E-Learning and students' cognitive expectations in introductory physics

Aprendizaje con computadores y expectaciones cognitivas en cursos introductorios de la física

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Abstract

The paper describes the use of e-learning resources - the Integrated Virtual Learning Environment [http://ivle.dlsu.edu.ph], physlets (short Physics applets / animations), and Internet sites dedicated to Physics students - in the author's Introductory Physics classes during the last two academic years. Using a survey instrument developed and validated by the University of Maryland Physics Education Research Group, the paper also documents how students' cognitive expectations - their expectations about the learning process and the structure of knowledge - change after going through their Introductory Physics course.

Key words*: cognition, e-learning, introductory physics, college-level teaching*

Resumen

Este trabajo de investigación explica el uso de las varias fuentes posibles del aprendizaje con computadores, como el medio virtual integral de aprendizaje [http://ivle.dlsu.edu.ph], animaciones en física, y sitios de la Internet. Todos éstos son dirigidos a los estudiantes que toman cursos de física básica, específicamente durante los dos últimos años académicos. Utilizando un instrumento de encuesta desarrollado por el grupo de investigaciones de educación en física de la Universidad de Maryland, este trabajo documenta cómo las expectaciones cognitivas de los estudiantes cambian después de haber tomado cursos introductorios en física.

Palabras clave*: cognición, aprendizaje, computadores, física básica, nivel universitario*

INTRODUCTION

Technological advancements during the close of the twentieth century ushered in the Internet and the World Wide Web. This development has made a profound impact on all aspects of human society. This worldwide computer network has enabled communication among millions in our digitally linked global community. The resources that had been made available through the web —such as virtual libraries and museums, electronic databases, and digital communities— promote a novel setting for new learning experiences.

KLASSEN & VOGEL (2003) put forward the idea that this new approach to teaching and learning, called by a variety of terms —networked learning, e-education, e-learning, virtual learning, or computer-mediated education— is challenging the traditional mode of operation for universities. Since information can be stored anywhere and transmitted anywhere, computer technology has broadened the choices for the mode of delivery, content, and access. The Internet has given rise to distance learning (HARASIM, 1990; THORPE, 1995; SPOONER, *et al.*, 1998), on-line learning (MASON, 1998; BENIGNO & TRENTON, 2001), and virtual universities / e-universities (POLLOCK & CORNFORD, 2000; MAES, 2001; PARIKH, 2003).

BROADLY defined, e-learning is networked, on-line learning that takes place in a formal context and uses a range of multimedia technologies. GARRISON & ANDERSON (2003) are strong in their position that "e-learning cannot be ignored by those who are committed to enhancing teaching and learning". Further, they challenge educators to put "more effort and creativity … into understanding and appreciating the integrating element of teaching presence to facilitate critical thinking and higher-order learning outcomes within an e-learning context". Teaching presence is 'the design, facilitation, and direction of cognitive and social processes for the purpose of realizing personally meaningful and educationally worthwhile learning outcomes' (ANDERSON, *et al.*, 2001).

Research has shown that students come to our science classrooms with pre-conceptions (based on their experience of the physical world) that are not necessarily matched with the concepts they have to learn (LAWSON, 1998). Activities that challenge students' initial conceptions have been shown to lead to a good understanding of basic scientific concepts (LAWS, 1997; VAN DOMELEN & VAN HEUVELEN, 2002). Research has also shown that students who had engaged in inquiry investigations significantly outperformed students who were taught using the straight lecture method (MARBACH-AD & CLAASSEN, 2001; MARSHALL & DORWARD, 2000). The use of the internet (HENZE & NEJDL, 1997; Marold, *et al.*, 2002) has also been cited as helpful in promoting conceptual understanding among students. Care must be taken however, to ensure that web-based instruction is grounded on learning theories to provide effective and efficient instruction (LEFLORE, 2000).

COGNITIVE EXPECTATIONS

The Physics Education Research Group of the University of Maryland posits that what students expect will happen in their Introductory Physics course plays a critical role in how they will respond to the course (REDISH, *et al.*, 1998). Students' understanding of what science is about and what goes on in a science class, affects what information they will listen to (and what they will ignore) given the often large amount of material we, their teachers, flood them with. By looking at how our students view science, we could use these initial conceptions to our advantage in our science classrooms.

