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Re-thinking physics teaching with web-based learning

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Abstract

There is extensive uptake of ICT in the teaching of science but more evidence is needed on how ICT impacts on the learning practice and the learning outcomes at the classroom level. In this study, a physics website (*Getsmart*) was developed using the cognitive apprenticeship framework for students at a high school in Australia. This website was designed to enhance students' knowledge of concepts in physics. Reflexive pedagogies were used in the delivery learning materials in a blended learning environment. The students in the treatment group accessed the website over a 10 week period. Pre and post-test results of the treatment (N= 48) and comparison group (N=32) were compared. The MANCOVA analysis showed that the web-based learning experience benefitted the students in the treatment group. It not only impacted on the learning outcomes, but qualitative data from the students suggested that it had a positive impact on their attitudes towards studying physics in a blended environment.

1. Introduction

Students view physics as a subject that is demanding, theoretical, abstract, and labour intensive (Angell, Guttersrud, Henriksen, & Isnes, 2004). In this large-scale study by Angell et al., students and teachers believed that unlike some subjects where rote learning was sufficient for their success, physics required understanding of abstract ideas. They also reported that educational practices such as chalk and talk lessons were viewed as boring, and students preferred active participation using strategies that involved more opportunities for interaction and discussions. It is probably this perceived difficulty and the way the subject is presented which leads to boredom, disengagement and eventually to poor learning outcomes. In his book “A funny thing happened on the way to the future”, the actor Michael J. explained his poor results in mathematics, physics and chemistry to his mum when he was a teenager in the following manner (Fox, 2010):

In the outright creative subjects (drama, music...) I'd bring home A's. But any subject based on fixed rules, like math or chemistry or physics, sent my grades into free fall... These are absolutes, Mom. They're boring... (p. 15)

In Angell et al's study (2004), didactic teaching approaches and poorly structured explanations (e.g., teachers were criticized for not showing the details of how problems were done on the blackboard) were some of the reasons which led students to suggest that pedagogies needed to be more student centred. Students in the focus groups described a good physics lesson as one that offered variations (Angell, Guttersrud, Henriksen, & Isnes, 2004). The authors also recommended that “physics courses [should be] tailored to the interest, plans and inclinations of various groups of pupils” (p. 702). So the issues raised by Fox (2010) were probably not wholly related

to the discipline – it was perhaps the classroom pedagogies that were applied to teach the subject.

With Web 2.0 tools teachers have the option to re-think their pedagogical approaches. Although the uptake of these tools is increasing in classrooms, there is an ongoing need to develop a greater understanding of “the impact of ICT on learning practice – as well as learning outcome” (Crook, Harrison, et al., 2010, p. 8). These authors pointed out that the existing literature was unclear about the effectiveness of ICT supported teaching and there was a need for research that “documents the reported experience of integrating technology into ongoing practices of teaching and learning, as they are pursued at the classroom level” (p. 8). Research was also needed which focussed on “pervasive practices” that did not have a “piecemeal” ICT focus “in a corner of the curriculum” (p. 8). They also argued that the classroom teacher was best positioned to capture and document the outcomes of such initiatives. Through such practices teachers’ can also evaluate their “own learning, their professional practice, and their pupils learning” (Cochran-Smith, 2005, p. 224) and in doing so become reflective practitioners.

This study investigates the impact of teacher produced online materials on students’ performance and attitudes in physics classes at a high school in Australia. A website was developed for this purpose and implemented in a blended learning environment. In this environment, online and face-to-face pedagogies are used to deliver course content. The study adopted a mixed methods approach with quantitative pre and post-intervention data complemented with qualitative feedback from open-ended surveys of the students.

2. Background

According to Brown (2006, p. 18), “today’s students are comfortable satisfying their immense curiosity on their own”. He also acknowledged that this “capacity is essential to their future well being” (p. 18),

These challenges require that we 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... (p. 18)

Brown also believed that the Internet was becoming a repository for demand-based learning. Many educators probably agree with this view. Earlier this decade in the U.S., 81% of all higher institutions offered at least one fully online course (Allen & Seaman, 2003). But more recently, an annual growth of more than 20% in online courses and programs has seen an increase in this mode of teaching (Allen & Seaman, 2007). The evolution of web technologies can be attributed to this growth.

The second generation of web design (or Web 2.0) enables users to actively participate as both producers and consumers of information. Web 2.0 fosters social networking and access to technical facilities which is leading to the emergence of new kinds of open participatory learning ecosystems (Brown & Adler, 2008). Web 2.0 tools can enable educators to create websites built on some of the existing models of teaching and learning (Brown, 2006). For instance, websites can be developed using the instructional methods of cognitive apprenticeship to facilitate learning (Seel & Schenk, 2003; Wang & Bonk, 2001). This study therefore has drawn on the instructional methods of cognitive apprenticeship to develop a website that uses the

new technologies to provide support and address learner needs on demand (Dennen & Burner, 2008).

