AC 2009-1071: CAPTURING DIFFERENCES OF ENGINEERING DESIGN LEARNING ENVIRONMENTS BY MEANS OF THE VANTH OBSERVATION SYSTEM

Lourdes Gazca, Universidad de las Americas, Puebla

Lourdes Gazca is Science, Engineering, and Technology Education Ph.D. Student at Universidad de las Americas Puebla in Mexico. She teaches mathematics and statistics related courses. Her research interests include faculty development, active and cooperative learning, and creating effective learning environments.

Enrique Palou, Universidad de las Americas, Puebla

Enrique Palou is Director, Center for Science, Engineering, and Technology Education; and Professor, Department of Chemical and Food Engineering at Universidad de las Americas Puebla in Mexico. He teaches engineering, food science, and education related courses. His research interests include emerging technologies for food processing, creating effective learning environments, and building rigorous research capacity in science, engineering and technology education.

Aurelio López-Malo, Universidad de las Americas, Puebla

Aurelio Lopez-Malo is Professor and Chair, Department of Chemical and Food Engineering at Universidad de las Americas Puebla in Mexico. He teaches food science and engineering related courses. His research interests include emerging technologies for food processing, natural antimicrobials, and active learning.

Juan Manuel Garibay, Universidad de las Americas, Puebla

Juan Manuel Garibay is Professor Emeritus of Universidad de las Americas Puebla (Mexico) where he taught education related courses. His research interests include collaborative learning, assessment, and building rigorous research capacity in science, engineering and technology education.

Capturing Differences of Engineering Design Learning Environments by Means of VaNTH Observation System

Keywords: Learning Environments, VaNTH Observation System, Engineering Design.

Abstract

Introduction to Engineering Design (EI-100) is a first-semester 3 credit required course for every engineering program of *Universidad de las Américas Puebla* (UDLAP). Course content and classroom activities are divided into three, two-hour sessions (Modeling, Concepts, and Laboratory) per week. Students have six different EI-100 facilitators (an instructor and teaching assistant for each session). UDLAP's engineering students have in EI-100 a great opportunity for a multidisciplinary collaborative experience. EI-100 is a team-taught course that uses active, collaborative and cooperative learning, which has been a major player in UDLAP's efforts of engineering education reform since 2001. However, EI-100 could be improved taking into account technological advances and recent research on human learning and cognitive processes that underlie expert performances.

The *How People Learn* (HPL) framework was used to redesign EI-100 to further promote an interactive classroom while integrating multiple formative assessments by means of Tablet PC technologies. The VaNTH Observation System (VOS) is an assessment tool developed to capture qualitative and quantitative classroom observation data from teaching and learning experiences of the bioengineering classroom. VOS is a four-part system that incorporates the elements of HPL framework and uses four recurring methods of collecting classroom data: recording student-teacher interactions, recording student academic engagement, recording narrative notes of classroom events, and rating specific indicators of effective teaching.

VOS was used to systematically assess HPL framework implementation in EI-100 classrooms. Observers measured differences in classroom experiences resulting from the innovations and redesigned learning environments. Over the course of the past year, three observers trained in VOS sat in EI-100 classrooms and observed 9 instructors, both junior and senior level, in over 60 class sessions from two different sections and the three different EI-100 sessions. Observers conducted a minimum of six observations per class. This past semester, observers achieved a 70 percent inter-rater reliability in using the VOS.

EI-100 redesign significantly ($p < 0.05$) increased student participation. Formative assessment and feedback were more common and rapid. Facilitators utilized the information gained through real-time formative assessment to tailor instruction to meet student needs. Particularly important were opportunities to make students' thinking visible and give them chances to revise, as well as opportunities for "what if" thinking. VOS captured differences in EI-100 classroom experiences. These differences may be used to measure levels of "HPLness" of a lesson. Moreover VOS clearly captured differences among facilitators' teaching styles and identified the effects of EI-100 three different sessions. In addition, VOS generated detailed feedback that facilitators may use to self-assess and further refine EI-100 redesign.

Introduction

Universidad de las Américas Puebla (UDLAP) is a Mexican private institution of higher learning committed to first-class teaching, public service, research and learning in a wide range of academic disciplines including business administration, the physical and social sciences, engineering, humanities, and the arts. The studied course, Introduction to Engineering Design (EI-100) is a first-semester 3 credit required course for almost every engineering program of UDLAP since spring of 2001. Course content and classroom activities are divided into three, two-hour sections (Modeling, Concepts, and Laboratory) per week. Students have six different EI-100 facilitators (an instructor and teaching assistant for each section). EI-100 goal is to introduce students to the Engineering Method, this is accomplished by focusing on six course objectives: self-regulation, communication, working cooperatively and collaboratively, problem solving, modeling, and quality. The "Modeling" section initiates students in the process of engineering modeling, using several software including spreadsheets. "Concepts" introduce students to the engineering design process, problem-solving techniques, working in teams, engineering as a profession, and planning for success that students then apply in "Laboratory" on two actual design projects. The "Concepts" section uses quizzes given in nearly every session to ascertain whether students have understood the material in their pre-class reading assignments. In addition, we encourage students to write brief reflective journal entries to further solidify and reinforce their own understanding, and demonstrate that improved understanding for an improved quiz grade.

UDLAP's Chemical, Civil, Computer, Electrical, Environmental, Food, Industrial, Mechanical, and Mechatronic engineering students have in EI-100 a great opportunity for a multidisciplinary collaborative experience. EI-100 is a team-taught course that uses active, collaborative and cooperative learning, which has been a major player in UDLAP's efforts of engineering education reform since 2001[31]. The major goal of the project "High-Quality Environments for Teaching and Learning Engineering Design: Using Tablet PCs and Guidelines from Research on *How People Learn*" (from which this paper is part) is to improve engineering design teaching and learning by creating richer learning environments that promote an interactive classroom while integrating formative assessment into EI-100 classroom practices. Re-designing the course EI-100 we could improve student understanding of the engineering method, and student ability to solve practical engineering problems and complete real-world engineering projects while increasing active student participation, peer-team interactions, and feedback processes.

Theoretical Background

EI-100 could be improved taking into account technological advances and recent research on human learning and cognitive processes that underlie expert performances.

Using Information About How People Learn

During the past 30 years, research on human learning has exploded. Although we have a long way to go to fully uncover the mysteries of learning, we know a considerable amount about the cognitive processes that underlie expert performances and about strategies for helping people increase their expertise in a variety of areas[9]. Several committees organized by the US National Academy of Sciences have summarized much of this research in reports published by the

National Academy Press. A key publication that informs our current discussion is *How People Learn: Brain, Mind, Experience and School*[8]. *Knowing What Students Know*[32], which builds on How People Learn, is also relevant to this discussion. Its focus is primarily on assessment.