In this paper, students' *cognitive expectations* —expectations about the learning process and the structure of knowledge— were documented using the Maryland Physics Expectations (MPEX) Survey. The Maryland Physics Expectations (MPEX) Survey is a five-point Likert-style questionnaire developed by Edward Redish, Jeffrey Saul, and Richard Steinberg of the Department of Physics, University of Maryland. A description of the development, validation, and calibration of the instrument may be found in the paper by REDISH *et al.* (1998).

The MPEX survey is designed to probe students' expectations, attitudes, and beliefs about six aspects or dimensions of learning physics. Three dimensions are taken from DAVID HAMMER'S (1994) research on student's epistemological beliefs. These dimensions are:

Independence —beliefs about learning physics— the learner takes responsibility for constructing their own understanding or the learner takes what is given by authorities (teacher, textbook) without evaluation.

Coherence —beliefs about the structure of physics knowledge— the learner believes physics needs to be considered as a connected consistent framework or the learner believes physics can be treated as unrelated facts or pieces.

Concepts —beliefs about the content of physics knowledge— the learner attempts to understand the underlying ideas and concepts or the learner focuses on memorizing and using formulae.

The dimensions that the Maryland Physics Education Research Group added include:

Reality link —beliefs about the connection between physics and reality— the learner believes that ideas learned in physics are relevant and useful in a wide variety of real contexts or the learner believes that ideas learned in physics has little relation to experiences outside the classroom.

Math link —beliefs about the role of mathematics in learning physics— the learner considers mathematics as a convenient way of representing physical phenomena or the learner views physics and math as independent with little relationship between them.

Effort —beliefs about the kind of activities and work necessary to make sense out of physics —the learner makes the effort to use available information and make sense out of it or the learner does not attempt to use available information effectively.

REDISH & STEINBERG (1999) report that based on the results from more than 1,500 students from six American colleges and universities, it is clear that many students come into physics courses with unfavorable views about the nature of learning physics. More worrisome is that these views tend to deteriorate after a semester of university physics. However, it does appear that, in certain modified learning environments, student views do evolve to be more favorable. In the *Workshop Physics* classes that REDISH & STEINBERG (1999) observed, the students showed a 2.5 standard deviation improvement on the average of the independence, coherence, and concepts clusters of the MPEX.

ELBY (2001) describe the curricular reforms instituted in a small high school – the use of small groups on activities and problems, parts of which resemble *Tutorials in Introductory Physics* (MCDERMOTT *et al.*, 1998) and *Real Time Physics* (SOKOLOFF *et al*., 1999) – that helped the students develop substantially sophisticated beliefs about knowledge and learning, as measured by the MPEX.

Working with Canadian college students, VAN AALST & KEY (2000) report results obtained with the Maryland Physics Expectations (MPEX) survey in: (a) a course for students who have not previously taken a second course in physics in high school; (b) physics for the life sciences; (c) honors physics; and (d) physics for engineers. Comparing the student responses with the "expert group" of REDISH, *et al.* (1998), the researchers found out that (i) over-all, agreement with experts decreased after two semesters of instruction, and (ii) there were significant differences between the response patterns for students in the first two courses compared with the last two (honors physics and physics for engineers).

E-Learning Resources in Introductory Physics

This section presents resources used by the author in the Introductory Physics courses he has taught during the last two academic years.

Integrated Virtual Learning Environment

The Integrated Virtual Learning Environment (IVLE) is a courseware management system designed to support the teaching-learning process over the Internet. Aside from facilitating the organization of course materials on the web, IVLE also provides a wide variety of tools and resources that could be added to the course.

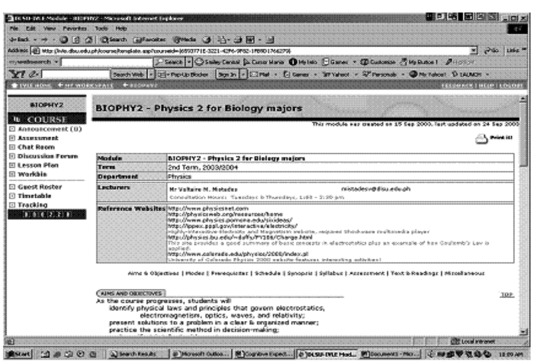

Figure 1. Screenshot of the IVLE BIOPHY2 page [http://ivle.dlsu.edu.ph]

The 'Assessment' tool allows students to answer review questions online in preparation for examinations in class. The 'Discussion Forum' tool provides a venue for the exchange of ideas even outside of classroom contact hours. Students submit web-based activities via the Workbin.

