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An Investigation into the Role that Information Communication Technology (ICT) Can Play in the Teaching and Learning of Leaving Certificate Physics

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0. Abstract

As a past teacher of Leaving Certificate Physics in Ireland, the researcher has experience of working with learners of the subject who frequently found many of the concepts on the syllabus difficult to grasp.

Currently in the USA, instructors of High School and First Year College Physics are taking advantage of widely available web-based technologies to develop interactive Java applets called Physlets® to better explain complex Physics concepts.

The aim of this paper is to investigate the role that information communication technology (ICT) in general, and Physlets® in particular, can play in the teaching and learning of Physics at Leaving Certificate level in Ireland.

To achieve this aim, this paper will describe the development of an interactive Physlet®-based lesson tailored for the Irish Leaving Certificate Physics syllabus, will describe the implementation of the lesson with current students of Leaving Certificate Physics, and will evaluate the use of this lesson as a teaching method or learning aid in the classroom.

1. Introduction

From professional experience of teaching Physics to Leaving Certificate students in Ireland and from personal experience of learning Physics, the researcher has come to know that the subject includes many concepts that learners frequently find difficult to grasp, often because these concepts are complex or abstract and cannot be visualised or made concrete, or else are such that it is not feasible or possible to demonstrate them in a practical way in the classroom. Hence this paper will explore the role that ICT can play in making it easier for learners to visualise and grasp such concepts.

In the USA, scriptable Java applets called Physlets®, are being built and shared for providing interactive demonstrations of and explorations into a wide range of physical phenomena including many of the concepts studied as part of the Leaving Certificate Physics syllabus. This new technology seems to be gaining popularity for delivery of both High School and early undergraduate courses in Physics in the USA and appears to be reaping a lot of positive results and feedback on it's use as a learning aid, but appears not to have gained widespread recognition in Ireland yet.

This paper will take a look at the use of Physlets® as a learning aid in the Physics classroom in the USA and at peoples' experiences of teaching and learning with them.

It will then describe the design and development, undertaken as part of this current research paper, of an on-line Physlet®-based lesson based on a section of the Irish Leaving Certificate Physics syllabus. This lesson will be developed using the ADDIE (Analysis, Design, Development, Implementation, Evaluation) systems development lifecycle approach to Instructional Design and will take into consideration usability and user experience goals with the objective of making the developed product easy, effective, and enjoyable to use.

This paper will go on to describe the implementation of the lesson with learners of Leaving Certificate Physics, the approach being to teach the content to one group of learners using the newly-developed Physlet®-based lesson and to teach the same content to another group using the traditional text-book/ chalk&talk method, and then to compare the ease and success of learning of each group.

Finally, evaluation of the use of the lesson as a teaching and learning aid will be based on Kirkpatrick's model for summative evaluation of instructional design. This will include reactions of learners and teachers to the use of the lesson in the classroom, actual evidence of learning on the part of students of the content contained in the lesson, as well as indication that students have transferred this learning to completing other classroom and exam-based problems based on the content.

The objective of this paper is thus an attempt to establish whether the use of ICT in general and Physlets® in particular can play a role in making easier the understanding and learning of concepts from the Irish Leaving Certificate syllabus.

2. Literature Review

According to the Irish government's Statistical Report 1999/2000 on uptake, participation, and grades achieved at Leaving Certificate level, only 15.4% of all students in the Leaving Certificate program in 2000 were taking Physics as a

subject, with this number comprising 24% of all male students and only 7.2% of all female students [DES 2000, p. 99-110].

A Task Force on the Physical Sciences was set up by the Irish government in October 2000 to inform on the state of participation in the study of the physical sciences in Ireland today and to address critical issues such as low uptake of Physics by second-level students and to offer recommendations for support for teaching this subject in schools. Their findings report a steady decline in the study of Leaving Certificate physics during the past 10 to 15 years, with participation declining from 20.4% of all Leaving Certificate students in 1988 to 16.4% in 2001.

The Task Force also found that many Leaving Certificate students say they did not choose Physics or Chemistry because of the difficulty of the subjects [DES 2002a, p. 47]. This perceived complexity or abstractness of the science subjects deter students from either selecting in the first place to study the subject at Leaving Certificate level or else, later on, from succeeding as well as they might expect.

