Transformative Learning: Shifts in Students' Attitudes toward Physics Measured with the Colorado Learning Attitudes about Science Survey

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ABSTRACT

The study presents a profile of the attitudes and beliefs of De La Salle University – Manila freshmen students enrolled in their General Education Introductory Physics course during Academic Year 2008-2009. Using the Colorado Learning Attitudes about Science Survey (CLASS), the research probed students' attitudes, beliefs, and assumptions about what sort of things they will learn, what skills will be required, and what they will be expected to do in a Physics class. Comparing the students' pre-instruction response with their post-instruction responses, the students posted high agreement with the experts' beliefs in the following CLASS categories: Personal Interest, Real World Connections, Problem-Solving (General), Problem-Solving (Confidence), and Sense-Making / Effort. Their experiences in the Physics course allowed them to appreciate the skills they gained through the various learning activities in the course and through the effort they have put in. The students affirm that the ideas learned in the classroom are relevant and useful in a wide variety of real-world contexts. The students likewise realized that the skills they gained in the course will be useful to their life outside of school.

KEYWORDS: Attitude, Belief, Introductory Physics, Transformative Learning, University Students

1. INTRODUCTION

The De La Salle University – Manila General Education Curriculum was implemented beginning Academic Year 2006-2007. The new curriculum is composed of "a set of foundational, formative, and integrative courses intended to inculcate in students 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:

"1) have the knowledge and skills to engage in more specialized study in the various disciplines and professions;

"2) 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;

"3) and have the foundation for lifelong learning." (Rapatan, et.al., 2005)

To assist curriculum planners, it is imperative to document the effect of this new curriculum on students' learning. The current study documented the impact of the physics component of the new General Education Curriculum. Specifically, the research looked at students' attitudes and beliefs towards learning physics.

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.

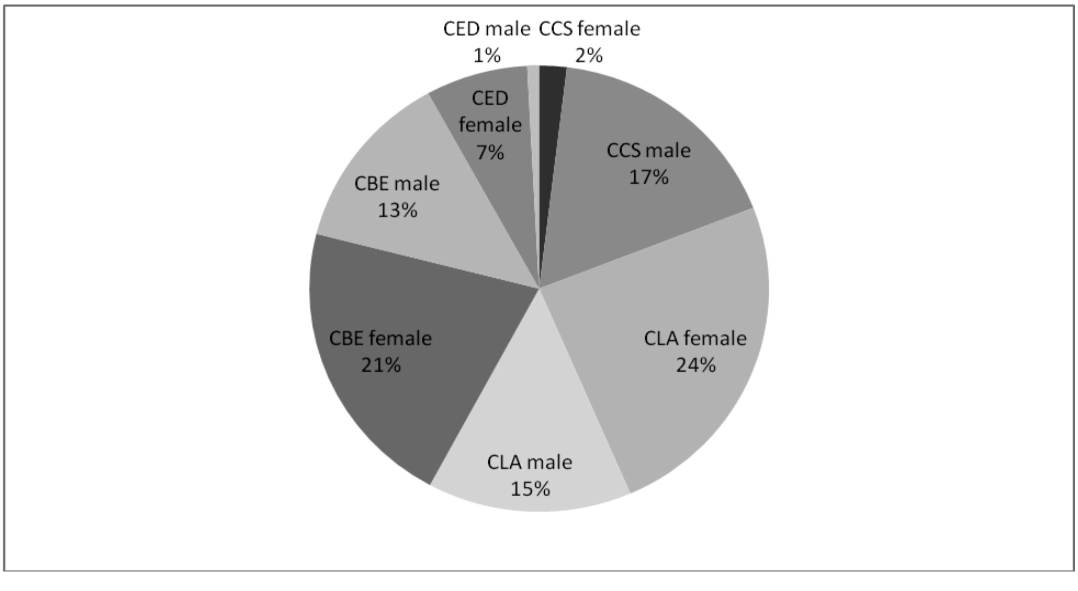
Studies of student expectations in science in pre-college classrooms (Carey, et.al., 1989; Songer and Linn, 1991) reveal that student attitudes towards their classroom activities and their beliefs about the nature of science and knowledge affect their learning. Research has shown that students bring with them their experiences of the world (Laws, 1997; Lawson, 1998; McDermott and Redish, 1999; van Domelen and van Heuvelen, 2002), which lead 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.