2.1. Previous research

Physics students in Angell et al.'s (2004) study indicated that they preferred more learner-centred instructional practices tailored to their needs – these practices can be addressed by using technologies. For this to occur, educators need to re-think the pedagogies associated with teaching physics. Instead of relying on mimetic pedagogy (Kalantis & Cope, 2008) that focussed only on teacher delivered facts in a fixed sequence, there is a need to embed more learner focussed pedagogies. Synthetic and reflexive pedagogies shift the balance of agency in favour of learners and as a consequence they can become more active in the learning process (Kalantis & Cope, 2008).

There is evidence in the literature which suggests that pedagogical shifts driven by ICT can enhance the richness of the learning environment. The noble laureate Wieman has argued “education research, careful measurement, and new technology make it possible to guide most students safely along the path toward a true understanding and appreciation of physics” (Wieman & Perkins, 2005. p. 40). Evidence supporting this optimism is emerging in a number of studies. The use of well researched pedagogical practices has influenced teaching with technology in the UK (Hennessy et al., 2007) where teachers are exploring the use of technologies to encourage students to engage in “What if” explorations using simulations. Simulations also feature in the work of PhET project where some 50 scenarios have been produced which foster conceptual understanding of complex ideas on quantum mechanics (see <http://phet.colorado.edu/>) (McKagen et al., 2008).

In higher education, web-based tools are becoming increasingly commonplace in teaching science (Singh & Haileselassie, 2010). For example, Singh and Haileselassie developed self-paced tutorials for students in an introductory physics course. According to the students, the interactive and self-paced nature of these tutorials made them very useful in developing their knowledge in Physics. In another study, Moodle was used as the platform for delivering a general physics course in a blended environment for the first time at a university in Spain (Martín-Blas & Serrano-Fernández, 2009). These researchers reported that the web interface enabled them to: (a) effectively organise, deliver, and manage courses and (b) interact easily with students. However, most importantly, those who used the online resources obtained higher scores at the end of the semester. According to Krusberg (2007), emerging technologies were creating new opportunities for cognitive scientists, physicists and researchers to rethink the goals of physics education and how students develop their understanding in the subject. New technologies such as java animations, tutorial systems, and microcomputer based laboratory tools presented “tremendous potential of education technologies” which could be delivered via the Internet (Krusberg, 2007, p. 411). The value of such options lies in the fact that the “juxtaposition of different representations” can lead to deeper understanding of concepts (Schwartz, Martin & Nasir, 2005, p. 32).

However, purposeless surfing of the net does not improve learning outcomes either (Brooks, Nolan & Gallagher, 2001) and given the redundancy and complexity of online knowledge, it is not surprising that open surfing on the Internet can be counterproductive and lead to confusion and misunderstanding. What is needed is a framework for instruction in such environments. As an instructional approach cognitive apprenticeship in a blended learning environment frames this research. We

hypothesise that a custom designed website can enable teachers to produce their own instructional materials and as a consequence tailor the learning needs of their students (Reid, 2002).

3. The study

This study had two key objectives. First to establish if an initiative involving students engaging with blended instruction incorporating pedagogical principles derived from cognitive apprenticeship accompanied by access to a dedicated website (*Getsmart*) impacted students' learning outcomes. The website was designed specifically to enhance students' knowledge of concepts in physics. Second to determine if students' believed that such an approach influenced their learning outcomes. The study had elements of a self-study that adopted an integrative research approach in which the investigation built "on everyday instances of material and social supports" (Schwartz et al., 2005, p. 31) to document and prescribe effective educational practices. Through such initiatives teachers can reflect and evaluate their "learning, their professional practice, and their pupils learning" (Cochran-Smith, 2005, p. 224). In this investigation, Senior Physics students used *Getsmart* – a teacher (the first author) designed website. These students were in Years 11 and 12 (last two years of high school) at a school in Queensland, Australia. The study was conducted in two parts namely the design of *Getsmart*, and the concurrent assessment of learning outcomes and attitudes of students.

3.1. The pedagogical design of Getsmart

For the purposes of this study, learning activities were designed on the instructional methods of electronic cognitive apprenticeship (Collins, Brown, & Newman, 1989; Dennen, 2004; Wang & Bonk, 2001). According to Dennen and Burner (2008), empirical studies show “that the cognitive apprenticeship model is an accurate description of how learning occurs...and...the instructional strategies...can be designed into...formal learning contexts with positive effect” (p. 426). The cognitive apprenticeship model is based on the proposition that learners should be exposed to “a variety of methods that systematically encourage student exploration and independence” and teachers should provide scaffolding and gradually “fade...handing over control of the learning process to the student” (Berryman, 1991, p. 4). With such an approach, teachers involve their students in their learning (Collins, Brown, & Newman, 1989). The cognitive apprenticeship model also proposed that “the learning environment should reproduce the technological, social, time, and motivational characteristics of real world situations” with varying levels of difficulty which enabled students to work with their peers in finding solutions to problems as it happened in the real world (Berryman, 1991, p. 5). However, one key aspect of this exercise was to break the learning activity into parts so that students could comprehend it easily. The design of *Getsmart* enabled students to engage learning materials that were driven by reflexive pedagogies. These included:

- a) activities which encouraged dialogue and group collaboration;
- b) a range of task options which catered for learner diversity;
- c) a feedback loop to facilitate learning, and
- d) activities which represented a mix of knowledge acquisition processes.

