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Student Expectations in a General Education Physics Course Taught Using a Transformative-Learning Paradigm

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Abstract: A new general education curriculum has been implemented beginning of the academic year 2006-2007 for the freshman students of De La Salle University – Manila. The study documented how the cognitive expectations of non-science majors changed after taking up an Introductory Physics course that was taught using a transformative learning framework. The paper describes what cognitive expectations are, and provides readers with a preview of how the transformative learning paradigm was used in the Introductory Physics class. By comparing the cognitive expectations profile of the freshmen during academic year 2005-2006 with the profile of the freshmen of academic year 2006-2007, the data generated is a valuable input towards the implementation of the new general education curriculum.

Introduction

The Lasallian (General Education) Curriculum has been implemented beginning of the academic year 2006-2007. The DLSU-Manila General Education Curriculum is "a set of foundational, formative, and integrative courses intended to inculcate students with a critical appreciation of the diverse fields of human knowledge, their principles and science, and their arts and methods of inquiry" (Preamble, General Education Curriculum, De La Salle University – Manila).

The General Education Curriculum is designed to enable Lasallian college students to:

- have the knowledge and skills to engage in more specialized study in the various disciplines and professions;
- have the capability to use the knowledge and skills in the University to effectively participate in varied developmental pursuits in the community, the country, and the world;
- have the foundation for lifelong learning.

To assist curriculum planners, it is imperative to document the effects of this new curriculum on students' learning. The research that had been undertaken documented the impact of the Physics component of the Lasallian (General Education) Curriculum on students' learning. Phase I of the research was conducted during the second and third trimesters of academic year 2005-2006. The data generated by this component of the research served as the baseline data from which comparisons were made later on. The second phase of the research was done during academic year 2006-2007, the initial year of implementation of the Lasallian (General Education) Curriculum.

The proponent investigated the extent to which College of Liberal Arts (CLA) and College of Business & Economics (CBE) students' cognitive expectations – expectations about the learning process in Physics and the structure of Physics knowledge – change after going through their Introductory Physics course. The first phase of the study documented the responses of DLSU-Manila CLA and CBE students who joined the University during academic year 2005-2006. The second phase of the study targeted the responses of students who entered the University during academic year 2006-2007 [this will be the first group of students who will undergo the Lasallian (General Education) Curriculum]. A comparison between the responses of these two groups was made to determine the effect of the transformative-learning framework.

The revised General Education Curriculum (GEC) aims to expand the students' critical and creative thinking skills by engaging in various modes of inquiry. The attainment of this general goal requires a new paradigm of instruction. In the traditional transmission model, knowledge is defined as a set of information waiting to be acquired. In transformative learning, knowledge does not exist as a given truth before the process of learning. Students develop knowledge as a result of their inquiry, action, or experimentation. Physics education research has documented interactive-engagement models and inquiry-based learning models that allowed students to construct more appropriate models of physical phenomena better than the traditional passive lecture (transmission) model (McDermott and Redish, 1999). Working with pre-service elementary teachers and general education students, Marshall and Dorward (2000) showed that students who engaged in inquiry activities performed significantly better in examination compared with students who did not.

Review of Related Literature

The University of Maryland Physics Education Research Group posits that what students expect will happen in their introductory college-level physics course plays a critical role in how they will respond to the course. These expectations affect what students will listen to and ignore in the "firehose of information provided during a typical course by professor, laboratory, and text" (Redish, et.al., 1998). The research conducted by David Hammer (1994) has shown how students' epistemological beliefs affect which activities students select in constructing their own knowledge base and in building their own understanding of the course material.