The Task Force reports that from the perspective of students, Physics is taught in a very formal presentation style, with the most frequent activities taking place in the science classroom being teacher explaining to class, students writing in notebooks, and students reading science textbooks [DES 2002a, p. 51].

According to the Leaving Certificate Physics syllabus, as prescribed by the National Council for Curriculum and Assessment, "the use of spreadsheets, data-logging, computer-aided learning, modeling, and simulation is recommended." [NCCA 2002, p. 2], thus clearly endorsing the use of ICT as a teaching and learning aid in the Physics classroom.

The government's Guidelines for Teachers document, published to support the implementation of the newly revised Physics syllabus, similarly recommends "ready access to information and communication technologies" [DES 2002, p. 6]. The Kilkenny Schools IT 2000 Project focused on the integration of ICT into the classroom in a number of pilot schools in Kilkenny as part of the Kilkenny Information Age initiative, and these schools are at the forefront in the use of ICT in Irish classrooms.

A key objective in each case was to determine the pedagogical benefits of the use of ICT in the classroom and the impact of this intervention on the participants. The findings of the project included that where good infrastructure and technical support and help were in place, the use of ICT resulted in "very high quality learning experiences" with children being "very enthusiastic about using ICT" [CRITE/KIA 2002 p. 15].

The Kilkenny project also reported that where successful integration of ICTs into learning took place, the common theme was ICTs' integration being made possible by people and ideas with technology being a "mere assistant" [CRITE/KIA 2002 p. 8]. There is little or no point in using ICT just for the sake of it and if not used properly, ICT can actually be a barrier to learning.

To illustrate this point with reference to the Physics classroom, a search on the word 'physics' on the Google search engine produces about 11,600,000 related pages, but the majority of these are probably useless or irrelevant to the teacher or learner of Leaving Certificate physics.

Browsing through some of these physics-related sites reveals that relevant internet resources do exist to support Irish teachers and learners of the Leaving Certificate Physics syllabus. If teachers were made aware of these and given the support to use the technology involved, they could be harnessed to enhance the teaching and learning of physics.

The *skoool* website, a collaboration between AIB Bank, The Irish Times newspaper, and Intel® Ireland, has excellent study notes for the purposes of revision, also pages on the structure of the examination paper along with model answers.

The *Scoilnet* website, developed as part of the government's Schools IT 2000 project, has no specific physics content but has been developed as a portal for educational information and support for teachers with news, links, and forums for supporting teachers and learners in various aspects of education.

The *IASTE* website, developed by the Institute for the Advancement of Science, Technology, and Economics, is an excellent resource with pages on a number of sections of the Leaving Certificate physics syllabus, the material developed specifically to cater for this category of learners. The material includes text-based explanations, illustrated examples, and animated demonstrations.

The *Physical Sciences Initiative* website, co-hosted by the Limerick Education Centre and the Department of Education and Science, again contains a vast amount of information on the Leaving Certificate physics syllabus, although most of this is in PDF document form, that is mostly text-based with static graphics for illustrations.

The website of the *Institute of Physics in Ireland* is another portal for information and links on events happening involving physics in Ireland, but doesn't contain specific syllabus-related resources, while the *Top Study* site, developed by Zenith Solutions in Cork city, offers a mixture of general information, current year examination timetables, a database of past examination papers, and links of interest to teachers and learners.

In the USA, an exciting new technology is being developed specifically for helping students of Physics to deepen their understanding of Physics concepts and better develop their problem-solving skills. Libraries of Java applets called Physlets®, are being built and shared for providing interactive demonstrations of, and explorations into, a wide range of physical phenomena. The term "Physlet®", meaning a Physics Java Applet, was invented by Wolfgang Christian of Davidson College in the USA, and most of the initial development work on this technology was done by Christian and a colleague in Davidson, Mario Belloni [http://webphysics.davidson.edu/Applets/Applets.html].