An organizing structure used in the *How People Learn* volumes (hereafter HPL) is the HPL framework. It highlights a set of four overlapping lenses that can be used to analyze any learning situation. In particular, it suggests that we ask about the degree to which learning environments are:

1. *Knowledge centered*. In the sense of being based on a careful analysis of what we want people to know and be able to do when they finish with our materials or course and providing them with the foundational knowledge, skills, and attitudes needed for successful transfer.
2. *Learner centered*. In the sense of connecting to the strengths, interests, and preconceptions of learners and helping them learn about themselves as learners.
3. *Community centered*. In the sense of providing an environment, both within and outside the classroom, where students feel safe to ask questions, learn to use technology to access resources and work collaboratively, and are helped to develop lifelong learning skills.
4. A*ssessment centered*. In the sense of providing multiple opportunities to make students' thinking visible so they can receive feedback and be given chances to revise.

The HPL framework provides a convenient way to organize a great deal of information about the nature of competent (expert) performance and about ways to help people develop their own competence[9]. The framework highlights a set of four overlapping lenses that are useful for analyzing the quality of various learning environments. Balance among the four lenses is particularly important to create high-quality learning environments; since for example, some learning environments can be knowledge centered but not learner centered, and vice versa. In addition, many environments lack frequent opportunities for formative assessment and revision, and many fail to promote a sense of community where learning (which includes admissions of "not knowing") is welcomed, and therefore are not aligned with the HPL framework four lenses.

Tablet PCs

In an increasingly collaborative, mobile and globally inter-connected environment, UDLAP envisions ubiquitous computing as a natural, empowering component of every teaching, learning, and research activity. UDLAP is committed not only to adopting and adapting technologies to all its scholarly endeavors, but also to playing an active role in their development.

Tablet PCs combine a standard notebook computer with a digitizing screen and a pen-like stylus device to produce a computer that allows ease of input of natural writing and drawing. Pedagogically, applications for the Tablet PC include lecture/presentation enhancement, problem-solving demonstrations, active learning support, guided brainstorming, reading, commenting, marking-up (providing feedback), and grading of student work. A review[42] of the current literature supports the following advantages in using a Tablet PC: First, digital ink enables instructors to write "on the fly" during class as one would write on a chalkboard or on a transparency[26, 27]. This is especially meaningful for engineering courses where examples and explanations are often mathematically and graphically intensive. Second, the freedom of marking-up significantly changes the way students and teachers interact[6]. It facilitates bi-directional sharing of information, moving students beyond merely observing presentations to interacting with the material, the teacher, and each other. In addition, the use of Tablet PCs supports more efficient management of information. Dynamic working notes can be saved in a searchable format, while lecture notes with vivid annotations become available for students' online viewing[4, 40-43].

Thanks to a Hewlett-Packard (HP) Technology for Teaching Higher Education grant UDLAP received 21 HP Tablet PCs to redesign EI-100. In particular, we are interested in using Tablet PC technologies to encourage active learning (interactive engagement) and probe student understanding through frequent formative assessment.

Redesign of the Course EI-100

A major issue is to help students develop the kinds of connected knowledge, skills, and attitudes that prepare them for effective lifelong learning[30]. This involves the need to seriously rethink not only how to help students learn about particular isolated topics but to rethink the organization of entire courses and curricula. People who want to improve educational quality often begin with a focus on teaching methods. Questions about teaching strategies are important, but they need to be asked in the context of whom we are teaching and what we want our students to accomplish[9]. The reason is that particular types of teaching and learning strategies can be strong or weak depending on our goals for learning and the knowledge and skills that students bring to the learning task[24, 33].

A model developed by Jenkins[24] highlights important constellations of factors that must be simultaneously considered when attempting to think about issues of teaching and learning. The model illustrates that the appropriateness of using particular types of teaching strategies depends on: (1) the nature of the materials to be learned; (2) the nature of the skills, knowledge, and attitudes that learners bring to the situation; and (3) the goals of the learning situation and the assessments used to measure learning relative to these goals. A particular teaching strategy may flourish or perish depending on the overall characteristics of the ecosystem in which it is placed[9]. The Jenkins model fits well with a proposal by Wiggins and McTighe[41]. They suggest a "working backwards" strategy for creating high-quality learning experiences. In particular, they recommend that educators: (1) begin with a careful analysis of learning goals; (2) explore how to assess students' progress in achieving these goals; and (3) use the results of steps 1 and 2 to choose and continually evaluate teaching methods. (Assumptions about steps 1 and 2 are also continually evaluated.) When using a "working backwards" strategy for EI-100, our choice of teaching strategies derives from a careful analysis of learning goals, rather than vice versa.

The ability to design engineering undergraduate courses and corresponding high-quality learning environments require that we move beyond procedural strategies and models. We also need to understand the kinds of skills, attitudes, and knowledge structures that support competent performance. Thus for the redesigning of the course EI-100 we "worked backwards" taking into account Jenkins model as well as the HPL framework. Especially important was knowledge of key concepts and models that provide the kinds of connected, organized knowledge structures and accompanying skills and attitudes that can set the stage for future learning[7]. Our redesign involved a transformation of EI-100 from a lecture-based format to a challenge-based format.

We use the term "challenge-based" as a general term for a variety of approaches to instruction that many have studied, this includes case-based instruction, problem-based learning, learning by design, inquiry learning, anchored instruction, and so forth. There are important differences among these approaches, but important commonalities as well[9, 18]. We used the HPL framework as a set of lenses for guiding the redesign of the lessons, development of our challenges but also the overall instruction that surrounded the challenges. Particularly important were opportunities to make students' thinking visible and give them chances to revise[9]. We also note the importance of provided opportunities for "what if" thinking, given variations on the challenge and for new problems that also involved the lesson's concepts. Attempts to help people reflect on their own processes as learners (to be metacognitive) were also emphasized.

Vast amounts of educational and psychological research support the efficacy of both active learning and frequent real-time formative assessment in improving learning[8, 9, 18, 25]. In EI-100 we used *InkSurvey* (http://ticc.mines.edu/csm/survey.php), a web-based tool developed specifically to allow an instructor to pose open-ended questions to students during class and receive real-time student responses. Students use Tablet PCs to respond to these questions with their own words/sentences/paragraphs entered manually via the keyboard, or with digital ink that allows handwriting, sketches, equations, graphs, derivations, etc. Confidence level can be included if desired. The instructor receives an instantaneous compilation of web-based student responses[26].

A variety of Tablet PC compatible tools are being used to facilitate communication within the classroom, such as *Classroom Presenter* (http://classroompresenter.cs.washington.edu). Using the work of Angelo and Cross[2], EI-100 faculty identified classroom assessment techniques (CATs) appropriate to each section of the course and then adapted them into the Tablet PC/ *Classroom Presenter* environment. Faculty also made use of CATs that are already features within Classroom Presenter, like the polling features[1]. Each instructor uses CATs to gauge student learning in real time and makes real-time pedagogical adjustments as needed.

Tools for solving engineering problems have become computer-based over recent years. In order to effectively demonstrate the use of computer-based tools in a classroom environment, teachers typically present the tool by projecting the computer screen display and verbally describing the operation. In EI-100 we utilized *WriteOn* (http://www.ee.vt.edu/~jgtront/tabletpc/writeon.html), a Tablet PC tool that was developed to allow the user to effectively draw on top of any application shown on the Tablet PC screen. Conceptually set up as a virtual transparency, *WriteOn* allows a presenter to annotate on an operational window as the target application dynamically runs[40]. Snapshots of the screen, including the electronic ink as well as the application output, can be captured and stored as class notes for later distribution through EI-100 website.