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). Using pre-instruction and post-instruction data obtained from the Maryland Physics Expectations Survey (MPEX), 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. 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. The current study will present the extent to which the attitudes and beliefs of the freshman class of Academic Year 2008-2009 of De La Salle University – Manila change after going through their General Education Introductory Physics course.

2. RESEARCH METHODOLOGY

During the first class session, the research proponents administered the Colorado Learning Attitudes about Science Survey (CLASS) questionnaire to the freshman students of Academic Year 2008-2009. During final examinations week, the proponents again administered the survey questionnaires to the students in the class to generate the post-instruction data. Figure 1 presents a profile of the students who participated in the study. This data only includes the students who took both the pre-instruction and post-instruction surveys. Adams, et.al. (2006) reported that in order to determine shifts in beliefs, it is important to include only the students who took both pre- and post-instruction surveys as this ensures that any calculated change in beliefs measures shifts in students' thinking rather than a difference in the sample population. For the present study, a total of 361 paired pre-instruction and post-instruction survey data were gathered from the freshman students broken down as follows: College of Business and Economics (CBE) [47 male students and 76 female students]; College of Computer Studies (CCS) [62 male students and 7 female students]; College of Education (CED) [3 male students and 26 female students]; and College of Liberal Arts (CLA) [52 male students and 88 female students].

Figure 1. Distribution of Students who Participated in the Study



The Colorado Learning Attitudes about Science Survey [CLASS] is built on work done by existing surveys. Three well-known surveys for probing student beliefs about the physical sciences are the Maryland Physics Expectations Survey (Redish, Saul, & Steinberg, 1998), the Views About Science Survey (Halloun & Hestenes, 1985), and the Epistemological Beliefs Assessment about Physical Science (Elby, 2001). The Colorado Learning Attitudes about Science Survey was developed to make the statements as clear and concise as possible (Adams, et. al., 2006). The survey probes students' beliefs about physics and learning physics, and distinguishes the beliefs of experts from those of novices.

Participants taking the CLASS inventory are asked to respond on a five-point Likert (agree-disagree) scale to 42 statements, such as the following:

> *"Learning physics changes my ideas of how the world works"* (Item # 28).
>
> *"If I get stuck on a physics problem on my first try, I usually try to figure out a different way that works"* (Item # 15).
>
> *"Reasoning skills used to understand physics can be helpful to me in my everyday life"* (Item # 30).

Scoring of the Colorado Learning Attitudes about Science Survey is calculated by determining the percentage of responses for which a respondent agrees with the experts' view (tagged as "percent favorable"). The average "percent unfavorable" is also determined by taking the number of responses for which the respondent disagrees with the experts' view.