(Kalantis & Cope, 2008).

Using this framework, web-based lessons, tests, online chats, and a range of interactive activities were developed and uploaded to *Getsmart*. Learning activities were linked to a range of other relevant websites. The rationale for the use of each instructional method of the cognitive apprenticeship framework and how it was embedded in *Getsmart* is presented in Table 1.

Table 1. Cognitive apprenticeship instructional method and its application in Getsmart

Instructional method/Purpose	How was the method embedded in <i>Getsmart</i> ?
<p><i>Modelling</i> Modelling provides opportunities for learning through observations and exemplars from teachers on tasks are completed.</p>	Online lessons contained concise notes, definitions, formulae, and explained solutions to problems. The latter showed a progression of steps: <i>What's given, Formula, Working</i> . Simulations modelled results of experiments. Structured worksheets summarised the lesson focussing on a range of thinking skills.
<p><i>Coaching</i> Coaching involves support through tasks such as diagnosing problems and offering verbal and non-verbal encouragement.</p>	Responses to emails, discussion in chat rooms, a list of key terms and formulae, hyperlinks in lessons provided student support and coaching. Each test page clearly stated what was expected of students, i.e. <i>If you do not get full marks, repeat the test until you do</i> .
<p><i>Scaffolding</i> Scaffolding involves support from teachers through suggestions and direct help. This support diminishes over time.</p>	The teacher provided support via emails, chats, and direction interaction during Internet lessons. Students also supported each other during Internet lessons and through web-based chats. Web-based quizzes gave instant results with a computer-generated comment, which correlated with their performance. <i>Excellent, Very good, Average, and You have to put in more effort</i> . The use of <i>hypertext</i> enabled users to jump from one idea to another (e.g., bookmarks) and hyperlinks allowed access to other websites and web pages. Hypermedia linked to multimedia also provides students with temporary support when they need more help with a problem or concept.
<p><i>Articulation</i> Through articulation, learners make their learning explicit so that it lays the foundations for interaction and discussion.</p>	Web-based chats, emails and the <i>Forum</i> (Online discussion board with questions) enabled students to express their thoughts to the community. Students also had the option to participate in web design which gave them an opportunity to demonstrate their knowledge in specific areas.
<p><i>Reflection</i> Reflection provides the learners with an opportunity to look back, analyse, and as a consequence improve their learning.</p>	Custom designed online quizzes gave students an opportunity to gauge their understanding. Poor performance in these quizzes signalled lack of understanding of the concepts – both to the teacher and student. The <i>Forum</i> and web-based chat also enabled students to demonstrate their grasp of a certain concept. Downloadable worksheets were completed and handed to the teacher for feedback.
<p><i>Exploration</i> Through exploration, students are expected to tackle and solve problems independently through guided activities set by the teachers.</p>	Links to related sites with real world examples were embedded on pages to build on their knowledge. This seeded ideas for further investigation. Animations, simulations, and applets also enabled students to learn about difficult concepts through hands on interactions.
<p><i>Questioning</i> Online questioning enables learners to discreetly clarify issues to enhance their understanding because not all students are comfortable with asking questions face to face.</p>	Chat and email options created an opportunity for students to voice their concerns. Internet lessons gave an opportunity to ask questions on a one to one basis.
<p><i>Performance feedback and management</i> Focussed feedback gives teachers and students an opportunity to evaluate progress and define future directions.</p>	Website login feature enabled student participation to be tracked. Scores of quizzes were recorded on a database. Students and teachers both had access to this data. It enabled teachers to: (a) monitor student participation; (b) identify the non-participants, and (c) identify student weaknesses and provide assistance as appropriate.
<p><i>Direct instruction</i> In a blended teaching approach, the student is not left alone as he or she has an opportunity to engage in direct instruction.</p>	Students engaged in direct instruction in normal lessons.

The table shows how the instructional methods of electronic cognitive apprenticeship were embedded in the design of Getsmart. For instance, scaffolding

occurred through emails, chats, online quizzes, and use of hypertexts. All users were assigned a unique user name and password – this gave them 24/7 access to the website.