WriteOn and *Classroom Presenter* allow the presenter to generate a movie of the screen activity including voice-over of the classroom discussion. Finally, *WriteOn* and *Classroom Presenter* can also broadcast the presenter's screen content to the entire class using wireless networking. In this mode the student clients can both receive the application output and the instructor's annotations as well as add their own annotations to the presentation[1, 40]. Students can then store a local copy of the fully annotated presentation on their machine for later review.

An important learning goal of EI-100 is to enhance students written and oral communication skills therefore multiple opportunities were given to the students to practice, receive feedback and enhance their written work-products and oral presentations. One of the skills we want students to develop over the semester is the ability to critically evaluate their own and others' work. In order to do this, students self-assessed most of their work while in "Laboratory" almost every week they peer-assessed other teams' work. This is a skill we think is very important to develop as future engineers so we take the peer assessment process seriously. For this to be an effective process, students must learn how to give and to take constructive feedback.

VaNTH Observation System

The VaNTH Engineering Research Center (ERC) for Bioengineering Educational Technologies was established in 1999 with funding from the National Science Foundation (NSF). VaNTH is a multi-university ERC developed to maximize the educational experiences of bioengineering students at Vanderbilt University, Northwestern University, the University of Texas at Austin, and the Harvard/Massachusetts Institute of Technology Division of Health Science and Technology. VaNTH involves a collaboration of professionals from Bioengineering Domains (e.g., Biomechanics and Biotechnology), Learning Sciences, Assessment and Evaluation, and Learning Technology[16]. The goal of the VaNTH ERC is to "unite educators and engineers, in industry and academia, to develop curricula and technologies that will educate future generations of bioengineers. These curricular changes were guided by the HPL framework[16].

The VaNTH Observation System (VOS) is an assessment tool developed to capture qualitative and quantitative classroom observation data from teaching and learning experiences of the bioengineering classroom. VOS is a four-part system that incorporates the elements of HPL framework and uses four recurring methods of collecting classroom data: recording student-teacher interactions, recording student academic engagement, recording narrative notes of classroom events, and rating specific indicators of effective teaching. VOS was developed from the Stallings Observation System[35-38], which consisted of three components that registered the presence and absence of over 600 in-class student and teacher behaviors and activities[16].

Similar to other classroom observation systems, VOS provides information about the types of pedagogy and interactions occurring within a class along with information about levels of student engagement. Unlike previous observation systems, however, VOS contains a category that explicitly measures the presence of the four HPL framework lenses and the interactions of these lenses within observed courses[16]. The four components of the VOS include the following: (1) the Classroom Interaction Observation (CIO), sampled real-time, which records student and faculty interactions; (2) a time-sampled Student Engagement Observation (SEO), which notes whether students are engaged or unengaged with academic tasks, (3) qualitative Narrative Notes (NN) on the lesson content, lesson context, extenuating circumstances, and additional information about the classroom, and (4) Global Ratings (GR), which provide summative information about major aspects of the pedagogy underlying the class session (Harris and Cox, 2003). VOS was used to systematically assess HPL framework implementation in EI-100 classrooms[3, 11-15, 20-23, 29].

Research Questions and Significance

Main questions of the project "High-Quality Environments for Teaching and Learning Engineering Design: Using Tablet PCs and Guidelines from Research on *How People Learn*" (from which this paper is part) are: 1) Are students gaining a deeper conceptual understanding of the engineering method than they did before the course was redesigned? 2) Has active student participation in class increased as compared with previous, non Tablet PC technologies and HPL framework-enhanced versions of the same course? 3) Are formative assessment and feedback more common and more rapid in the redesigned course than in the previous course offerings? Does the facilitators utilize the information gained through real-time formative assessment to tailor instruction to meet student needs? 4) Are peer-team formative assessments better than in the previous course offerings, and the redesigned course improved feedback processes so that "Laboratory" work resubmission decreased?

For this reason, the main question for this paper asks: is the VaNTH Observation System sensitive enough to capture differences (including HPL-related) in learning environments at an introduction to engineering design course? The research presented in this paper is significant for several reasons. First, it examines ways of quantifying the amount of HPL-oriented instruction within VOS-observed classes outside bioengineering. Second, this study introduces VOS to a different country setting (Mexico) and adapts it to another language (Spanish). Also, this research examines differences within and across faculty in their use of HPL in a freshman course, thereby setting the stage for faculty development programs targeted at improving pedagogy within first year engineering classrooms.

Methods

Effective design requires collaboration among people with specific kinds of expertise (content knowledge, learning, assessment, technology). UDLAP's Center for Science, Engineering and Technology Education (CECIT) expertise was used to enhance Tablet PC technologies to effectively support students and faculty in EI-100 academic projects. CECIT experts contributed in the design of rubrics and assessment procedures (including classroom activities), as well as evaluation of learning outcomes for the redesigned EI-100 course using Tablet PC technologies and HPL framework to compare the results of the previous course (we have comprehensive data from six years of implementation) and the redesigned one to be sure of the impact of this proposal on teaching, classroom activities and student learning[8, 32, 34].

In order to perform an effective assessment of EI-100 redesign, we needed an instrument that would provide in-depth knowledge of the subject while identifying differences among course sections and sessions, as well as among the different facilitators. We decided to perform a combination of qualitative and quantitative research. For the former, ethnographic-type research was performed; for the latter, VOS was chosen. The main reason for choosing VOS over other observation systems was to enable us to discern differences related to HPL framework implementation through direct classroom observation, as well as our interest in using VOS for the first time in Mexico, in Spanish and for the observation of other engineering disciplines outside bioengineering for which it had been originally developed.

The study population was made up of first-semester students of the School of Engineering at UDLAP. No sampling was performed; the entire population was surveyed. The unit of statistical analysis was comprised of the students enrolled in the course for the Fall 2008 semester, professors, teacher assistants (TAs) and other persons related to the course; and finally, all printed and electronic materials related to the course and available for analysis[28].

As part of the research, and after having selected VOS as the observation instrument, during the Spring 2008 semester a series of preliminary observations were performed in the EI-100 course. There were two main objectives for this preliminary observation: that observers were trained while becoming familiar with the course and with the instrument itself. The results obtained in these preliminary observations allowed us to get to know the typical student who was enrolling at UDLAP to study engineering, while allowing observers to become familiar with the learning scheme of EI-100, which is a course very different from traditional courses offered in high school and at UDLAP itself. The preliminary observation stage also gave us an opportunity to familiarize ourselves with the VOS instrument as well as with the proposed observation cycle. Tests using more than two observers were carried out in order to validate the observations. We found that observers required a lengthy training period before their observations could be considered to be valid.