Beliefs are described as "propositions that are held to be true and are accepted as guides for assessing the future, are cited in support of decisions, or are referred to in passing judgment on the behaviour of others" (Goodenough, 1963, as cited by Richardson, 1996). Green (1971), as reported by Richardson (1996), re-iterated the definition provided by Goodenough (1963), by describing belief as "a proposition that is accepted as true by the individual holding the belief". Green made a distinction between belief, which is a psychological concept, and knowledge, which is a construct that implies epistemic warrant. Richardson (1996) provides us with the definition given by Rokeach (1968), "beliefs are heuristic propositions that may begin with the phrase, 'I believe that …'". Rokeach also postulated that some beliefs are more central than others and that central beliefs are more difficult to change.

Studies of student expectations in science in pre-college classrooms (Carey, et.al., 1989; Songer and Linn, 1991) reveal that student attitudes towards their classroom activities and their beliefs about the nature of science and knowledge affect their learning.

Research has shown that students bring with them their experiences of the world (Laws, 1997; Lawson, 1998; McDermott and Redish, 1999; van Domelen and van Heuvelen, 2002), which leads them to develop many concepts of their own about how the world functions. These concepts are often not matched with what they are supposed to learn in physics courses (Hestenes, et.al., 1992; Hestenes and Wells, 1992; Halloun and Hestenes, 1985; Maloney, et.al., 2001). These pre-conceptions make it difficult for students to learn the material needed in their college-level physics course.

It is not only physics concepts that a student brings into the physics classroom. The University of Maryland Physics Education Research Group (Redish, et.al., 1998) coined the term cognitive expectations to describe a student's set of attitudes, beliefs, and assumptions about what sorts of things they will learn, what skills will be required, and what they will be expected to do. These cognitive expectations focus on students' understanding of the process of learning physics and the structure of physics knowledge rather than about the content of physics itself.

Redish, et. al. (1998) described the work done by Perry (1970) with Harvard and Radcliffe students throughout their college career and the longitudinal study done by the group of Belenky, et. al. (1986). Both studies found an evolution in the expectations of their subjects – moving through a "received knowledge" stage, in which they expected to learn the "truth" from authorities, to a sophisticated "consciously constructivist" stage, where the subjects accepted their own personal role in deciding what views were most likely to be productive and useful for them.

Redish and Steinberg (1999) report that based on the results from more than 1500 students from six American colleges and universities, it is clear that many students come into physics courses with unfavourable 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 favourable. In the Workshop Physics classes that the researchers observed, the students showed a 2.5 standard deviation improvement on the average of the independence, coherence, and concepts clusters of the MPEX.

Working with Canadian college students, Van Aalst and 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 responses with the "expert group" of Redish, et.al. (1998), the researchers found out that (i) overall, 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 ascompared with the last two.

Local studies have focused on documenting science majors' cognitive expectations in their Introductory Physics classes. Mistades surveyed Biology majors (2004a) and Physics majors (2004b) taking up Physics Fundamentals 1 (Mechanics). Comparing pre-course and post-course data, the students' responses showed an increased agreement with experts in the six dimensions (about the nature and structure of learning): (a) independence, (b) coherence, (c) concepts, (d) reality link, (e) math link, and (f) effort link.

Activities that challenge student's initial conceptions have been shown to gather a good understanding of basic scientific concepts (Laws, 1997; McGinnis, et.al., 2002; van Domelen and 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 (Cheng, et.al., 2004; Hake, 1998; Marbach-Ad and Claassen, 2001; Marshall and Dorward, 2000; Thacker, et.al., 1994; Thornton and Sokoloff, 1998).

Given that the objective of the General Education curriculum is to lay the foundations that will allow the students to be life-long learners, there is a need to document students' views, attitudes, and beliefs about the learning process.

Research Objective, Statement of the Problem, and Significance of the Study

The proponent investigated the extent to which College of Liberal Arts (CLA) and College of Business & Economics (CBE) students' cognitive expectations – expectations about the learning process in Physics and the structure of Physics knowledge – changed after going through their Introductory Physics course.