Physlets® are small with simple graphics and no extraneous details, allowing them to be embedded in almost any type of HTML document and downloaded over the internet. Physlets® are independent of teaching style and can be used as traditional lecture demonstrations, as end-of-chapter homework, as tutorials, peer instruction, just-in-time teaching, or as an element of any number of other methodologies.

Experiences of using Physlets® as a teaching aid report their benefits to include "increased visualization" and "creativity on the part of the student that is difficult to replicate in a paper-based problem", with students finding Physlet® problems to be "exciting and relevant" [Dance et al. 2002, p. 495-496].

3. Methodology

Physlets® as described above are an innovative new technology and are gaining popularity for delivery of High School physics in the USA. Their use in interactive lessons is reaping a lot of positive results and feedback as a learning aid, but appears not to have gained widespread recognition in Ireland yet.

The key feature of these Physlets®, and the reason they have the power to grab interest and stimulate learners much more than the previously mentioned on-line resources, is the interactive element. Not only does the animation allow the learner to visualise events that it is normally not possible for them to see, but the facility to interact with the Physlet® to find out information and solve problems, by making changes to input parameters (such as time, velocity, acceleration, force, and so on) and measuring resulting changes in outcomes, has been shown to easily inspire the learner into predicting, either qualitatively and/or quantitatively, what will happen.

The possibilities for extending the use of Physlets® are wide-ranging, allowing the learner to work independently either in school or at home. The technology allows for experimentation on phenomena such as free-fall due to gravity, nuclear fusion/fission, electromagnetism, and many others from the physics syllabus, to better help students to visualise physical situations that are not possible or safe to explore under normal classroom conditions without the use of such technology.

As well as the existing libraries of Physlets® being freely downloadable for non-commercial use, the Physlets® are scriptable so that the Physics contained within can easily be change and modified, so that it would be possible for teachers in this country to take advantage of work already done and tailor the technology to reflect more fully the Irish Leaving Certificate Physics syllabus. The Davidson College website provides comprehensive documentation and tutorials on both modifying existing Physlets® as well as how to go about scripting one from the ground up.

In an attempt to gain insight into the role that ICT can play as a teaching and learning aid in the Physics classroom, the method of research for this dissertation will involve development of an interactive lesson based on the Irish Leaving Certificate Physics syllabus.

The concepts chosen for the lesson are from the Mechanics section of the syllabus, sub-section Motion, topic Linear Motion. As well as knowledge and understanding of the fundamental principles and laws of Physics, the recently revised Leaving Certificate syllabus stresses the importance of placing these "within relevant contexts by referring to the applications of physics and solving problems set in the everyday world" [NCCA 2002, p. 2] and this is followed through in the lesson.

Lesson Design

Module Aim

The aim of the module is to support students of the Leaving Certificate Physics course in their learning of the Linear Motion sub-section of the Mechanics section of the syllabus.

Module Objectives

1) The student will complete the module and all the component exercises.
2) The student will demonstrate knowledge and understanding of the concepts covered in the module.
3) The student will demonstrate practical application of their learning by successfully completing a written assessment based on the module content, with questions similar to those they will face on the topic in the Leaving Certificate examination.

Module Syllabus

Mechanics – Motion – Linear Motion. Learning concepts:

1) Scalar and Vector quantities – definitions and the differences between them.
2) Displacement – definition and units of measure.
3) Speed – definition and units of measure.
4) Velocity – definition and units of measure.
5) Acceleration – definition and units of measure.

6) Equations of Linear Motion – knowledge of formulae and application in problems.

Module Content

Scalar quantities

- do not have a direction associated with them
- examples include time, mass, volume
- can be added using the normal rules of algebra

Vector quantities

- do have a direction associated with them
- examples include velocity, acceleration, force
- can not be added algebraically unless they act in the same direction
- can be subtracted algebraically if two vector quantities act in exact opposite directions
- must be added trigonometrically, i.e. by breaking into vertical and horizontal components

Displacement is the distance in a straight line from a starting point (metres).

Speed is the total distance covered divided by the time taken (metres/second).

Velocity is the total distance covered in a particular direction divided by the time taken (metres/second).

Acceleration is the change in velocity divided by time taken, i.e. the rate of change of velocity (metres/second/second).