In the preliminary analysis stage, a series of workshops were held with the professors and TAs who had taught the course in Spring 2008, and including professors and TAs who were scheduled to teach the course in Fall 2008. We shared the results from the preliminary observation with them. We gave them feedback about their work, their tendency to carry out HPL-classified activities, students' level of engagement in desirable and undesirable activities, and the percentage of time devoted to both, traditional and HPL-centered activities. We also got feedback from the professors and TAs about the instrument and the observations cycle. Since an important component of the course redesign, in addition to the focus on HPL, was the introduction of Tablet PCs as a classroom instruction tool, during some of the workshop sessions with the professors and TAs we had them work with the Tablets, become familiar with them as well as with the educational software to be used in EI-100. Finally, in the workshops the facilitators were trained on the HPL framework and changes were made to course materials, content, assessments, and teaching techniques. By the end of the workshops, every facilitator knew how to use the HPL framework and they had redesigned (working in teams) the contents, assessments, and materials for at least the first four weeks of the course so that sessions would be better aligned among them.

Following the first stage of observations, two steps were taken. First, we did a preliminary analysis of the results, which helped us make some changes to the course and provide feedback to facilitators as explained above. Second, VOS was slightly modified, especially instrument's content and the observation cycle scheme. Content-wise, items were added which were considered important for the type of work done in the EI-100 course and for the need to observe students' performance using the Tablet PCs.

The items added were the following: in the first part of the CIO instrument we included a "collaborative problem solving" item in the category of "WHAT"; and we included also the Tablet PC as another learning tool in the category of "MEANS". After having observed many students wandering outside the classroom in the preliminary observation stage, we decided to include the item “Absent” in “UNDESIRABLE ACTIVITIES” as part of the second VOS instrument (SEO). Finally, in the fourth instrument (GR), a “professor visibly demonstrates enthusiasm” item was added.

In addition to the four items added to the original instrument, VOS was translated into Spanish and employed using all the other items of its original version. Nonetheless, we had to make some adjustments to the observation scheme cycle. These modifications were made necessary by the fact that the class sessions to be observed were each two hours long, three times a week; that one section to be observed had 40 students and the other about 70; in each section there were three professors and three TAs working as facilitators. Modifications consisted in performing a total of six observations during the two hours of class (one observation every 20 minutes) using the CIO, SEO and NN instruments and making a final observation at the end of class using the GR instrument. Observations were carried out using the new scheme in order to verify that the changes still enabled us to accurately identify HPL levels as well as differences among facilitators and sessions, which it did. After the changes to the instrument had been implemented and tested, and following facilitator workshops, we proceeded to observe the redesigned course during the Fall 2008 semester. There were two sections, EI-100 section 1 with 40 students and EI-100 section 2 with 68 students. Thus, using the CIO, NN and GR, a total of 252 observations were performed in each of the sections (504 in all) during the semester at a rate of six observations per class and three classes per week for 14 weeks. In terms of SEO, there were more observations because of the number of students enrolled in the courses: 3360 observations for section 1, and 5712 observations for section 2. While the VOS observations were being performed, we also did an ethnographic-type study in order to get information on the engineering student culture from the students’ point of view.

In summary, VOS was used to systematically assess HPL framework implementation in EI-100 classrooms. Observers measured differences in classroom experiences resulting from the innovations and redesigned learning environments. Over the course of the past year, three observers trained in VOS sat in EI-100 classrooms and observed 9 instructors, both junior and senior level, in over 60 class sessions from the three different EI-100 sessions. Classes ranged in size from 30 to 70-plus; some were designated as control (prior to be redesigned) classes, some as experimental (redesigned) classes. Observers conducted a minimum of six observations per class. During Fall 2008 semester, observers achieved a 70 percent inter-rater reliability in using the VOS. Preliminary and actual observation stages were accompanied by a review of course-related materials from the present and previous (we have comprehensive data from six years of implementation) semesters, such as grades, homework, journals, models, projects, quizzes, self- and peer-assessments, designs, student evaluations, among others.

Once observations were concluded in December 2008, we proceeded to the analysis of the data obtained, which we will be covered in the next section. Results have enabled us to provide feedback to the professors and TAs who taught the course and have also given us an opportunity to improve EI-100 course by further redesigning some topics and materials. They also paved the way for organizing new workshops and seminars for facilitators on the topics of HPL and using Tablet PCs.

Results and Discussion

EI-100 redesign significantly ($p < 0.05$) increased student participation. Formative assessment and feedback were more common and rapid. Facilitators utilized the information gained through real-time formative assessment to tailor instruction to meet student needs. Particularly important were opportunities to make students' thinking visible and give them chances to revise, as well as opportunities for "what if" thinking (data not shown).

Analysis of the results of the use of VaNTH Observation System to capture differences in the course EI-100 will be divided into two main categories:

1. HPL Centeredness of the Course

In order to determine the level of HPL centeredness in the course, three VOS instruments were used:

a. The Classroom Interaction Observation instrument allowed us to determine the level of HPL centeredness in each of the two EI-100 sections (1 and 2) and in each of the three sessions (Modeling, Concepts and Laboratory). CIO enabled us to evaluate classroom interaction between professors and students, including WHO, TO WHOM, WHAT, HOW, and THROUGH WHICH MEANS interaction took place. From this instrument, HOW was chosen as the criterion which specifically observes classroom HPL centeredness level.

b. Use of the Narrative Notes instrument enabled us to identify important aspects of the class such as content, context and special circumstances in the classroom. NN allowed us to determine whether or not there was a difference between sessions and among sections in terms of the percentage of HPL characteristics in the class. Based on this instrument, we isolated certain characteristics that should be present in an HPL-centered classroom. The characteristics chosen were: students explain how to solve a problem; collaborative learning takes place in the classroom; the professor guides higher-order discussion; and the professor leads an HPL-based question and answer session.

c. Use of the Global Ratings instrument allows for general comments on the session and professor observed by gathering data at the end of class. GR helped us to determine if there are differences among professors from the two sections and their respective sessions in terms of HPL-classified activities. Based on this instrument, certain characteristics were identified which should be promoted by a professor conducting an HPL-oriented class. The selected characteristics were: offering HPL challenges; connecting with prior learning; formatively assessing at the beginning, during, and at the end of class; using appropriate visual aids; and asking hypothetical questions.

2. Degree of Student Engagement in the Course

SEO instrument was used to determine the level of student involvement in desirable and undesirable activities. This enabled us to determine the percentage of students involved in desirable and undesirable activities in each of the six groups (two sections and three sessions for each section).

1. HPL Centeredness of the Course

a. Use of the CIO allows us to determine what the HPL centeredness level is in each of the two EI-100 sections and what the HPL centeredness level is in each of the three sessions (Modeling, Concepts and Laboratory) of the course by answering how the classroom interaction took place.

Figure 1 presents the differences observed among the different sessions and sections of EI-100 course in terms of the level of HPL centeredness present in the classroom. The six groups (two sections and three sessions) showed that they had participated in activities focused on the four lenses of HPL. Every one of them carried out knowledge-, student-, assessment-, and community-centered activities. The percentages relating to organization-centered activities were nearly insignificant (less than 2%) and therefore not present in this figure.

