative Problem-based Learning Model for Science* was developed for to facilitate this approach (Figure 1). There were six key stages within this model: (i) The teacher conducted the demonstrations of discrepant events which were connected to the real world, (ii) The teacher stated the problem, (iii) Students analysed the problem individually, (iv) Students were given the option to refine their solutions through consultation within their learning community (e.g. peers, teachers, parents) and research (eg. Internet, library), (v) Students submitted their solutions to the teacher, (vi) The teacher initiated classroom discussion as feedback is provided. The demonstration then formed the basis of the rest of the lesson(s).

This paper describes a case study in which the *Integrative problem based learning model for science* was implemented in a year nine science class. The study was conducted at a secondary school in Australia. This case study addressed two research questions –

a) Do students learn science from demonstrations?

b) How can value be added to science demonstrations using Web 2.0 technologies?

Research Methodology

Context and participants

This research was conducted by a high school teacher in his year nine science class (second year of high school). This class had 25 students – 8 boys and 17 girls (13-14 year olds). In this class, the students had two 70-minute science lessons each week. Over a 12 week period, the teacher conducted five demonstrations and all were presented as problems –*Why does popcorn pop?, Why does the can collapse?, Will the water overflow?, Why does a mixture of Coke and Mentos erupt? Why do you see layers?* and *What is the problem with the door?* The demonstrations were ‘unseen’ (students in this class had never seen them before) and were conducted at the start of selected lessons and lasted for about 15 minutes. These demonstrations were focussed on science concepts which were relevant to the topics taught. Additionally, such an approach (i.e., connecting the learning to the real world) addressed students’ beliefs about science and as a consequence had a greater chance to enhance student interest and curiosity (Osborne et al., 2003; Wieman, 2007). It was a change from traditional practice where the teacher would introduce the topic by writing notes on the board and give students all the answers which they were expected to regurgitate later on. A concerted effort was made to ensure that the activities had a high task value (Eccles & Wigfield, 1995).

Data collection

For students to comprehend scientific concepts associated with demonstrations there is need for a scaffolding process which facilitates students thinking and questions (Kelter, 1994). These views are also echoed by Wieman (2007), who believed that “getting students engaged and guiding their thinking is just the beginning of true learning” (p. 13). For these reasons, after observing the demonstrations students were also asked to complete the “Why is it so?” worksheet which had a series of signposts in the form of questions (e.g., *What was the demonstration about? What did you see? Can you explain what you saw?*). They were also given a choice of doing further research on their own before they submitted their worksheets. (*You may do some research and ask other people about what you saw in this demonstration. If you have a better explanation-rewrite it. Include the sources who provided you the extra information*).

Once the worksheets were completed and submitted, the teacher initiated a feedback session focussed on the demonstration. Wieman (2007) pointed out that feedback was an essential part of the process. When giving this explanation, the teacher created numerous opportunities for the students to observe how he dealt with the problem and asking relevant questions along the way. This approach was consistent with the views held by Meyer et al., (2003) who believed in the use of nurturing questions that led to explanations associated with underlying scientific concepts. It also created an environment where explanations were developed through meaningful conversations between students and their teacher (Milne & Otieno, 2007).

Data analysis

Students’ explanations on the worksheet were arbitrarily differentiated using the criteria in Table 1. For each student, the key question on the worksheet – *Can you explain what you saw?* was marked and scored on a 4 point scale. The scores given for the explanations were for research purposes only – they were not given to the students. The data gathered was used to determine the arithmetic means for each demonstration.

Table 1

Criteria for assessing explanations

Score	Descriptor
4	The explanation has one minor error (or omission)
3	The explanation has two or three minor errors (or omissions)
2	The explanation is satisfactory and includes some valid points
1	The explanation makes at least one valid point
0	There is no response or the explanation lacks substance

In retrospect, more development of these criteria is indicated. For example, the number of 'valid points' is not necessarily an indicator of quality of understanding.

Findings

Students’ responses to the item (*Can you explain what you saw?*) on each of the worksheets were marked on a 4-point scale. For the six demonstrations, the means for the explanations ranged from 1.0 to 2.1. The individual means for each demonstration were as follows - *Why does popcorn pop? (M = 1.0), Will the water overflow? (M = 1.2), What is the problem with the door? (M = 1.3), Why does the can collapse? (M = 1.4), Why does the Coke and Mentos mixture erupt? (M = 1.5), Why do you see layers? (M = 2.1).* These means suggest that the demonstrations posed varying levels of difficulty. Individual student means ranged from 0 to 2.7. Overall across the items, 20% of the sample achieved a mean between 0 and 0.4 (rounded to 0), 36% had a mean between 0.5 and 1.4 (rounded to 1), 40% achieved a mean score between 1.5 and 2.4 (rounded to 2), and 4% achieved a mean between 2.5 and 3.4 (rounded to 3).

There was evidence of independent thinking in student responses. For example in the *Why does the corn pop* demonstration, Rhonda scored a ‘3’ for her explanation. She wrote:

When heated up the molecules (molecules) of the popcorn began to expand, this indicated the popcorn was beginning to cook. When the pressure from the expanding molecules (molecules) becomes too hot for the kernel to contain it explodes exposing the cooked side of the kernel.