3.2. *Design and procedure*

A non-equivalent groups, pre-post intervention design was adopted for this study to monitor impact on learning outcomes. For the *electronics* and *atomic physics unit* the lessons were implemented in a blended environment. The content of the web-based lessons in this study represented a blended or hybrid course because more than 30% of the learning activities were online (Allen & Seaman, 2003). The treatment group was engaged in this blended mode over a school term of 10 weeks. Five lessons were conducted in normal classrooms while a one lesson was conducted in the computer laboratory to consolidate and revise learning. Students could also access the *Getsmart* website in their own time at school and at home. Chat sessions were also made available after school and moderated by a teacher while students participated on line from their homes. The teacher's presence as a moderator was a pre-requisite for use of the chat software but his role was limited to the management of the discussions. The comparison class also experienced six lessons but had no exposure to the *Getsmart* website or chat sessions but were provided with regular homework and text based material to reinforce learning. Both classes also participated in laboratory exercises necessary to develop science process skills.

4. **Participants**

The participants consisted of Year 12 students (16 - 17 years old) from an Australian High School. The study was undertaken over two cycles. In the first cycle, the comparison group ($N=32$) studied the *electronics* and *atomic physics* units in the traditional mode. In the second cycle, the treatment group ($N = 48$) studied the same unit in the blended environment. Two experienced physics teachers (including the researcher) participated in this study. The researcher and his colleague both taught the treatment class and comparison classes. Both groups were required to meet similar syllabus outcomes.

4.1. *Pre and post test measures*

Students in senior physics were taught and assessed across three performance dimensions: *Knowledge*, *Science Processes*, and *Complex Reasoning Skills*. The *Knowledge* dimension of the assessment examined students' abilities to recall and apply their understanding to simple situations. *Science Processes* measured their abilities to collect, present, and interpret data. The *Complex Reasoning Skills* dimension measured their ability to apply themselves in problem solving situations. As a consequence was the most difficult because students were expected to demonstrate competence in "higher order or more involved problem-solving processes that provide challenge" (Queensland Board of Senior Secondary School Studies, 2000, p. 33).

In this investigation, there was a written pre-test that focussed on assessing students understanding on a just completed *waves* and *electricity* unit across the three dimensions and was implemented at the commencement of the study. The intent of the pre-test was to establish the level of performance and hence comparability of the

two classes. Similarly there was a written post-test administered after students completed the *electronics* and *atomic physics* electronics unit. The teachers (the researcher and colleague) who taught the unit established the content and face validity of the test questions. Both teachers agreed that the unit tests were comparable in terms of the level of difficulty, style, wording of questions and met the requirements of the syllabus. Responses of the top 10% of the students were analysed by the panel of teachers to establish if there was evidence of any misunderstanding. No such evidence was found.

4.2. *Qualitative Data*

At the end of the *electronics* and *atomic physics* unit, open-ended surveys were administered to all participants in the treatment group to establish if they believed that the blended learning approach impacted on their learning. They were invited to comments on questions such as:

1. Do you think that *Getsmart* improved your results in Physics? Give reasons.
2. Do you believe that it is a good idea to supplement in class teaching with teacher-developed websites such as *Getsmart*? Give reasons.

Their chat room data were also gathered. Unstructured interviews were also conducted with the participating teachers.

4.3. *Data analysis*

Pre and post-test data for the treatment and control groups were analysed using SPSS. Given that this study used a non-equivalent group design, a Multivariate Analysis of Covariance (MANCOVA) was used to interpret the statistical differences between the test scores. The pre-test scores across the three dimensions (*Knowledge*,

Science Processes and Complex Reasoning Skills) in the *waves and electricity* unit served as the covariates. The post-test scores across these dimensions for *electronics* and *atomic physics* unit were the dependent variables.

The data gathered through written surveys were initially sorted on the basis affirmative or negative responses to questions. They were then coded and analysed using the “Noticing, Collecting and Thinking” strategy proposed by Siedel (1998).

5. Results

5.1. Learning outcomes

The mean and standard deviation of the pre and post-test scores of the comparison and treatment groups are presented in Table 2.

Table 2. Mean and standard deviations of pre and post-test results across performance dimensions.

Performance dimensions	Sample size (N)	Mean(%)		Standard deviation	
		Post-test	Pre-test	Post-test	Pre-test
Treatment group					
Knowledge	48	72.0	59.2	17.2	21.6
	Comparison group				
	32	66.4	66.2	14.2	12.0
Treatment group					
Science processes skills	48	69.8	59.1	16.6	15.6
	Comparison group				
	32	69.8	56.6	13.1	15.9
Treatment group					
Complex reasoning skills	48	34.4	43.3	24.6	30.5
	Comparison group				
	32	25.8	48.2	15.3	31.1

A MANCOVA analysis was undertaken in SPSS using the generalised linear model (GLM) routine. Preliminary descriptive statistical analysis revealed that assumptions underlying a MANCOVA analysis were not violated. The three dependent variables were: Post-test Knowledge, Post-test Science Processes and Post-test Complex Reasoning. There were three dependent covariate variables namely Pre-test

Knowledge, Pre-test Science Processes and Pre-test Complex Reasoning.