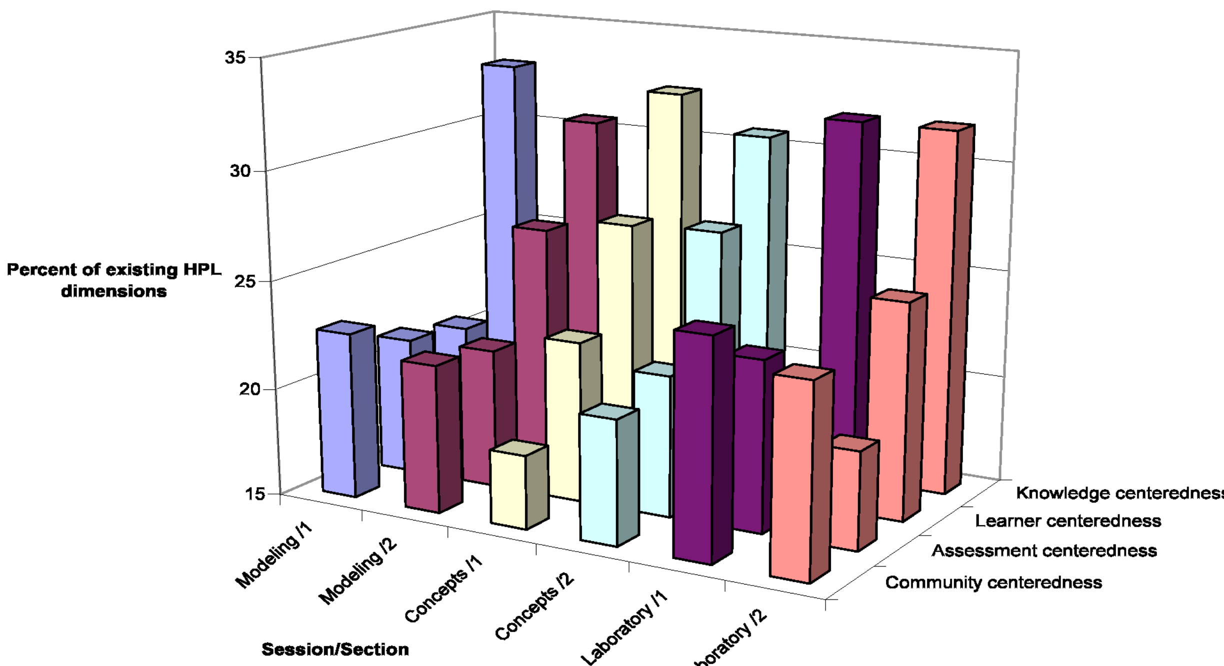

Figure 1. Percent of existing How People Learn (HPL) dimensions in the course Introduction to Engineering Design sessions (Modeling,Concepts and Laboratory) in sections 1 and 2

In a pattern common to all the sections and sessions, the highest percentage was found in knowledge-centered activities, with a percentage of approximately 30% in the six groups observed (32.89%, 32.29%, 31.78%, 30.56%, 30.68% and 31.78%, respectively). The Modeling and Laboratory sessions of both sessions displayed their second-highest percentages in community-centered activities. These results are logical if one considers that in these two sessions most problems and projects are solved in teams and most of them are related to the real world.

On the other hand, the Concepts sessions, which comprise the theoretical portion of the EI-100 course, have their second-highest percentage in learner-centered activities, followed by assessment-centered activities. It is important to point out that even though there are differences between the percentages of HPL-centered activities, all six groups are working in alignment with the four HPL lenses and to a greater or lesser extent, took knowledge, the learner, assessment and the community into account.

There are some opportunities for improvement for certain professors and sessions. In the Concepts sessions, it would be desirable to increase the percentage of community-centered activities, while the Laboratory sessions need to work on increasing the amount of learner-centered activities. The results also clearly show the difference among professors who have more experience with the EI-100 course, and especially with the HPL framework. Thus, the Laboratory session of section 2 presented the lowest percentages of HPL in all the lenses since the professor was the second time she taught the course and is a junior faculty, while the Concepts sessions of section 2 and the Laboratory session of section 1 obtained the highest percentages in the four lenses since both professors have taught EI-100 at least 8 times and both are senior faculty.

Finally, it is important to remember that during the entire course Tablet PCs were being used as a teaching tool, especially in the Concepts and Laboratory sessions. The Tablet PCs were used to carry out activities mainly centered on knowledge, assessment and the community. Activities were designed in which students had to solve problems in teams and send their results to their professor through *Classroom Presenter* software. These activities promoted knowledge-, student-, assessment- and community-centered environments in the classroom, and this is reflected in Figure 1.

When the percentages of the combinations of activities centered on the HPL lenses were analyzed, section 2 exhibited higher average values for the activities centered on the four lenses. However, statistical results (t test for independent groups) show no significant ($p > 0.05$) difference between the two sections in the percentages of activities centered on each one of the four lenses. Returning to the original question, despite not having found significant differences between the results from the two sections, observations demonstrate that there is a high proportion of activities centered on each of the four lenses of the HPL framework in the six groups; thus EI-100 is aligned with the HPL framework and the course redesign was successful in that regard.

b. Use of the NN instrument enabled us to determine if there was a difference between sections and among sessions in terms of the percentage of characteristics of the HPL framework present in class. The characteristics chosen were: students explain how to solve a problem; collaborative learning takes place in the classroom; the professor guides higher-order discussion; and the professor leads an HPL-based question and answer session.

As has been previously mentioned, a series of characteristics, which should be present in a classroom aligned on the HPL model were selected from the NN instrument. Figure 2 presents the results obtained from the observations carried out in the two sections of EI-100 relative to those four selected characteristics.