RIFFEL & SIBLEY (2005) described a hybrid course format (part on-line, part face-to-face) they developed to deliver a high enrolment introductory environmental biology course to non-science majors at a large public university. The hybrid course was structured to include bi-weekly on-line assignments and weekly meetings in the lecture hall that focused on active learning exercises. Students reported a higher quality of interaction with the instructor compared with a second group of students who were taught using passive lectures instead of on-line assignments. The researchers also found that performance gains were greater for upperclassmen than for freshmen, indicative of hybrid course formats being a better option for upperclassmen while satisfying general science requirements (terms like 'upperclassmen' may need defining for a non American readership).

PHYSLETS

The use of Physics applets (Physlets) was maximized throughout the Introductory Physics courses taught during the last two academic years. Physlets are small, scriptable Java applets capable of displaying physics content. DANCY *et al.* (2003) report the ease of use of Physlets since they are based on standard non-proprietary Internet technologies.

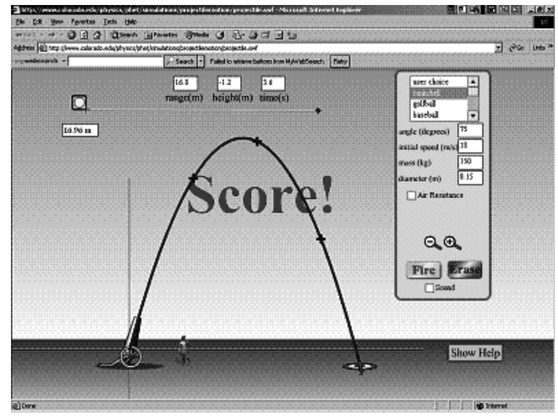

Figure 2. Screenshot of a Physlet on projectile motion [http://www.colorado.edu/physics]

There are several websites that provide access to Physlets, including:

(a) National Taiwan Normal University http://www.phy.ntnu.edu.tw/ntnujava,

(b) Davidson College http://webphysics.davidson.edu/applets, and

(c) University of Toronto http://www.upscale.utoronto.ca/GeneralInterest/Harrison/Flash.

Physics Internet Sites

The Physics Education Technology (PhET) [http://www.colorado.edu/physics/phet] website offers simulations designed to build students' explicit bridges between their everyday understanding of the world and their underlying physical principles. The simulations are highly interactive and engaging, and they provide animated feedback to the user. The highly visual, dynamic representation of Physics principles had been carefully prepared to ensure that they model accurate Physics principles.

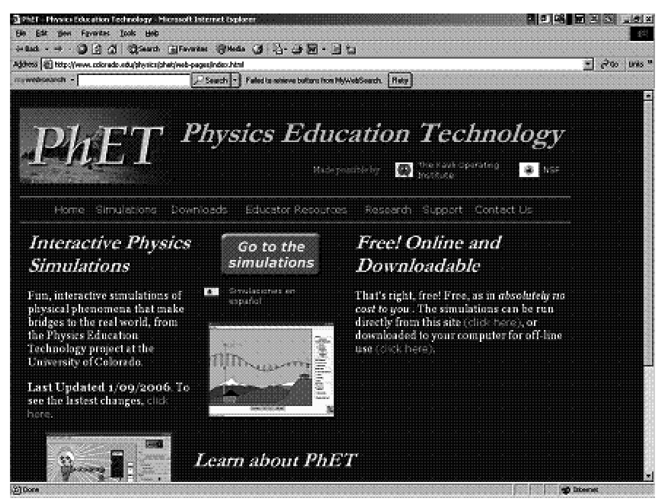

Figure 3. Screenshot of the PhET website (University of Colorado) [http://www.colorado.edu/physics/phet]

FINKELSTEIN *et al.* (2005) have demonstrated that properly designed simulations used in the right contexts can be as effective as real laboratory equipment in introducing students to principles and concepts in the physical sciences.