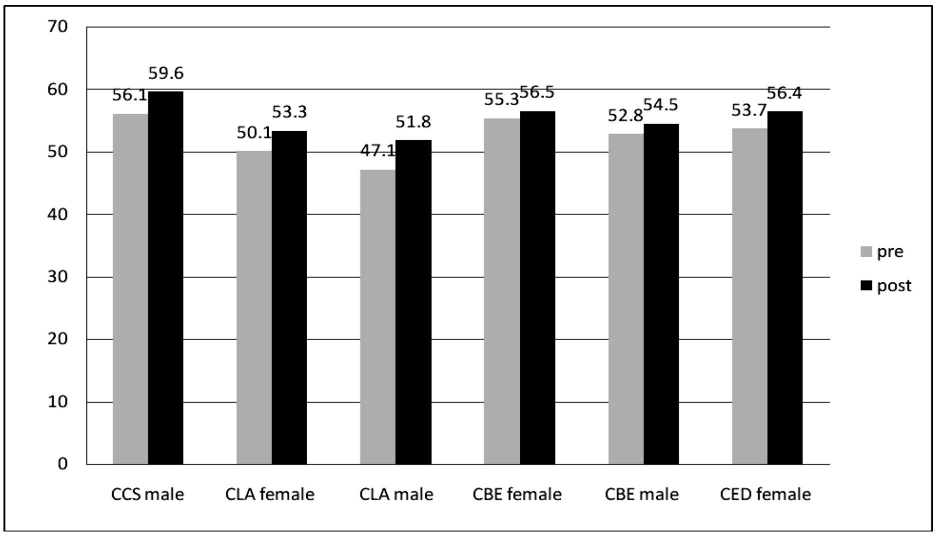
The survey is scored "overall" and for the following eight categories: (a) Real World Connection, (b) Personal Interest, (c) Sense Making / Effort, (d) Conceptual Connections, (e) Applied Conceptual Understanding, (f) Problem Solving [General], (g) Problem Solving [Confidence], and (h) Problem Solving [Sophistication]. Each category consists of four to eight statements that characterize a specific aspect of thinking. Together, these categories include 27 of the 42 statements. The overall score includes these 27 statements, plus an additional nine statements, all thirty-six of which passed the validity and reliability tests conducted by the University of Colorado Physics Education Research Group (Adams, et.al., 2004). In the current version of the survey (version 3, available through http://CLASS.colorado.edu), six statements do not yet have an "expert" response and are not included in the analysis.

3. RESULTS AND DISCUSSION

3.1. Over-all CLASS Results

Figure 2 presents the pre-instruction and post-instruction favorable responses of the students measured by the Colorado Learning Attitudes about Science Survey (CLASS). The group composed of the male students from the College of Liberal Arts (CLA) posted the highest shift (+4.7%) when comparing pre-instruction responses with post-instruction responses. The students from the College of Business and Economics (CBE) reported the lowest shift: +1.2% for the female group and +1.7% for the male group. Although the reported shifts for the over-all profile in the present study does not qualify as statistically significant following the criteria put forward by Redish, et.al. (1998), a closer look at the individual categories would provide us with insights on the effect of the General Education Introductory Physics course on the students' attitudes towards learning Physics.

Figure 2. Over-all Percentage Favorable Rating for the Colorado Learning Attitudes about Science Survey (CLASS)



The over-all favorable profile reported for the present study is comparable to the over-all favorable profile reported by Adams, et.al. (2004) for the group of non-science majors taking up their first college Physics course. The study they conducted during the fall of Academic Year 2003-2004 revealed a 57% post-instruction favorable profile reported by seventy-six non-science students enrolled in a state research university.

3.2. Personal Interest Category

This category probes whether the respondents see a "connection" with the study of physics. The College of Education (CED) students posted a statistically significant increase in their favorable responses in this category, from 56.2% pre-instruction profile to 70.5% post-instruction profile. When asked if they *"think about the Physics (they) experience in everyday life"* [CLASS item # 3], only 8% of the Education majors gave a response that is contrary to the experts' response. By comparing the students' pre-instruction responses to their post-instruction responses for CLASS item # 14, *"I study physics to learn knowledge that will be useful in my life outside of school"* (figure 3.a) and for CLASS item # 30, *"Reasoning skills used to understand physics can be helpful to me in my everyday life"* (figure 3.b), we can say that after their Introductory Physics course, the students realized that the ideas learned in class are useful to their everyday life and that the skills they gained in the course are helpful to their life outside of school.

Figure 3.a. Students' Responses to CLASS item # 14
"I study physics to learn knowledge that will be useful in my life outside of school"