The first phase of the study documented the responses of DLSU-Manila CLA and CBE students who joined the University during academic year 2005-2006. The second phase of the study targetted the responses of students who joined the University during academic year 2006-2007 [this will be the first group of students who will undergo the Lasallian (General Education) Curriculum]. A comparison between the responses of these two groups was made.

The present study attempted to answer the following questions:

- What arethe students' cognitive expectations as compared with the responses made by the life-long learners (experts) in the study by Redish, et.al. (1998)?
- Is there are favourable shift in the students' cognitive expectations after going through their Introductory Physics course?
- Is there a significant difference in the responses of the students who were freshmen during academic year 2005-2006 and the students who were freshmen during academic year 2006-2007 [first academic year of implementation of the Lasallian General Education curriculum]?

The data generated by the research is a valuable input for the curriculum planners and module designers of the Lasallian (General Education) Curriculum. From the perspective of the classroom teacher, if we are to achieve our goal of increasing students' appreciation and understanding of science, we need to look at how our students view science and how we could use these initial conceptions to our advantage in our science classrooms. Finally, the findings of the study will be a valuable input in line with the DLSU-Manila Physics Department's continuing thrust of improving the delivery of Physics instruction to students.

Research Method

Both phase I (2nd and 3rd term, 05-06) and phase II (academic year 06-07) of the study followed the same methodology, as described in the paragraphs that follow.

One week before the trimester began, the research proponent, through the Physics Department chairperson, invited the faculty members of the DLSU-Manila Physics Department who will be teaching Introductory Physics for Liberal Arts students and Environmental Physics for Business & Economics students to participate in the study. During the first class session, the proponent administered the Maryland Physics Expectation Survey (MPEX) to the students.

The Maryland Physics Expectation Survey (MPEX), developed and validated by the University of Maryland, was utilized in the study to document cognitive expectations. An elaborate description of the development and validation of MPEX is given in the paper by Redish, et.al. (1998).

During the first class session, the proponent administered the Maryland Physics Expectation Survey (MPEX) to the students. During final examinations week, the proponent again administered the Maryland Physics Expectation Survey (MPEX) to the students in the class to generate the post-course data. The MPEX is a 34-item agree-disagree (five-point Likert-scale) survey that probes attitudes, beliefs, and assumptions about Physics. The survey was developed by the Department of Physics, University of Maryland (Redish, et al., 1998). The six dimensions of learning Physics that are probed by the MPEX are: Independence, Coherence, Concepts, Reality Link, Mathematics Link, and Effort Link.

Three dimensions of the survey are taken from David Hammer's research (1994) on student's epistemological beliefs. These dimensions are:

Independence – beliefs about learning physics – the learner takes responsibility for constructing her/his 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 that parts of 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 formulas.

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

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 Link – 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.

Discussion of Results

The student's 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. In presenting the MPEX data, students' responses are coded as either favourable (in agreement with experts' response) or unfavourable (not in agreement with experts' response). Redish, et.al. (1998) put forward the use of a Gaussian approximation to the binomial distribution to determine if a difference or shift in the means is significant. For large populations (N >= 450), a shift of 5% is considered significant; for smaller populations, a 10% shift may be considered significant.

Table 1 Pre-course Profile of Liberal Arts Students

MPEX	Academic Year 2005-2006		Academic Year 2006-2007	
CLUSTER	Favourable	Unfavourable	Favourable	Unfavourable
Independence	34.81%	34.81%	30.60%	36.85%
Coherence	27.41%	43.70%	24.57%	43.53%
Concepts	26.54%	42.59%	26.62%	43.35%
Reality Link	57.41%	18.52%	47.44%	21.29%
Math Link	41.36%	32.10%	33.57%	30.16%
Effort Link	61.48%	14.81%	63.42%	10.17%