Treatment/comparison group membership was treated as the independent variable.

An ANOVA analysis on the covariate dependent variables (Pre-test: Knowledge, Science Processes and Complex Reasoning) revealed no significant differences indicating independence of the covariate and treatment (Table 3).

Table 3. Difference in classes on Pre-test measures.

Performance Dimensions		Sum of Squares	Df	Mean Square	F	Sig.
Knowledge (Pre)	Between Groups	517.229	1	517.229	1.716	.194
	Within Groups	22603.447	75	301.379		
	Total	23120.675	76			
Sci Processes (Pre)	Between Groups	289.126	1	289.126	1.397	.241
	Within Groups	15519.186	75	206.922		
	Total	15808.312	76			
Complex Reasoning (Pre)	Between Groups	461.500	1	461.500	.504	.480
	Within Groups	68609.281	75	914.790		
	Total	69070.781	76			

The effect of each factor is presented in Table 4. All effects are significant.

Combined pre-test variables account for 58.6% variability in performance on post-tests. Group membership, namely class contributed to 24.5% of the variability.

Table 4. Multivariate Tests

Effect	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	.702	9.635 ^a	3.000	68.000	.000	.298
Knowpre	.728	8.461 ^a	3.000	68.000	.000	.272
SciProPre	.852	3.936 ^a	3.000	68.000	.012	.148
CompPre	.834	4.503 ^a	3.000	68.000	.006	.166
GROUP	.755	7.337 ^a	3.000	68.000	.000	.245

The univariate effects for factor and interaction each covariate are presented in Table 5. The main effect is significant for Knowledge and Complex Reasoning but not for Science Processes.

Table 5. Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	Know(Post)	10768.643 ^a	4	2692.161	21.706	.000	.554
	SciPro(Post)	8470.395 ^b	4	2117.599	23.699	.000	.575
	Comp(Post)	15545.639 ^c	4	3886.410	14.438	.000	.452
Intercept	Know(Post)	1181.244	1	1181.244	9.524	.003	.120
	SciPro(Post)	2026.339	1	2026.339	22.678	.000	.245
	Comp(Post)	158.142	1	158.142	.587	.446	.008
Knowledge pre-test	Know(Post)	1970.359	1	1970.359	15.886	.000	.185
	SciPro(Post)	840.933	1	840.933	9.411	.003	.119
	Comp(Post)	2405.347	1	2405.347	8.936	.004	.113
SciProcesses Pre-test	Know(Post)	713.715	1	713.715	5.754	.019	.076
	SciPro(Post)	813.107	1	813.107	9.100	.004	.115
	Comp(Post)	.729	1	.729	.003	.959	.000
Complex reasoning Pretest	Know(Post)	423.268	1	423.268	3.413	.069	.046
	SciPro(Post)	697.682	1	697.682	7.808	.007	.100
	Comp(Post)	2067.953	1	2067.953	7.682	.007	.099
GROUP	Know(Post)	1371.642	1	1371.642	11.059	.001	.136
	SciPro(Post)	121.724	1	121.724	1.362	.247	.019
	Comp(Post)	3159.820	1	3159.820	11.739	.001	.144

a. R Squared = .554 (Adjusted R Squared = .528)

b. R Squared = .575 (Adjusted R Squared = .551)

c. R Squared = .452 (Adjusted R Squared = .421)

5.2. Student participation

Students engaged in a range of activities on *Getsmart*. In their Internet lesson which accounted for 16% of their physics contact time in school, students would normally access a lesson, discuss the content with their peers, access hyperlinks, do the quizzes, and complete other tasks online as required. The majority of the students (more than 90%) accessed the website after school. Cumulative login data patterns

showed that on weekdays most logged in after 4.30 pm until 11.30 pm. It was also interesting to note that the website had no users between the hours of 3.30pm and 4.30pm (school finished at 3.00pm) and also in the early hours of the morning (2.30 to 4.30 am). On average the website had at least one or more users for up to 20 hours per day. Sheppard and Robins (2009) make an important point that “physics is a 21st century subject confined to a 19th century time allocation” (p. 49). Students’ participation in this study suggests that websites can facilitate learning beyond the boundaries of classrooms and school timetables.

As an example of their participation, chat sessions that were organised in groups after school hours were very effective. Each session ran for an hour and students were allocated chat time of approximately 20 minutes each. Each group comprised of four to five students. These groups were created on the basis of student’s abilities. The transcript from a part of the chat session is reproduced in Table 6.

Table 6 Part of a chat session.