The equations of linear motion are:

$$v = u + a\,t$$

$$v^2 = u^2 + 2\,a\,s$$

$$s = u\,t + \tfrac{1}{2}\,a\,t^2$$

$$s = \frac{(u + v)\,t}{2}$$

User Profile

- The user will be a Leaving Certificate level student, average age 16 to 18 years old.
- Assuming all users will have successfully completed the Junior Certificate Science examination, there is no other prerequisite knowledge. There is no other section of the Leaving Certificate Physics syllabus that they need take before tackling this module.
- The user will be familiar will standard PC and internet technology, web browsers, and so on.
- User competence and motivational levels, as regards the learning of the subject matter, may be varied.

Usability goals of the application

- Easy to learn, use, and remember – the user should be able to sit down and within minutes be comfortable using and navigating through the module.
- Effective and efficient to use – the user should be able to focus on learning about Linear Motion, rather than on how to use the software – that is, unimpeded by the burden of multi-level menus, complex keystrokes combinations, and so on.
- Safe and reliable – the user should be able to click and explore freely without causing system errors or crashes, losing data or getting lost in the application.

Look and Feel

- The application will consist of a number of linked HTML pages, viewed through an internet browser. The pages will include:

1. Homepage – welcome and links to content.
2. Theory page – reference information, definitions, units of measure, formulae.
3. Speed & Velocity – lesson based on Physlet® animation & exercises.
4. Linear Motion (Freefall) – lesson based on Physlet® animation & exercises.
5. Acceleration – lesson based on Physlet® animation & exercises.

- The embedded Physlets® (java applets) will be relatively heavy on processor and memory usage, so to otherwise maximise performance of hardware and software, the look of the application will be simple and clean, with no flashing or superfluous graphics.
- Links will be simple text-based hyperlinks rather than icons or buttons.
- All pages will have a consistent style in terms of text (font, size, style), background image (mute and non-distracting), layout of text and Physlets® on screen, and so on.

4. Data Analysis

The intended methodology was to teach the chosen concepts to one group of students using the interactive lesson and to teach the same concepts to another group using a traditional textbook/ chalk&talk approach. However, due to difficulties of getting access to a school and due to other unforeseen events causing the project to run behind schedule, the lesson was eventually tried out by a trial group of three students only.

Given this very small sample size and thus the very narrow scope of the project, this paper cannot offer concrete evidence of the value of introducing ICT in general, and Physlets® in particular, into a Physics lesson. Rather it relates personal experience of a small practical implementation of such an approach and provides initial feedback on the reactions of learners towards the use of this technology, focused more on motivation and interest than the learning achieved.

To evaluate success of use of the interactive lesson as a learning aid, the approach was to use Kirkpatrick's four-level model of summative evaluation.

In the first level, students' reaction, the students were observed during completion of the lesson and afterwards were asked for their opinions and comments on it. In spite of the shortness of the time involved, with the group exposed to the lesson for just one hour, as well as being crowded around just one PC, the general reaction seemed to be curiosity, enthusiasm, and enjoyment, with the group becoming absorbed in the lesson.

Continuous interaction and collaboration also took place between them as they navigated through the content, as they discussed their way through completion of the problems. The group was all frequent PC users and had no difficulties in navigating their way through the pages of the lesson. Comments afterwards included that "it was more interesting than listening to the teacher" and "it will be easier to remember from doing it on the computer than if we just did it from the book".

However an interesting finding was that the students preferred to print out the theory page rather than jump back to it on-screen when they needed to refer to it, reinforcing the importance of integrating media and blending approaches in the classroom, with technology as partner rather than the sole medium of instruction. It was also noticed that on numerous occasions one or two of the group jotted notes on the margins or back of these pages.

For a larger implementation, a 'smile sheet' questionnaire could include questions on the relevance of the material, amount of exercises, ease of navigation, and so on.

Level Two in the Kirkpatrick model measures learning results and for this the students completed a post-test, a written lesson review, with problems based on each of the concepts presented in the lesson, that is Speed and Velocity, Freefall, and Acceleration. Again with a larger sample size, it would be useful to summarize the scores of students to more accurately evaluate learning results of the lesson. The test group of three students ended up collaborating on completion of the lesson review and together managed to successfully solve all the problems. It was noticed however that the group needed repeated urging to switch their attention to the written lesson review exercises, stating at the time that they would rather stay "messing around" with the computer. While integrating ICT into the classroom may increase motivation and interest in the "fun stuff", a teacher may be faced with increased reluctance to attend to non-computer-based activities.