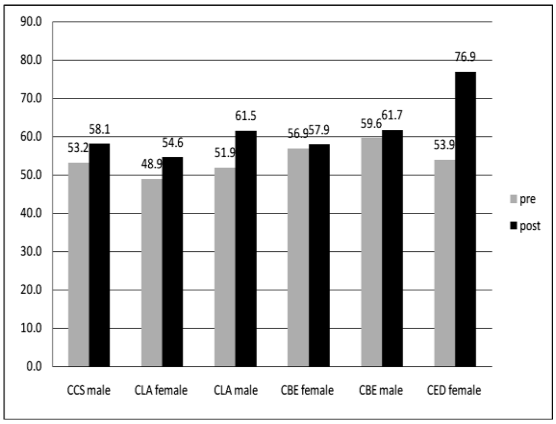
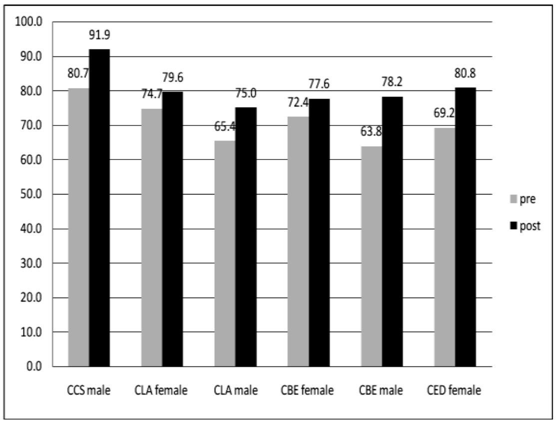


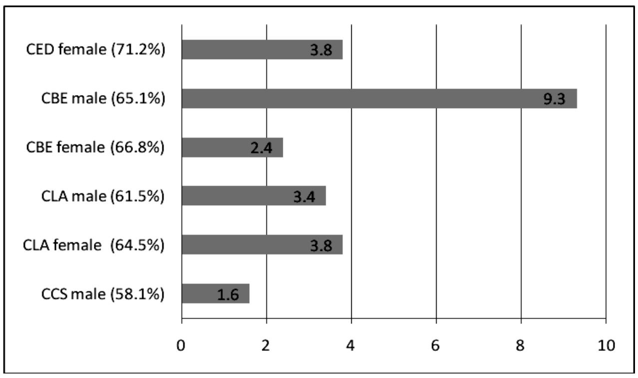
Figure 3.b. Students' Responses to CLASS item # 30
"Reasoning skills used to understand physics can be helpful to me in my everyday life"



3.3. Real World Connections Category

In the Real World Connections category, the students are asked if they believe that the ideas learned in a Physics class are relevant and useful in a wide variety of real-world contexts. The post-instruction percentage favorable responses and the positive shifts in their responses (figure 4) reveal that the Introductory Physics course was successful in showing the link between Physics and their real-world experiences. The students reported that they *"think about their personal experiences and relate them to the topic being analyzed"* [CLASS item # 37]. The Education majors posted a 65.4% agreement with the experts for this statement; the female Business majors posted a 60.5% favorable response; while the male Business majors reported a 66.0% favorable response. For the same statement, the Liberal Arts majors and the Computer Studies majors posted data that are comparable to each other: 55.7% (CLA female students), 57.7% (CLA male students), and 58.1% (CCS students).

Figure 4. The percentages in parenthesis show the post-instruction favorable response of the students in the Real World Connections category, while the bar graph represents the shift [post-instruction favorable response minus pre-instruction favorable response] in the students' response profile.



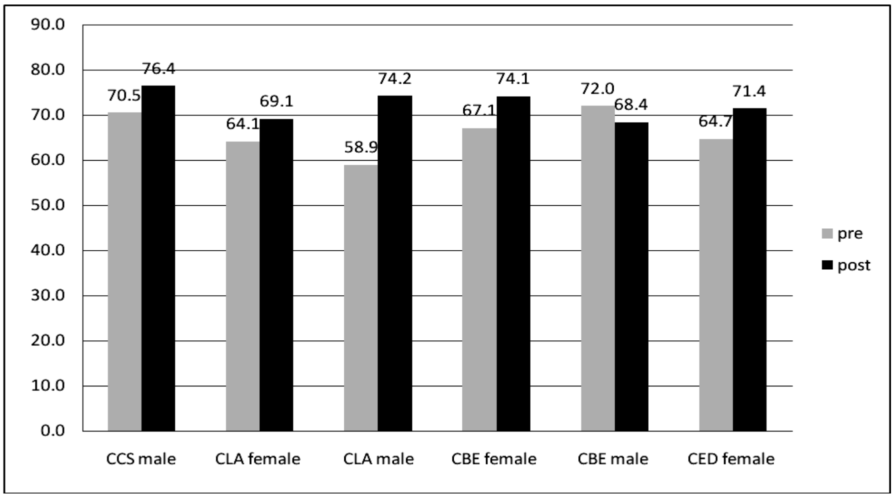
When asked if learning physics *"changed (their) ideas about how the world works"* [CLASS item # 28], the students responded very positively with their favorable responses: Education majors, 76.9%; female Business majors, 77.6%; male Business majors, 72.3%; female Liberal Arts majors, 75.0%; male Liberal Arts majors, 65.4%; and Computer Studies majors, 69.4%.