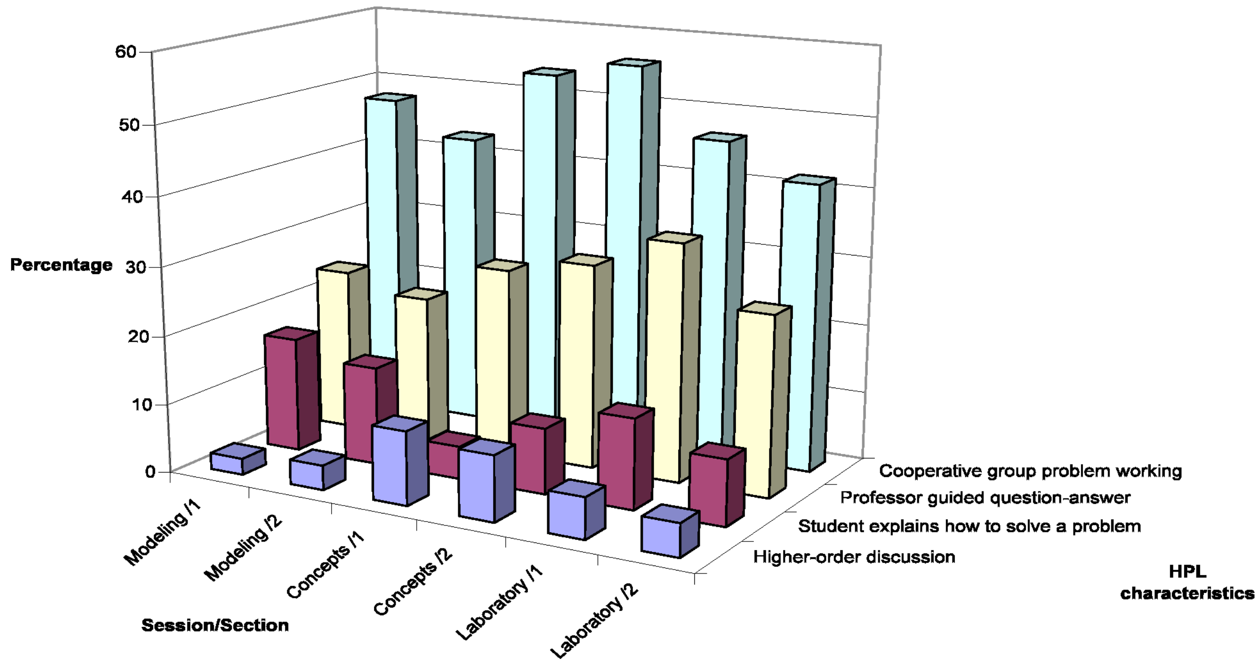

Figure 2. Percent of How People Learn (HPL) oriented Instruction features in the course Introduction to Engineering Design sessions (Modeling,Concepts and Laboratory) in sections 1 and 2

According to Figure 2, the six groups (the two sections in their three respective sessions) worked in such a way so that the four selected characteristics of the HPL framework are present in the classroom. Every one of class sessions worked intensively on a cooperative group to solve problems, which is an expected result given the learning outcomes of the course. EI-100 is designed so that students may work more collaborating with others than individually on problem solving. This is true for Modeling, Concepts, and Laboratory sessions. It is also important to point out the fact that the highest percentages in cooperative work were in the Concepts sessions and the lowest in the Laboratory sessions.

A second important characteristic that should be observed in an HPL-centered classroom is that the professor guides HPL-centered questions and answers. The six groups displayed this characteristic throughout the semester, although with a lower percentage than the one for cooperative work. Concepts (sections 1 and 2) and Laboratory (section 1) sessions displayed the highest percentages of HPL-centered questions and answers in the observation. This may be explained by the fact that they were the sessions in which the professors were senior faculty and the ones most familiar with the HPL framework and therefore implemented it the most in the classroom.

One of the characteristics that should be present in an HPL-centered classroom is the design of environments in which students are motivated to show how they solved a given problem. This explanation may be given individually or in groups. In this sense, the six groups showed low percentages, with the highest percentages in the Modeling sessions (an important learning outcome of this session) and the lowest in the Concepts sessions (for both sections).

These percentages were part of the feedback provided to the different professors, and they will be taken into account for further redesign of EI-100. For every session, it will be of the utmost importance to maintain the percentages shown for cooperative work while designing learning environments that favor an increase in the percentages of HPL-centered questions and answers and student problem-solving explanations, while higher-order discussion should be further promoted in every session.

These results have enabled us to emphasize, in the feedback provided to the professors, the need to design learning environments in which all four characteristics are considered, pointing out to them that higher-order discussion is of great importance when one wants to promote the HPL framework.

Finally, returning to the question that triggered this discussion section, it may be stated that there are differences between the six groups observed in terms of the presence of the four characteristics. However, the presence of the four characteristics in every one of the six groups leads us to affirm that EI-100 is oriented towards the HPL framework, even though some sessions are better designed and implemented than others.

c. Use of the GR instrument helped us to determine which differences there were between the professors of the sections and their respective sessions in terms of the percentage of use of HPL activities (offering HPL challenges; connecting with prior learning; formatively assessing at the beginning, during, and at the end of class; using appropriate visual aids; and asking hypothetical questions).

In order to complement the information, a series of characteristics that every professor should promote in an HPL-centered classroom were selected from the GR instrument. Figures 3 and 4 present the results obtained from the related observations in the two sections of the EI-100 course during Fall 2008 semester.

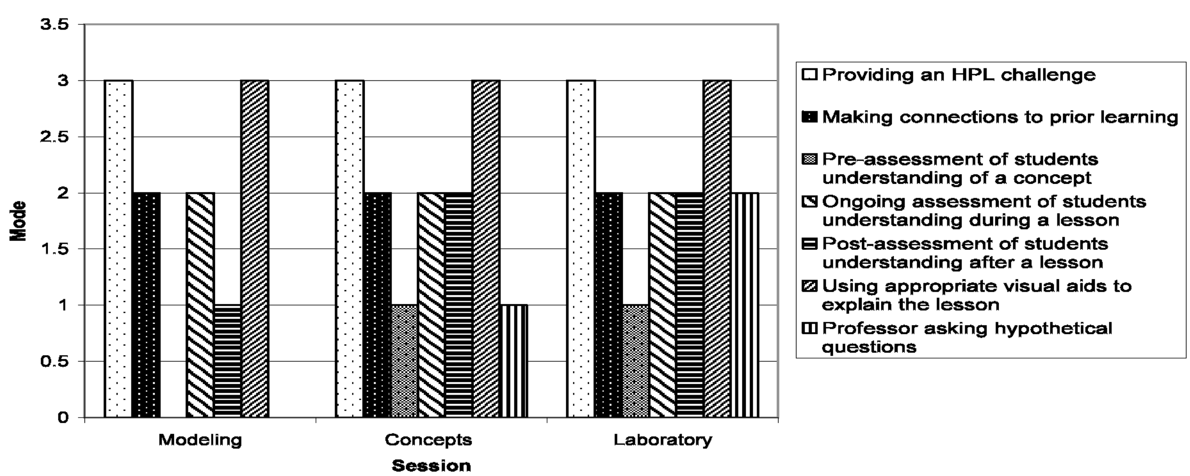

Figure 3. Mode of existing How People Learn (HPL) oriented Instruction teacher actions in the course Introduction to Engineering Design sessions (Modeling,Concepts and Laboratory) in section 1 .

It is important to remember that GR, the fourth instrument of the VOS uses a Likert scale related to the presence of different actions by the professor, assigning a 0 score when the behavior was never observed and 5 when the behavior was always observed. For analysis purposes, the observation modes were considered. In both sections observed, professors revealed the seven observed activities. The highest observed modes were for those related to providing students with HPL challenges and employing appropriate visual aids for instruction. Connecting to prior learning was observed in lesser frequency than the other activities, while formative assessment during, and at the end of class was carried out in all six groups observed.