Date/time	Chat room discussion
Aug 13 16:44:	TEACHER> Here is today's question - A beam of electrons with energy 4.0eV is directed towards sodium vapour in an evacuated chamber. Electrons with energies of 4.0eV, 1.9eV and 0.8eV are detected on the sensor. What conclusions can you draw from this observation?
Aug 13 16:46:	Jones> the 4eV electron goes straight through as it has not collided with any other particle as it has not lost any energy. The electron with 1.9eV left lost 2.1eV worth of energy as it collided with particles and caused another electron to gain an energy level. The electron with 0.8eV left lost 3.2eV of energy as it collided with another particle, causing an electron to go up to level 2. Hence, it can be concluded that in a Sodium Atom, the ground state has 0eV, the second level requires 2.1eV of energy and the third level requires 3.2eV of energy.
Aug 13 16:47:	Cheeru> The electrons that came out with 1.9 eV hit one of the Na atoms and gave it 2.1 eV to raise it to an excited state. To raise it to the next level requires 3.2 eV of energy. Hence, it can be concluded that there will be fluctuations every 2.1 V in the I - V graph. It can be drawn from the statement that the electrons that came out with 4 eV went straight through without colliding with any Na atoms. The ones that went through and hit one Na electron lost 2.1 eV, and the other electrons that hit two other Na atoms would have lost 3.2 eV.
Aug 13 16:47:	Danzel> The 1st level is at 0eV, the 2nd is at 2.1eV and the third at 3.2eV. This explains the loss of energy for the 1.9 and 0.8eV electrons because it was used to go to the next level. The 4eV electron must have passed through without colliding and therefore didn't lose energy
Aug 13 16:47:	Charlie> the first energy level is at 2.1eV and the 2 nd at 3.2eV
Aug 13 16:47:	Charlie> you just beat me to it!!!
Aug 13 16:47:	TEACHER> Jones I have to give you 3/3
Aug 13 16:48:	Jones> thankyou
Aug 13 16:48:	TEACHER> <u>Cheeru</u> - 3/3
Aug 13 16:49:	Charlie> Oh, I consider ground level as level 0
Aug 13 16:49:	<u>Cheeru</u> > Excellent, Jones.
Aug 13 16:49:	TEACHER> <u>Danzel</u> - 3/3
Aug 13 16:49:	TEACHER> Yes, Charlie
Aug 13 16:49:	Jones> excellent <u>Cheeru</u> and <u>Danzel</u>
Aug 13	TEACHER> <u>OK boys here is the next part of the question - Another beam...</u>

In the five minute segment (from 16:44 to 16:50) shown in Table 6, there were 15 interactions within the group comprising of the teacher and four students. Through these interactions, three out of the four students successfully answered the question, which could be considered to be of moderate difficulty. The chat in Table 6 reflects the quality of the interactions that can occur in such an environment. It shows how a *scaffolded* problem-solving can be implemented. As the conversations show, the teacher's engagement was minimal. All participants were on task in contrast to what can happen in a classroom where some of the students hide from discussions. This resistance to engagement may be due to factors such as their lack of understanding, poor motivation or language difficulties. As a consequence, there is a tendency for the more confident students to dominate the discussions. For the chat sessions, students had the convenience of interacting from the comfort of their homes. They were able to *articulate* their understanding (See Danzel's reasoning at 16.47 – *the first level is at 0eV...*). This interaction further enhanced their understanding of the subject matter. For example at 16.47, Charlie states that *the first energy level is at 2.1eV...* but then corrects himself at 16.49 to state that *Oh, I consider ground level as level 0*. They also received *feedback* from the teacher (*Jones I give you 3/3*) and their peers. Students explained the significance of chat room interactions as follows:

I must admit, however, that the chat sessions were quite helpful. It forced me to keep up with the work being covered in class and presented some more stimulating questions.

The chat worked well, because I had to actually keep up with what was going on in class. In that, it kept me more involved and interested.

New approach...The idea of after school chat lessons with a teacher is enough to attract the laziest of students.

With a group of motivated learners, the right questions often led to a highly productive and efficient discussion in two ways. Firstly, through the teacher's *scaffolding*, the students were working in a zone of proximal development (Vygotsky, 1978). The right *scaffolds* and *questions* enabled students to *articulate* their understanding and as a consequence facilitate deep learning of concepts. Teachers also got an opportunity to gauge the gaps in students' knowledge and provide *coaching* in real time. Secondly, the sense that teachers are interacting with individuals and responding to individual issues contributes to a sense of community where ideas are transacted with peers and teachers. Self-determination theory privileges elements such as autonomy and relationships as conditions for intrinsic motivation. The comment that *all students have a say* (from a teacher) is indicative of a feeling of autonomy. This was evident in one of the teacher's comments:

While an online chat is probably not too different from an in-class discussion, the chat enables all students to have a say, if teachers scaffolded the session effectively. Even the shy ones get an opportunity to think independently and contribute...this is sometimes not possible in a traditional classroom.