3.4. Sense Making / Effort Category

This category probes whether the learner makes the effort to use available information and make sense out of the information in learning physics. The Sense Making / Effort category presents to us a very interesting pre-instruction vs. post-instruction profile of favorable responses. Figure 5 shows us that except for the male Business majors, all student groups reported a positive shift of at least 5%.

The male Liberal Arts majors posted a statistically significant shift in this category, from 58.9% pre-instruction favorable profile to 74.2% post-instruction favorable profile. The students in this group reported a positive shift in their responses for all seven statements in this category. The highest positive shift reported by the male Liberal Arts majors is for CLASS item # 32, *"Spending a lot of time understanding where formulas come from is a waste of time"*. The experts' response for this statement is 'disagree' and 23% of the students reported a shift in their pre-instruction response of 'agree' to a post-instruction response of 'disagree'. By the end of the Introductory Physics course, only 7.7% of the group held an unfavorable view for this statement.

Figure 5. Favorable Rating Profile for the Sense Making / Effort Category



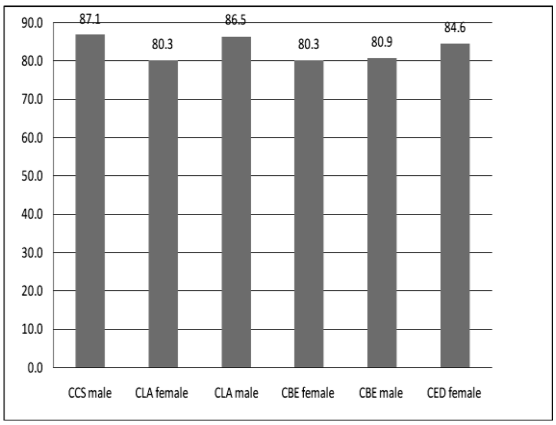
It is interesting to note that the downward shift in the favorable responses of the male Business majors for this category is also due to how they responded to CLASS item # 32. But unlike their counterparts in the College of Liberal Arts, the male Business majors reported a 19.2% downward shift in their favorable response for this statement.

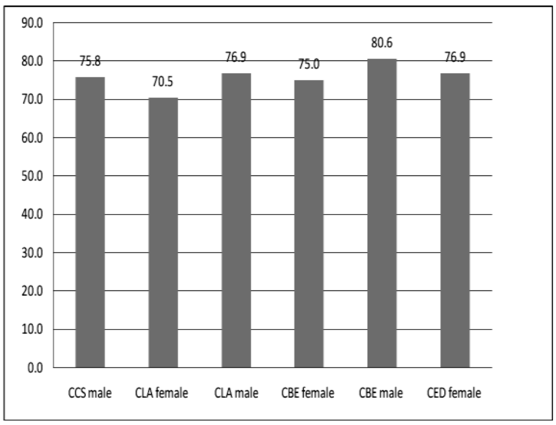
Figure 6.a. Students' Favorable Responses to CLASS item # 24

"In Physics, it is important to make sense out of formulas before they can be used correctly"

Figure 6.b. Students' Favorable Responses to CLASS item # 39

"I explicitly think about which Physics ideas apply to a problem"





This is indeed a revelation because Liberal Arts majors are stereotyped as being fearful of working with mathematical equations, while the Business majors are believed to be more adept when it comes to working with formulas and equations. The encouraging results in this category may be attributed to the positive view taken by the students with regard to how they should make sense out of the ideas presented to them. By the end of their Introductory Physics course, the students reported that *"it is important (for them) to make sense out of formulas before they can be used correctly"* [CLASS item # 24] (figure 6.a). Further, they articulated that they *"explicitly think about which Physics ideas apply to a problem"* [CLASS item # 39] (figure 6.b).