Table 2 Post-course Profile of Liberal Arts Students

MPEX	Academic Year 2005-2006		Academic Year 2006-2007	
CLUSTER	Favourable	Unfavourable	Favourable	Unfavourable
Independence	37.93%	40.69%	35.00%	34.00%
Coherence	26.21%	49.66%	36.09%	35.84%
Concepts	29.89%	43.10%	40.83%	34.79%
Reality Link	62.93%	17.24%	46.88%	26.56%
Math Link	37.93%	36.78%	35.43%	31.66%
Effort Link	65.52%	13.79%	65.75%	11.00%

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30.16%
10.17%

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Unfavourable
34.00%
35.84%
34.79%
26.56%
31.66%
11.00%

Table 3 Pre-course Profile of Business Students

MPEX CLUSTER	Academic Year 2005-2006		Academic Year 2006-2007	
	Favourable	Unfavourable	Favourable	Unfavourable
Independence	26.96%	46.67%	35.67%	41.00%
Coherence	22.32%	48.41%	28.43%	50.50%
Concepts	25.85%	51.45%	24.17%	54.72%
Reality Link	38.41%	34.78%	53.33%	26.25%
Math Link	29.95%	39.61%	38.16%	35.10%
Effort Link	51.88%	20.00%	65.00%	11.00%

Table 4 Post-course Profile of Business Students

MPEX CLUSTER	Academic Year 2005-2006		Academic Year 2006-2007	
	Favourable	Unfavourable	Favourable	Unfavourable
Independence	30.12%	43.86%	39.33%	31.38%
Coherence	28.67%	43.86%	34.58%	40.42%
Concepts	28.71%	51.41%	39.72%	41.11%
Reality Link	45.48%	25.30%	46.35%	27.08%
Math Link	36.35%	36.75%	51.79%	30.56%
Effort Link	59.04%	13.49%	68.75%	12.08%

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.

Comparing the data found in tables 1 and 2, we see a slight positive shift in the Liberal Arts students' responses to the questions in this cluster. The freshmen of Academic Year 2005-2006 reported a 3% upward shift in their agreement with the experts' responses, while the freshmen of Academic Year 2006-2007 posted a 4.4% increase in their agreement with the experts' responses.

The results gleaned from the present study are comparable to the results reported by Mistades (2006) in a survey conducted during academic year 2003-2004 on Liberal Arts students taking up their Introductory Physics course. The survey showed that for the independence cluster, there was an upward shift in responses, from 36.0% favourable responses (pre-course profile) to 41.3% favourable responses (post-course profile).

The responses of the Business majors for the Independence cluster was very similar to the response pattern of their Liberal Arts counterparts. Data shown in tables 3 and 4 reveal a 3% increase in agreement with the experts' responses for the Business freshmen of Academic Year 2005-2006, while the Business freshmen of academic year 2006-2007 reported a 4% upward shift in their agreement with the experts' responses.

The findings in this cluster and the average 4.2% favourable shift in responses could be attributed to the use of the discovery method advocated by the transformative-learning paradigm.

Coherence Cluster

Redish, et.al.'s (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. The profile shown by tables 1 to 4 reveal that the students are beginning to view the study of Physics as a coherent structure. However, 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", leads us to posit that up to the end of the course, 35% of the Business majors and 42% of the Liberal Arts majors focus on memory work, rather than finding the relationships between concepts. One trimester may not yet be enough to shift the freshmen students' learning style from reliance on memory work to finding relationships between concepts learned.

Using a group of science and engineering majors, Patricio, et.al. (1999) reported a 32% favourable response for this cluster. A similar finding is reported by Mistades (2004b), a 34.3% favourable response given by freshman Physics majors.

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 unfavourable 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 studies conducted on science and engineering majors (Patricio, et.al., 1999) and on physics majors Mistades (2004b) reveal that these groups of students have developed an expert-like belief in the concepts cluster of MPEX (science and engineering majors reported a 45% agreement with experts; Physics majors, 48%).