The students in my Introductory Physics classes described the following sites as useful supplements to classroom discussion:

http://www.physicsnet.com

http://physicsweb.org/resources/home

http://www.physics.pomona.edu/sixideas

http://ippex.pppl.gov/interactive/electricity/

http://www.rsc.org/Education/Teachers/inspirational.asp

http://www.rsc.org/Education/Teachers/Games.asp

http://www.newscientist.com/lastword.ns

http://www.challenger.org/about/index.cfm

http://www.scitechdaily.com/

Profile of Students' Cognitive Expectations

The students who participated in the study include:

- Biology majors enrolled in BIOPHY2 (Physics 2 for Biology students),
- Physics majors enrolled in PHYFUN1 (Physics Fundamentals 1), and
- Liberal Arts majors enrolled in INTPHYS (Introductory Physics for Liberal Arts students).

The students took the MPEX as a pre-course survey (pre-test) during the first week of class and again during the final exam week as a post-course survey (post-test).

The students' response for each item in the MPEX was compared with the "experts' response". During the development of the MPEX instrument, REDISH, *et al.* (1998) conducted consultations with lifelong learners (experienced physics instructors who have a high concern for educational issues and a high sensitivity to students) in order to develop the instrument's answer key. When a student's response to the survey item is in agreement with the response of the "expert group", the response is described as *favorable*, otherwise it is described as *unfavorable*. Table 1 shows the summary of the students' agreement / disagreement with the expert response for the six dimensions (clusters) probed by the MPEX.

INDEPENDENCE CLUSTER

This cluster looks at how students think they acquire knowledge and understanding about Physics. Do they get it from the instructor or can they develop it on their own? If students believe that they can develop understanding of Physics independently, they are more likely to take responsibility for their own learning. PERRY (1970) notes that the more mature students understand that developing knowledge is a participatory process. As the learner matures, s/he takes responsibility for constructing knowledge.

Lifelong learners (the 'experts' in REDISH *et al.,* 1998 study) believe that students should disagree with MPEX item # 13, "My grade in this course is primarily determined by how familiar I am with the material. Insight or creativity has little to do with it." At the beginning of the course, only 34% of the Biology majors and 35% of the Physics majors exhibited the experts' response. By the end of the course, two-thirds of the Physics and Biology students surveyed said that creativity and insight is needed to learn Physics. However, only 33% of the Liberal Arts majors gave a favorable response for this item.

Coherence cluster

REDISH, *et al.* (1998) experts strongly emphasize that students should see Physics as a coherent, consistent structure. Students who view science as a collection of facts fail to see the integrity and coherence of the whole structure. For MPEX item # 12, "Knowledge in Physics consists of many pieces of information each of which applies primarily to a specific question", 90% of the Physics majors, 95% of the Biology majors, and 88% of the Liberal Arts students agreed with this statement at the beginning of the course, which is contrary to the experts' response. By the end of their Introductory Physics class, 46.3% of the Physics majors gave the same response as the experts.

A good number of the Biology majors and the Liberal Arts majors still failed to see the relationships between the different concepts they have learned. This observation is supported by the students' response on MPEX item # 29, "A significant problem in this course is being able to memorize all the information I need to know". The students' responses reveal that up to the end of the course, 33% of the Biology majors and 50% of the Liberal Arts majors focus on memory work, rather than finding the relationships between concepts.

Concepts cluster

This cluster is intended to probe whether students are viewing the solving of Physics problems as simply a mathematical manipulation of an equation, or if instead, they are aware of the fundamental role played by Physics concepts in complex problem solving. For students who had high school Physics classes dominated by "simple problem solving" (find the right equation, then calculate a number), it is expected that mostly unfavorable responses will be found in this cluster. Learners who are aware of the fundamental role played by physics concepts in problem-solving view doing physics as more than the "substitute–the–givens–and–solve–mathematically" approach in high school physics.

The favorable shift in the students' responses to MPEX item # 4, "Problem solving in physics basically means matching problems with facts or equations and then substituting values to get a number." [Physics majors: 21% to 57% favorable response (disagree); Biology majors: 15.6% to 35% favorable response], MPEX item # 19, "The most crucial thing in solving a physics problem is finding the right equation to use." [Biology majors: 9.4% to 43.8% favorable response (disagree)], and MPEX item # 26, "When I solve most exams or homework problems, I explicitly think about the concepts that underlie the problem." [Liberal Arts majors: 61% to 93% favorable response (agree); Physics majors: 78% to 93% agreement with the experts] show that the students have taken a conscious effort in learning the concepts.