3.5. Conceptual Connections and Applied Conceptual Understanding Cluster

Life-long learners of physics strongly feel that students should view physics as a coherent and consistent structure (Redish, Saul, & Steinberg, 1998). Students who emphasize science simply as a collection of facts fail to conceptualize the integrity and coherence of the whole structure of physics. The two categories discussed in this section obtained the lowest average percentage favorable responses, which leads us to hypothesize that the students still need to mature in conceptualizing physics as a coherent structure and in drawing out connections between the different ideas learned. The consolidated Conceptual Connections profile of the freshman students of Academic Year 2008-2009 showed a 48% agreement with the experts' response, while the consolidated Applied Conceptual Understanding profile revealed a 36% agreement with the experts' response. Figures 7 and 8 provide us with a detailed view of how the students in each group responded to the two categories. We note that only the students from the College of Computer Studies (CCS) reported an encouraging positive shift for both categories.

Figure 7. Favorable Rating Profile for the Conceptual Connections Category

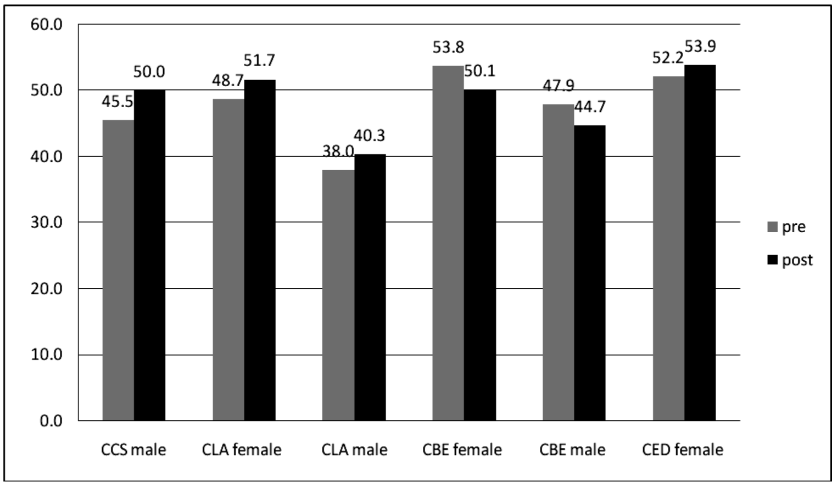
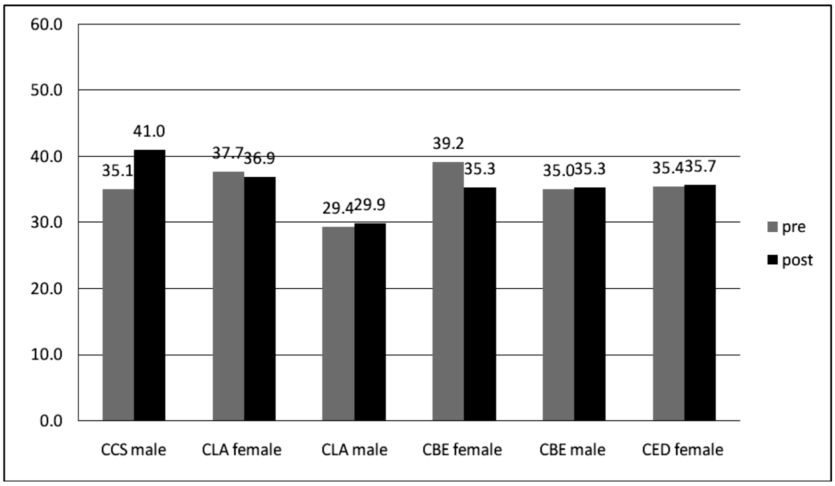


Figure 8. Favorable Rating Profile for the Applied Conceptual Understanding Category



The students' responses for two statements in this cluster seem to contradict each other. Although 77.5% of the students gave an expert-like response to CLASS item # 42, *"When studying Physics, I relate the important information to what I already know, rather than just memorizing it the way it is presented"*, there seems to be a disconnect with how the students view their learning process because 50% of the respondents reported that *"a significant problem in learning Physics is being able to memorize all the information I need to know"* [CLASS item # 1].