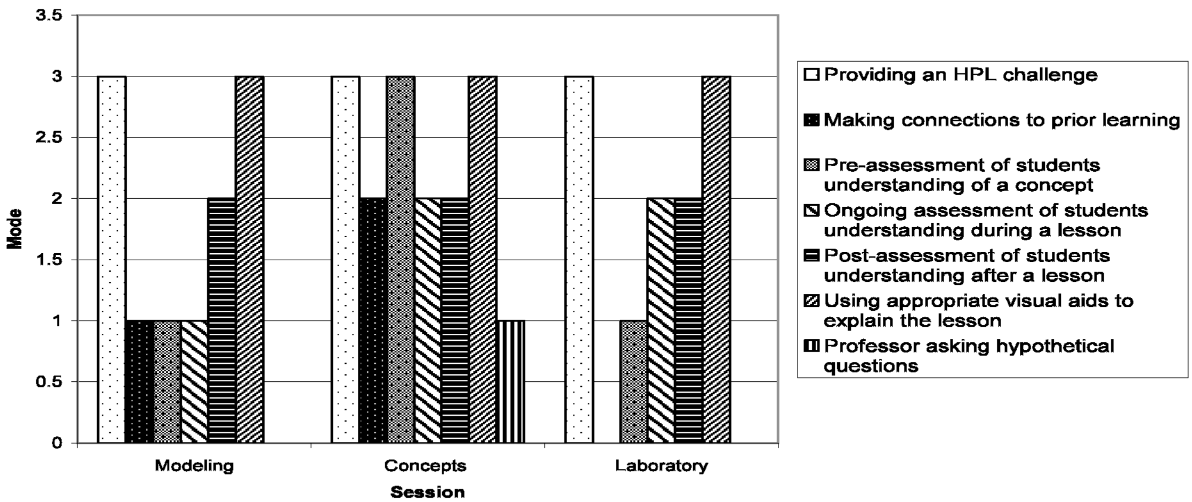

Figure 4. Mode of existing How People Learn (HPL) oriented Instruction teacher actions in the course Introduction to Engineering Design sessions (Modeling,Concepts and Laboratory) in section 2.

Especially low modes were observed in pre-assessment (in Modeling session, section 1), connecting with prior learning (in Laboratory session, section 2), asking hypothetical questions (in Modeling session, section 2 and Laboratory session, section 2); values were too low to be shown in the corresponding figure.

Only in three sessions were observed the seven characteristics: Concepts (sections 1 and 2) and Laboratory (section 1); both sessions are taught by professors with plenty of experience in the course and the HPL framework. The results obtained from the observation of these activities enabled us to provide a more accurate feedback to different professors, showing them the importance of each of the activities and the opportunities for improvement they contained for future courses.

Returning to the hypothesis that initiated this results discussion section, it may be concluded that differences exist among the six groups observed. We found that the sessions with the highest desirable HPL activities were those taught by the professors most familiar with the HPL framework and the course.

Based on the use of the first three VOS instruments (CIO, NN and GR), it may be concluded that the Introduction to Engineering Design course is aligned with the HPL framework. In the six groups observed (two sections and its three corresponding sessions), a great deal of knowledge-, learner-, assessment- and community-centered activities were observed, as well as characteristics that should be present in an HPL-centered classroom such as students explain how to solve a problem, cooperative learning takes place in the classroom, the professor guides higher-order discussions, and the professor leads an HPL-based question and answer session. Further, several characteristics that should be promoted by a professor conducting an HPL-oriented class were also observed, for instance offering HPL challenges; connecting with prior learning; formatively assessing at the beginning, during, and at the end of class; using appropriate visual aids; and asking hypothetical questions.

However, some important differences were found from one session and section to the next. It is important to point out that the use of the three instruments allowed us to observe in each session the type of activity for which it was designed. For example, there were a higher percentage of assessment- and community-oriented activities in the Laboratory sessions, because that was precisely how that portion of the course was designed. Likewise, use of the three instruments allowed us to discern important differences among professors. What stood out was that the sessions with the highest percentages of HPL-oriented activities were those taught by facilitators who had more experience with the course and the HPL framework. This demonstrates the need that exists, on the one hand, to train professors on the HPL framework so that they can develop an in-depth knowledge of it and then apply it in the classroom, and on the other hand, the importance of the professor's experience in using HPL.

2. Degree of Student Engagement in the Course

Use of the SEO instrument enabled us to determine the percentage of students engaged in both desirable and non-desirable activities in each of the two sections and their corresponding three sessions. Figures 5 and 6 present the percentage of students involved in desirable and undesirable activities in the two sections of EI-100 during Fall 2008 semester.

Analysis of the results for desirable and undesirable activities exhibited a higher percentage of desirable than undesirable activities in only two of the six groups observed (Concepts 1 and 2). Laboratory sessions (sections 1 and 2) presented a higher percentage of undesirable activities, along with the Modeling session of section 1. The fact that in the Concepts session there is a greater percentage of students in desirable activities can be explained by the context of the course. The Concepts session comprises the theoretical portion of the course, and in it student achievement is mainly assessed through individual examinations, while in Modeling and Laboratory is through team-based assessments. If we recall that EI-100 is a course for first-semester engineering students, it is reasonable to conclude that students are more concerned with "paying attention" in courses in which they know that they will be assessed individually. Furthermore, they are accustomed to high school, in which theoretical subjects are the "most important" to their courses of study.

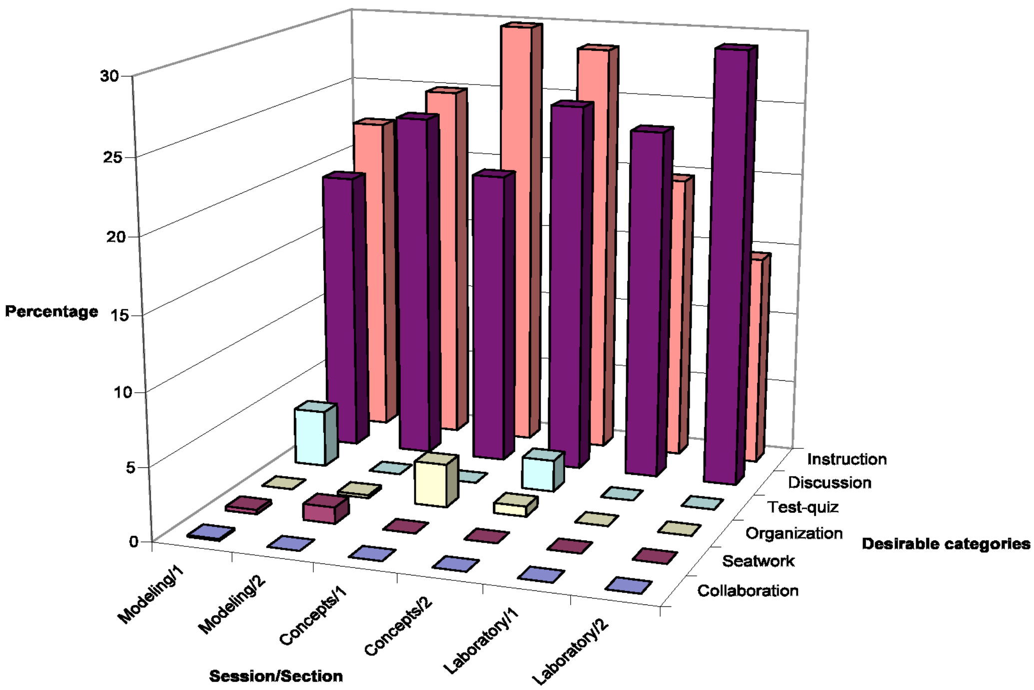

Fig. 5 Percentages of desirable categories observed in the Introduction to Engineering Design course sessions (Modeling, Concepts and Laboratory) in sections 1 and 2.