While students did not highlight any disadvantages of the approach, one of the teachers pointed out the following:

Chat-sessions were good and effective. However, they were very labour intensive. Teachers have to find the additional time and resources to make this activity happen.

While chat-sessions created opportunities for applying some of the instructional methods of cognitive apprenticeship, emails created additional opportunities (Figure 1). For instance, in the first emails is from a student who has done an online quiz and

is seeking clarification on her answer. In the second sample, the student is seeking a time for further assistance.

Sample A

In the diagram above, what is the correct ascending order of the refractive indices of the five media?

- (a) 2, 3, 5, 1, 4
- (b) 4, 1, 3, 5, 2
- (c) 2, 5, 3, 1, 4
- (d) 2, 5, 3, 4, 1
- (e) 4, 1, 3, 2, 5

I chose (b) because it is from least dense to most dense. I thought the denser the object, the higher the refractive index. I also thought ascending means from the smallest to the largest number.

But the answer is (c). Please tell me what's wrong with my choice.

Sample B

I've done the revision questions from the website. I'm having some difficulty with the "harder questions" at the end. I was wondering if it's possible for me to meet you tomorrow and work through the questions. Sorry to do this on such short notice. Could you please confirm sometime today? Thank you very much

Figure 1: Samples of emails

5.3. *Attitudes to blended learning*

An open-ended survey was administered to ascertain the extent to which the students believed that the web-based approach helped them with their learning. The first question was: *Do you think that the blended approach and Getsmart helped you with your learning?* Students were able to respond with comments.

The majority of the students (85%) believed for various reasons that such an approach facilitated their learning. They commented positively on the layout of the content, quality of the examples and online tests. There was evidence of how *modelling* impacted on their learning:

Content provided is short and concise – it is easier to learn, multiple choice questions provide practice, challenging questions in the Forum assisted me to answer complex type questions.

Examples helped me understand how formulas work.

The tutorials are helpful as they are concise and condensed notes and explanations. I prefer this than reading pages and pages...in the textbook.

The responses also showed how instructional methods of *feedback* and *reflection* helped them with their learning:

Multiple choice tests helped. If I got a question wrong, I could look back at the work and analyse why it is wrong.

The summaries and multiple choice tests really helped me revise what I had learnt over the term. The practice complex reasoning questions were a big help.

Materials on the website also provided an alternative approach to learning. This was acknowledged in some of the responses as follows:

Some concepts that I did not understand in class could be explained through online tutorials.

Given the positive outcome of the test results, it was important to seek students' views on whether they believed that *Getsmart* helped them do better in the physics tests. This formed the basis of the second question: *Do you think that Getsmart improved your results in Physics? Give reasons.*

The majority of the group (72%) were positive that the website did improve their results. How the instructional methods helped was evident in their explanations.

I believe that "Getsmart" improved my Physics results because I learn by looking at examples. This website contains worked examples which

helped me better understand the work done in class. [Modelling] Also, the tests at the end of each page helped in my revision before the examination.

[Reflection]

The multiple choice tests allowed me to see if I really knew the work and how much (more) work I need to do.

Variety in how the concepts were presented was also viewed as a significant advantage.

I believe it improved my marks because it explains things in different ways.

It adds more variety to learning and made me more interested in the subject.

Twenty-two percent of the treatment group did not think that *Getsmart* improved their results and about 6% were unsure. The reasons for not improving were varied such as *no time to commit to lessons*. Another student wrote:

It didn't because I am not a computer person. I dislike computers...that's why I don't access the website although the net is available to me at all times.

In this group, none of the students saw the design of the website as a factor which prevented them from achieving higher results in the subject.

The third question asked was: *Do you believe that it is a good idea to supplement in class learning with teacher developed websites such as Getsmart? Give reasons.*

More than 80% responded positively and stated that such an approach was a good idea with reasons such as *individuals learn at their own pace...rather than at teacher's pace*. Other reasons included:

People like me learn better from notes and when I didn't get notes from my teacher I relied on Getsmart.

Gives an opportunity to review the work without distraction and creates a greater opportunity to concentrate on the work.

Personally...I find it hard to follow lectures. Without the online notes...I had to write as the teacher spoke and that can become a frustrating task when I cannot keep up.

Getsmart improved my results without a shadow of doubt because it provides students with two different learning environments.

The fourth question asked was *What are your thoughts of the online tests?*

Three students in this sample chose not to respond. However, 90% of the students in this group had at least one positive comment about these tests. A variety of reasons outlined why students perceive *reflection* and *performance feedback* as critical aspects of their learning:

I think they are good; in that when you are done, you can see what you have done.

It provides an excellent opportunity to test what you know.

They help to make your understanding of the lesson more solid and in the long term it is easier to prepare like this for an examination.

Tests were an excellent way of understanding what you have just been taught.