3.6. Problem Solving Cluster

The Problem Solving cluster looks at three inter-related categories. In the Problem Solving (General) category, the students are asked how they view the role of mathematical formulas in expressing relationships between physical quantities. The Problem Solving (Confidence) category probes if students are able to figure out a way to solve physics problems [CLASS item # 34] especially if they get stuck on their first attempt [CLASS item # 15]. The Problem Solving (Sophistication) category determines if the students are able to apply a method used to solve one physics problem to another related problem / situation.

Fig. 9.a. College of Education (CED)
Favorable Response Profile

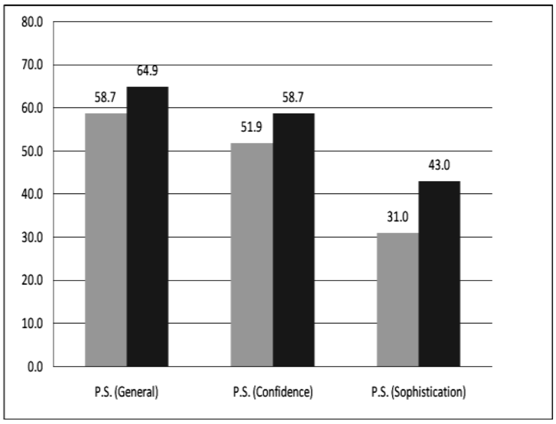


Fig. 9.b. College of Computer Studies (CCS)
Favorable Response Profile

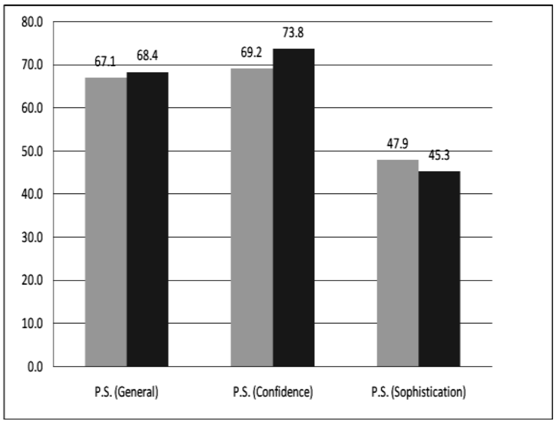


Fig. 9.c. College of Liberal Arts (CLA) [female]
Favorable Response Profile

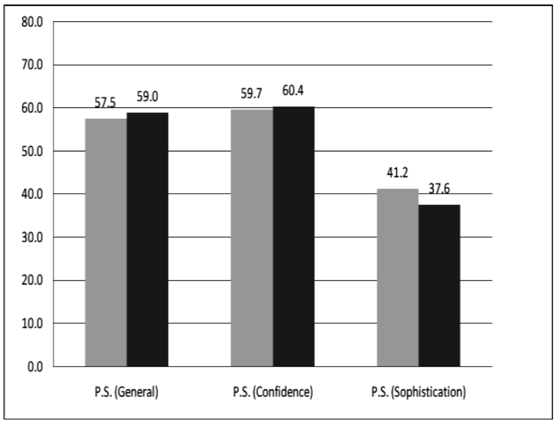


Fig. 9.d. College of Liberal Arts (CLA) [male]
Favorable Response Profile

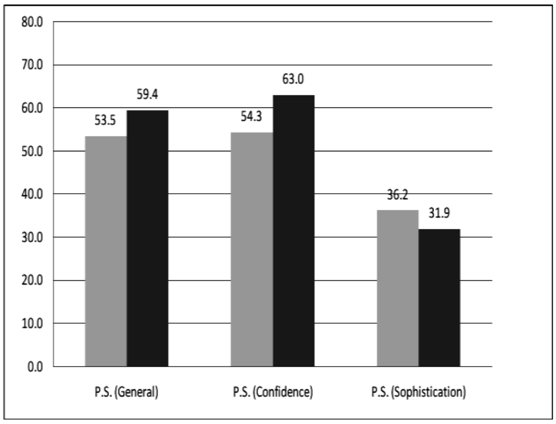


Fig. 9.e. College of Business & Economics (CBE) [female]
Favorable Response Profile

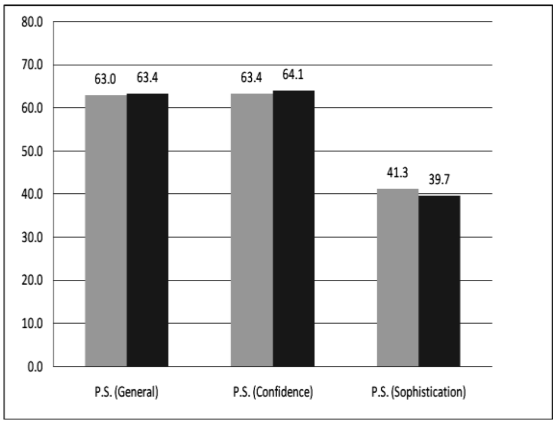
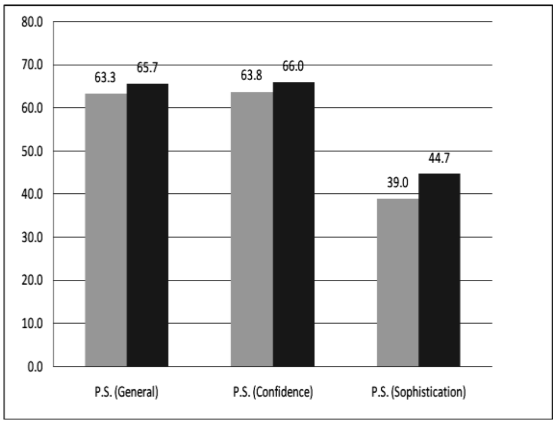


Fig. 9.f. College of Business & Economics (CBE) [male]
Favorable Response Profile



As shown in figures 9.a to 9.f, the students surveyed in the present study reported a commendable favorable response profile (agreement with experts' response) in the first two categories, Problem Solving (General) and Problem Solving (Confidence). Sixty-seven percent (67%) of the respondents reported that they can usually figure out a way to solve physics problems.