Here, Rhonda demonstrates an understanding of why the corn pops. She has the basic idea that heat causes pressure to increase but does not clearly show the connection. She later refines her explanation and rewrites it as follows:

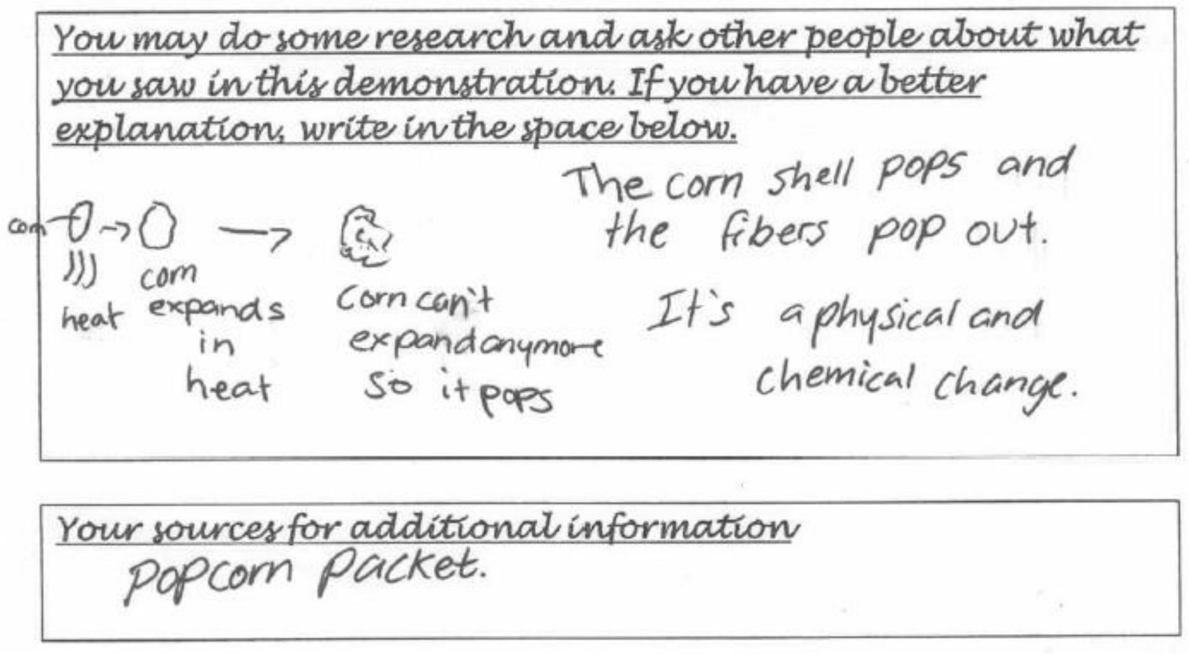
When heated up the moisture and the molecules of the kernel begin to expand. The heat makes the molecules begin to vibrate violently, this causes expansion. The pressure of the expanding molecules becomes too much for the kernel to contain, it explodes exposing the cooked inside of the kernel.

Rhonda achieved a score of ‘4’ for her refined explanation. In her worksheet she indicated that her source of information were her parents and one of her teachers. They helped her write her refined explanation. It is not clear how the Rhonda came upon the concept of 'vibrating molecules' used in her explanation.

Salote scored a 1’ for her explanation:

When heat was applied to the corn, the fibres inside the corn expanded in the heat and broke the outside shell.

Her idea that there is expansion inside the popcorn is correct. Salote consulted the “popcorn packet” and rewrote her explanation and achieved a score of 2. She had some ideas which can be considered as valid such as 'heat causes expansion'.



You may do some research and ask other people about what you saw in this demonstration. If you have a better explanation, write in the space below.

The corn shell pops and the fibers pop out.

It's a physical and chemical change.

Your sources for additional information

popcorn packet.

For this demonstration, 44% of the sample scored “0”. In most of these low scoring responses, students merely restated their observations. For instance, Njak wrote his explanation as follows:

The Bunsen burner heats up the corn then the corn pops.

As explained previously, while 20% of the students (across the six demonstrations) were unable to propose an explanation which was meaningful in terms of what they observed, 80% of them were able to make at least some connection with the demonstrations. It was also interesting to note that there were few blank responses – every student had some contribution to make.

As the results suggest, meaningful demonstrations can create curiosity and as a consequence the majority of the students can be engaged instead of the elite few (Goodrum et al., 2001). One quarter of students opted to refine their explanations and their ratings improved by at least level. From this simple data, it is concluded that an effective demonstration can engage students and this is where further exploration and research can be done using Web 2.0 technologies outside the classroom (Brown, 2006).