One student wrote that online tests *work well because they make you think about which is the correct answer*. This response highlighted the reason why the test was designed in a manner that gave *feedback* on percentage correct but did not indicate the ones they had wrong. The idea was that a score of less than 100% would challenge

students to reason for themselves. They could also discuss with their peers and teachers to identify and work through to the correct answer. By doing so they had a much greater probability of learning more about the concepts underlying the question and seek the correct solution at the same time.

6. Discussion and conclusions

Crook, Harrison et al. (2010) highlighted the need to understand how “pervasive” use of ICT impacts on learning outcomes (Crook, Harrison et al. 2010). This study has addressed this priority. Multivariate analysis of the pre and post-test results suggested that the main effect was significant for two of the three performance domains – Knowledge and Complex Reasoning skills.

The website was designed to enhance students knowledge of concepts in physics. Statistical analysis shows that this objective was achieved. It also impacted positively on their scores in Complex Reasoning dimension because for students to succeed in these challenges, they need to have good knowledge. For instance, while solving problems using the formulae for photoelectric effect and photon energy may be a part of a complex reasoning challenge of Atomic Physics unit, students need to develop a good knowledge of photoelectric effect before they can succeed in such problems (Queensland Board of Senior Secondary School Studies, 2000). This probably explains the main effect which was significant for these two domains.

On the other hand, items on the science process tests were administered in a such way that all the information which was required by students to succeed in the question was embedded within it. For instance, a question such as “Interpret tabulated data to predict emitted photon frequency and wavelength” does not necessarily require a

strong knowledge in order to succeed in simple scientific process tasks (Queensland Board of Senior Secondary School Studies, 2000, p. 27). Since the website was not designed to enhance students' science process skills, the main effect was not significant for this domain. Further research is required to explore this further.

Qualitative data gathered from the students' gave further insight into whether the approach was effective in engaging them with physics. The majority of the students believed that such an approach helped them with their learning (85%) and as a consequence impacted positively (72%) on their learning outcomes. They also believed that web-based learning supplemented in-class learning (80%) and that online quizzes (90%) were an effective way to receive *feedback* and facilitated *reflection*. *The tests...helped me in my revision*. Qualitative feedback such as this shed more light on how the website supported student learning. *Modelling* strategies were identified as critical to this understanding. For example, online notes were *short and concise* which made it *easier to learn*. *Examples helped me understand how formulas work...I learn by looking at examples*. In a large-scale study conducted in Norway, teachers were criticized "for not showing the details of calculations when doing problems on the blackboard" (Angell et al. 2004, p. 692). Alternative modelling approaches adopted in this study shows how this issue can be addressed (e.g. *Personally...I find it hard to follow lectures. Without the online notes...I had to write as the teacher spoke and that can become a frustrating task when I cannot keep up*).

Some students claims were specific in terms of how the website impacted on specific aspects of the performance domains, for example as one student commented that the *challenging questions in the Forum assisted me to answer complex type questions*. In Angell et al.'s (2004) study, students rated chalk and talk lessons as

boring - they preferred other strategies that promoted active participation. Chats in this study were suggested as a strategy that can enthuse *the laziest of students* because it *forced them to keep up with the work being covered in class and presented some more stimulating questions*. Chats were facilitated by *coaching, scaffolding, articulation and questioning* - strategies of the cognitive apprenticeship model.

The students also identified variety as an effective teaching strategy of this approach because it developed understanding and sustained interest. The website *adds more variety to learning and made me more interested in the subject*. Some students believed that variety *improved their marks because it explains things in different ways*. The literature has identified variety as an important strategy because it facilitates the “juxtaposition of different representations” which can lead to deeper understanding of concepts (Schwartz, Martin & Nasir, 2005, p. 32). Hence, students’ positive learning outcomes in this study could be attributed to the juxtaposition factor identified here.

What is also noteworthy is that the instructional methods of cognitive apprenticeship supported reflexive pedagogies (Kalantis & Cope, 2008). For instance the website facilitated:

- a) coaching, scaffolding, articulation through online chat which encouraged dialogue and group collaboration;
- b) modelling and exploring through concept focussed web pages and links to real work examples to cater for learner diversity;
- c) questioning via email and feedback to online quizzes to enhance learning through reflection;
- d) activities which represent a mix of knowledge processes by adopting a blended approach.

From the results of this study, it is plausible to suggest that web-based learning can make a difference to learning outcomes. But the classroom learning environment can be influenced by the interplay of a range of factors. As Johansson and Gärdenfors (2005) pointed out:

In cognitive psychology and other descriptive theories, one tries to isolate variables that are relevant to learning to experimentally investigate their effects. In contrast, in a real-life setting all variables are active at the same time and cannot be treated in isolation, so a holistic solution to the educational framework must be sought. (p. 3)

Web technologies are dynamic and always evolving. This investigation has opened a window of opportunity which suggests that web-based learning can make a difference to practices and learning outcomes. But given the nature of field, in order to develop a holistic solution, further ongoing research is warranted.

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