Three out of every four students (77.5%) reported that if they get stuck on a physics problem, there is still a chance that they will figure it out. Seventy-six percent (76%) of the students reported that they share the experts' view that, *"In Physics, mathematical formulas express meaningful relationships among measureable quantities"* [CLASS item # 26]. However, figures 9.a to 9.f also reveal that the students' level of sophistication when approaching problem solving in physics is an area that can be further improved.

4. SYNTHESIS

The freshman students of Academic Year 2008-2009 who took the General Education Introductory Physics course reported agreement with the experts' beliefs in the following categories of the Colorado Learning Attitudes about Science Survey (CLASS): Personal Interest, Real World Connections, Problem-Solving (General), Problem-Solving (Confidence), and Sense-Making / Effort. Their experiences in the Physics course allowed them to appreciate the skills they gained through the various learning activities in the course and through the effort they have put in. The students affirm that the ideas learned in the classroom are relevant and useful in a wide variety of real-world contexts. The students likewise realized that the skills they gained in the course will be useful to their life outside of school. The students' responses in the Conceptual Connections category and in the Applied Conceptual Understanding category obtained the lowest percentage favorable responses. The challenge to educators is to lead students to maturity in conceptualizing physics as a coherent structure and to bring students to seeing the relationship between and among the ideas learned.

5. ACKNOWLEDGEMENT

This research was made possible through a grant from the University Research Coordination Office (URCO), De La Salle University, Manila, Philippines.

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