Reality Link cluster

Learners who believe that ideas learned in physics are relevant and useful in a wide variety of real contexts will give a high rating to this dimension. The items probe whether the students feel that their personal real-world experiences are relevant for the Physics course. The high agreement with experts reported by the students (Physics group, 72.6%; Biology group, 78.1%; and Liberal Arts group, 66.7%) reveal that the students who took the Introductory Physics course saw the link between physics concepts and real-life experiences. For the Biology majors, for example, the medical applications (magnetic resonance imaging, ultrasound, ECG) of the physics concepts learned reinforced the link between physics concepts and reality.

This cluster also looks at the likelihood a student will think about the reality of a solution to a given problem. The experience of Physics teachers leads us to posit that many students will make calculations and not even think about whether the answer makes sense. REDISH, *et al.* (1998) presented, as an example, a student who does a calculation of the speed with which a high jumper leaves the ground and comes up with 8,000 m/s (as a result of recalling numbers with incorrect units and forgetting to take a square root) may not bother to evaluate that answer and see it as nonsense on the basis of personal experience.

Table 1

Percentage of Physics majors, Biology majors, and Liberal Arts majors whose response is the same as experts (favorable) and whose response differs from the experts (unfavorable)

	Physics Majors				Biology Majors				Liberal Arts Majors			
	% favorable		% unfavorable		% favorable		% unfavorable		% favorable		% unfavorable	
MPEX Dimension	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Independence	29.3	51.0	46.0	34.2	36.5	42.7	38.4	39.4	36.0	38.5	41.3	29.2
Coherence	34.3	46.3	47.3	32.8	33.8	31.2	43.8	51.3	20.0	23.1	53.3	43.1
Concepts	48.2	68.4	32.6	14.0	43.2	53.1	39.4	33.8	25.6	31.1	46.2	41.1
Reality Link	54.2	72.6	19.8	9.8	74.0	78.1	8.3	8.3	51.9	66.7	16.7	15.4
Math Link	35.4	43.8	36.8	28.2	39.4	50.6	31.9	28.1	34.6	33.3	29.5	41.1
Effort Link	63.8	68.2	12.6	11.2	73.1	74.4	10.0	10.0	61.5	69.3	12.3	8.0
Over-all	44.2	58.4	32.5	21.7	50.0	55.0	28.6	28.5	38.3	43.7	33.2	29.7

Math Link cluster

An important component of a Physics course is the development of students' abilities to use abstract and mathematical reasoning in describing and making predictions about the behavior of real physical systems. The responses in the math link cluster show that the Liberal Arts students [33.3% favorable responses] who participated in the study have not yet seen the deeper physical relationships present in the equations.

The responses in the math link cluster of the Biology majors [pre-course 39.4% agreement with experts; post-course 50.6% favorable responses] and the Physics majors [35.4% pre-course favorable responses to 43.8% post-course favorable responses] show that these two groups of students could see the deeper physical relationships present in the equations, rather than simply using math in a purely arithmetic sense.

Effort Link cluster

This cluster measures the willingness of students to put forth the effort necessary to make sense of topics in Physics. Three-fourths of the Biology majors and 70% of the Physics majors and the Liberal Arts majors have responded that the effort they exert in learning Physics is similar to the effort exerted by the life-long learners (experts) interviewed by Redish *et al.* (1998). The results reported in this study [an increase in the percentage of students giving a favorable response] differ from the results obtained by Redish *et al.* (1998) in their original study where they found a downward shift in the effort the students exerted. Similar to what this present study obtained, Van Aalst & Key (2000) also reported a positive change in the effort cluster for the students they surveyed.

Synthesis

Comparing the students' cognitive expectations before taking their Introductory Physics course and at the end of the course, we find a favorable shift in their beliefs about the nature of Physics and learning Physics in the following dimensions: (a) independence, (b) concepts, (c) reality link and (d) effort link.

The students reported they were exerting the effort required of them that will allow them to understand Physics. They have likewise seen the value of learning the fundamental concepts in the study of Physics. There is a need, though, to strengthen the integration between the various concepts learned, as reflected in the data obtained for the coherence cluster of the MPEX.

Conclusion: Pedagogical Implication

Web-based learning, or e-learning, provides the learner with an any-time, any-place accessibility. Using this technology, the learning environment may include multimedia such as text, audio, graphics, video, and animation; these learning materials could be revised easily, allowing for the content to be as up-to-date as possible. At this point in time, we cannot categorically state that e-learning resources will solve all the pressing concerns that educators face. What we do know is that, if properly designed, utilized, and applied in the appropriate context, e-learning resources have a place in our science classrooms.

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