Level Three of Kirkpatrick's model attempts to answer whether or not students' behaviours actually change as a result of new learning, that is whether any of the new knowledge and skills are retained and transferred back to completing other textbook exercises and exam questions based on the content. Level Four attempts

to measure whether students are more effective in their work by applying the subject material, that is whether they become more effective in learning Physics concepts in general and in thinking as a physicist does.

These last two levels are ideally measured three to six months after the learning event, the reasoning being that by allowing some time to pass, students have the opportunity to implement new skills and their retention rates can also be checked. It would involve getting feedback from the regular subject teacher. Measurement may even include achievement in end-of-year tests and in the Leaving Certificate exam itself. Thus they are outside the scope of this paper.

Given that time and resources were short, the implementation of the lesson was successful in so far as the students seemed to learn from it, they enjoyed the learning experience and completed the work without objections.

However it was realized that true exploitation of ICT in the learning process would involve a lot more than offering an occasional computer-based lesson. It would involve fairly major changes in the whole course design, learning and assessment activities. ICT-based materials that are "bolted on" to the main course, as done for the purposes of this research paper, are at risk of being seen to be fun and non-assessable or even of remaining unused. The key to success seems to be combination of subject knowledge and pedagogical understanding driving a holistic systems analysis and design life-cycle approach to integration of ICT into the course syllabus, course activities, and assessment exercises [LDTI 1996 p. 9].

5. Conclusions

During informal discussion with the group on the use of computers to learn Physics, one comment made was that students would still need the textbook for doing homework and study at home, a reminder that not all students will yet have access to computer and internet technology at home. An important lesson learned in this research was the value of traditional teaching methods and activities and the conclusion that the role that ICT can play in the classroom is that of an added resource. This concurs with the reminder given to attendees of the recent 3rd Annual Irish Educational Technology User's Conference that "students do not learn *from* technology, they learn from thinking and engaging in activity" and the promotion of technology-as-partner rather than technology-as-teacher [Doolittle 2002, p. 5].

During research for this paper, certain issues were identified that would merit significant research in the future. These include the issue of support that teachers have access to in the use of ICT in the Physics classroom. There is no single cohesive on-line public forum for Physics teachers in Ireland to raise issues and difficulties that they are facing in the classroom, no one common portal to comprehensive evaluations of currently-available technologies, software, and

resources. There is no on-line one-stop shop for Physics teachers. ICT suggests a flow of information via technology-based channels of communication and this does not seem to be happening.

While research did source, due mostly to luck and previous experience of using search engines, a number of lists of links to physics-related sites with potential for use in the classroom, some of these links were found to be obsolete, and those that did still exist were not tailored to use in the Physics classroom, particularly not in Irish second-level schools. There seems to be a need for much more web-based resources specifically designed and developed to support the teaching and learning of Leaving Certificate Physics, including guidelines and support for the building of specific lessons and activities around these resources.

From informal discussions with teachers of second-level Physics, it seems that even where teachers are enthusiastic and willing to introduce innovative approaches to teaching the subject, they are hindered by lack of training and technical support in the use of the hardware, particularly in terms of having access to immediate support when problems occur with hardware or software.

The burden of overcoming technical obstacles will hinder the harnessing of ICT as a teaching and learning aid in the Physics classroom, with the focus being on how to use the technology itself rather than on the learning that should be taking place.

It is not enough that technology is in place and teachers are willing. It is essential that support is readily available in every aspect of introducing and implementing the use of ICT in the classroom.

It would seem to be of value to gather comprehensive data on current practice and particularly best practice in the use of ICT in the Irish Physics classroom, not just the existence of ICT hardware and software but the actual and positive employment of this technology. It would then perhaps be of value to Physics teachers to collate and make this information available on a public site where they could not only access it but also add to it and communicate with fellow teachers of Physics in this country.

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