The favourable shift in the students' responses to the questions found in this cluster [Liberal Arts majors, Academic Year 05-06: 26.5% to 29.9% favourable responses; Business majors, Academic Year 05-06: 25.9% to 28.7% agreement with the experts;

Liberal Arts majors, Academic Year 06-07: 26.6% to 40.8% favourable responses; Business majors, Academic Year 06-07: 24.2% to 39.7% agreement with the experts] show that the students have taken a conscious effort in learning the basic concepts in the study of Physics.

It is noteworthy to point out that there is a marked difference in the favourable shift in the students' responses, with the freshmen of Academic Year 06-07 clearly showing an increased favourable response (average of 14% favourable shift) when compared with their counterparts during Academic Year 05-06 (~ 3% favourable shift).

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 was whether the students feel that their personal real-world experiences are relevant for the Physics course. The students who took the Introductory Physics during Academic Year 2005-2006 course saw the link between the physics concepts and real-life experiences. The post-course survey generated 62% agreement with the experts for the Liberal Arts students and a 67% agreement for the Business majors. The examples given in class – medical applications (magnetic resonance imaging, ultrasound, ECG) and the environmental applications of the physics concepts learned – reinforced the link between the physics concepts and reality.

Data for the freshmen of Academic Year 2006-2007 reveal a different picture, with the Liberal Arts students posting a very slight decline from 47.4% to 46.9% agreement with the experts and the Business majors presenting a statistically significant decrease in agreement with the experts from 53.3% to 46.4%.

This finding underscores the need to strengthen the application component of the Physics module by introducing additional real-world experiences related to the study of Physics. This cluster also looks at the likelihood that 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.

Math Link Cluster

An important component of a Physics course is the development of students' ability to use abstract and mathematical reasoning in describing and making predictions about the behaviour of real physical systems. The responses in the math link cluster show that the Liberal Arts students who participated in the study have not yet seen the deeper physical relationships present in the equations [only 38% favourable responses]. The response of the Liberal Arts group surveyed by Mistades (2006) yielded a 33.3% favourable response in this cluster. We see an improvement, albeit slight, in how the Liberal Arts students view the role of mathematics in the study of Physics.

The responses of the Business majors in the math link cluster [pre-course 36.4% agreement with experts; post-course 51.8% favourable responses] show that this group 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. Majority of the Liberal Arts majors and the Business 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 favourable response; Liberal Arts students, 63% to 66%; Business students, 65% to 69%] 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 and Key (2000) also reported a positive change in the effort cluster for the students they surveyed. Mistades (2006) also reported a positive trend in the responses of the groups surveyed during academic year 2003-2004, where three-fourths of the Biology majors and 70% of the Physics majors and the Liberal Arts majors have responded in a manner similar to the response of the life-long learners (experts) group.

Conclusion

The data gathered for the first academic year of implementation of the Lasallian General Education Physics Course for non-science majors reveal the positive gains in students' attitudes towards learning Physics brought about by the introduction of the General Education Physics course taught using the transformative-learning paradigm.

The responses of the students who were surveyed reflected high agreement with the 'experts' response' in the effort link cluster of the Maryland Physics Expectations (MPEX) Survey. The students reported they were exerting the effort required of them that would allow them to understand Physics. They have likewise seen the value of learning the fundamental concepts in the study of Physics. This is reflected in the favourable shift in the students' responses in the concepts cluster. The responses of the students in the independence cluster reflect their openness to take responsibility for constructing their own knowledge. There is a need, though, to strengthen the application component of the Physics module by introducing additional real-world experiences related to the study of Physics the integration between the various concepts learned, as reflected in the data obtained for the reality link cluster of the MPEX for the students during Academic Year 2006-2007.

Student beliefs play an important role in student's understanding and appreciation of the Physics we teach them. The study has shown that it is possible to move our students from a novice-like view of Physics towards an expert-like view. As with any new undertaking, it is inevitable to find aspects of the program that need further enhancement and fine-

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