As an example of utilising these technologies, a search on Google for the question *Why does corn pop* yielded more than 14 million hits. The first page of the results pointed to 10 websites. Of these four provided detailed information (e.g., NASA, n.d.) www.nasa.gov/audience/forkids/home/popcorn.html). The other six were less detailed but very much to the point. For example, on the website wiki.answers.com – the following explanation was provided (amongst others):

> *Steam pressure builds in the interior of the kernel until a breaking point occurs in the kernel's shell. Because so much pressure has built up, the interior explodes through the shell and is instantly filled with air, thus its puffiness. The trick is to find the right thickness of the shell, humidity, heat, etc to allow for the largest popped corn.*
>
> *http://wiki.answers.com/Q/Why_do_corn_kernels_pop#ixzz1ys1UNCpc*

On the website yahoo.answers.com, the following answer was posted (amongst others):

> *It gets so hot inside the kernel that the insides liquefy and the air heats up and expands so when it pops that is the kernel exploding and then the liquid hits the colder air out side and solidifies.*
>
> *http://answers.yahoo.com/question/index?qid=20111214153916AAeeple*

These two answers create opportunities for further questioning and critiquing by the students. In science, students are generally given problems and questions – they are then expected to find answers. There are very opportunities for them to critique answers. The two examples cited above show how students can be challenged to accept or modify or reject such responses which are uploaded as blogs and wikis.

Videos on the internet (e.g., youtube.com) present another opportunity to understand why corn pops. A search for *Why does corn pop* on youtube generated 689 results. The videos uploaded in slow motion (e.g., http://www.youtube.com/watch?v=yv7DZ7tY-bM, http://www.youtube.com/watch?v=Bo2CE8RlGx4&feature=related) presented a unique close up of a popping corn. Such videos can be rewound and paused when needed to develop a better understanding of problem. In a conventional demonstration on why corn pops, this level of understanding would be difficult to deliver. Most importantly, such videos have a high probability of enhancing interest, curiosity and thinking (Miller, 1988). As a consequence it has the potential to engage students in problem solving at a deeper level (Meyer et al., 2003).

Conclusion

Well thought out and meaningful demonstrations in science lessons have been acknowledged as tasks of high value. Globally, the access to ICT has been on the rise. As a consequence, education systems throughout the work are in a unique position to optimise the of Web 2.0 technologies to their advantage. As this study shows, the task value of science demonstrations can be enhanced through the use of what the Internet has on offer. There is a need for further research to evaluate the impact of demonstrations in science supported by the Internet on student learning.

References

Barrows H.S. & Tamblyn R.M. (1980) *Problem-Based Learning: An Approach to Medical Education*. New York: Springer Publishing Company, p.1.

Boud, D. (1985). Problem-based learning in perspective. In D. Boud (Ed.), *Problem-Based Learning in Education for the Professions* (pp. 13-18). Higher Education Research Society of Australasia.

Boud, D., & Feletti, G. (Eds.). (1997). *The Challenge of Problem-Based Learning*. London: Kogan Page.

Brown, J. S. (2006). New learning environments for the 21st century: Exploring the edge. *Change, 38*(5), 18-24.

Eccles, J. S., & Wigfield, A. (1995). In the mind of the actor: the structure of adolescents' achievement task values and expectancy-related beliefs. *Personality and Social Psychology Bulletin*, 21, 215–225.

Gibbs, W., & Fox, D. (1999). *The false crisis in science education*. Retrieved 16 October, 2003, from http://www.sciam.com/print_version.cfm?articleID=00057DAF-D262-1C73-9B81809EC588EF21

Goodrum, M., Hackling, M., & Rennie, L. (2001). *The status and quality of teaching and learning of science in Australian schools*. Canberra: Department of Education, Training and Youth Affairs.

Kelter, P. (1994). Are our demonstration-based workshops doing more harm than good? *Journal of Chemical Education, 71*, 109-110.

Lynch, M. J., & Zenchak, J. J. (2002, January 10 -13). *Use of scientific inquiry to explain counterintuitive obsevations.* Paper presented at the Annual International Conference of the Association for the Education of Teachers in Science, Carlotte, NC.

Meyer, L. S., Schmidt, S., Nozawa, F., & Panee, D. (2003). Using demonstrations to promote student comprehension in chemistry. *Journal of Chemical Education, 80*(3), 431-435.

Miller, J. S. (1988). *Why is it so?* Ringwood, Victoria: Penguin Books Australia Ltd.

Millar, R., & Osborne, J. (1998). *Beyond 2000: Science education for the future*. Retrieved 16 October, 2003, from www.kcl.ac.uk/depsta/education/publications/bey2000.pdf

Milne, C., & Otieno, T. (2007). *Understanding Engagement: Science Demonstrations and Emotional Energy*. Retrieved September 23, 2007, from http://steinhardt.nyu.edu/scmsAdmin/uploads/000/402/Milne%20&%20Otieno.pdf

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: a review of the literature and its implications. *International Journal of Science Education, 25*(9), 1049-1079.

Professor Julius Sumner who? (2004). Retrieved February 10, 2006, from http://www.abc.net.au/science/features/whyisitso/about.htm#who

Roberts, J. (2002, April 20). High school teachers 'letting science down'. *The Australian,* p. C13.

Wieman, C. (2007). Why not try: a scientific approach to science education? *Change, 39*(5), 9-16.