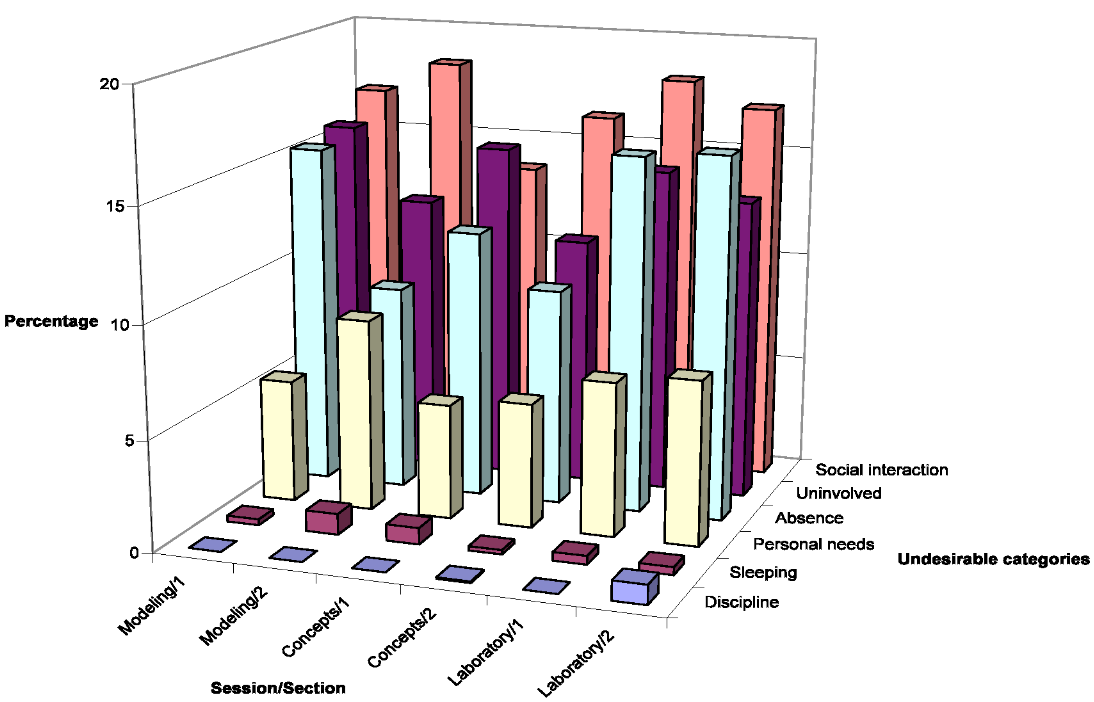

Fig. 6 Percentages of undesirable categories observed in the Introduction to Engineering Design course sessions (Modeling, Concepts and Laboratory) in sections 1 and 2.

In analyzing the different categories of desirable activities for the six groups, the highest percentages were found in the instruction and discussion categories, although there were some differences among the six groups. It is important to point out that there is a great opportunity for improvement for every one of the professors observed. Through feedback, we showed them that there are other desirable activities (besides instruction and discussion) in the classroom that would be worthwhile to foster in students. Analyzing the percentages of students engaged in undesirable categories, some differences among sessions stand out. For example, the Modeling session displayed the highest percentages in social interaction for both sections (16.9% and 18.3%, respectively). In the Concepts session, in section 1 the highest percentage was in the uninvolved category (15.2%); in section 2, it was in social interaction (16.2%). In the Laboratory sessions, the highest percentage category in both sections was social interaction (18.1% and 17.1%, respectively).

Statistical results (t test for independent groups) showed no significant ($p > 0.05$) difference in the percentage of students engaged in desirable activities between the two sections of either Modeling, Concepts, and Laboratory sessions. Similarly, there is no significant ($p > 0.05$) difference in the percentage of students engaged in undesirable activities between the two sections of the three EI-100 sessions. However, for section 1 the Concepts session displayed a significantly ($p < 0.05$) higher percentage of students engaged in desirable activities than did the Laboratory session. Additionally, the Concepts session showed a significantly ($p < 0.05$) lower percentage of undesirable activities than the Laboratory session. When comparing the three sessions (Modeling, Concepts and Laboratory) for section 2, the results were the same as the above mentioned.

In order to complement the study of the percentage of students involved in desirable and undesirable activities, an analysis is currently being performed of the change in percentages over the course of the semester by session and section. So far, the pattern shows that during the course of the semester there is an increase in the percentage of students involved in undesirable activities and a decrease in the percentage of students in desirable activities. This occurs differently in each of the six groups and is found at different times in the semester. We are in the process of analyzing which circumstances in the course and activities carried out are influencing the observed percentages. Accordingly, we are performing a class-by-class analysis to evaluate how the change in the percentage of students involved in desirable and undesirable activities came about in every class period. As in the semester-long variation analysis, class-by-class analysis has shown that as the class period advances, the percentage of students involved in desirable activities decreases as the percentage of students in undesirable activities increases. We are further investigating in order to determine which factors are triggering the percentages and determine if situations such as the length of the class period (two hours) are having a negative influence on the in-class activities of first-semester students.

In conclusion, VOS captured differences in EI-100 classroom experiences. These differences may be used to measure levels of “HPLness” of a lesson. Moreover VOS clearly captured differences among facilitators’ teaching styles and identified the effects of EI-100 three different sessions. In addition, VOS generated detailed feedback that facilitators may use to self-assess and further refine EI-100 redesign.

Final Remarks

The Introduction to Engineering Design course has undergone many changes since its inception, the most important of which have sought to orient the course towards the How People Learn framework. VaNTH Observation System enabled us to identify two very important aspects of EI-100 in its two Fall 2008 sections and three sessions (Modeling, Concepts and Laboratory). On the one hand, this led us to determine that it is in fact a course designed according to the HPL framework, and that every one of the sessions, following the framework under which they were re-designed, employ learning environments that are knowledge-, learner-, assessment-, and community-centered.

Using the Classroom Interaction Observation instrument of VOS, we were able to identify important differences between the six groups (two sections and three sessions) observed in terms of the extent to which each one of them is centered on the four lenses of HPL. This information was complemented using two other VOS instruments, Narrative Notes and Global Ratings. Use of the CIO also enabled us to carry out observations related to the use of the Tablet PCs as a learning tool in this course, identifying important differences between sessions and the facilitators who taught the course.

From the aforementioned data, it became clear that the differences among the different groups basically depend on the facilitator. The knowledge and experience of him/her with Tablet PCs and especially with the HPL framework are indispensable prerequisites for the course to be HPL-centered, and they are also determining factors to achieve satisfactory learning outcomes.

The Student Engagement Observation instrument of VOS allowed us to determine the percentage of students engaged in desirable (and undesirable) activities in each of the six studied groups. There was an important number of students engaged in undesirable activities that leads us to believe that first-semester students arrive at UDLAP accustomed to a traditional teaching scheme and for whom taking a course with a radically different model from the one they are used to, has a strong impact on them. This impact is even greater since the course is taught and assessed by six different facilitators, two for each session (Modeling, Concepts and Laboratory). This makes the need all the greater for facilitators and freshman students to be trained on the HPL framework. Facilitators need to be very familiar with the framework, its use and assessment, while students need a period of time to become familiar with the new framework before they can become successful with it.

Another important result derived from this study has been the timely feedback we have been able to provide to every facilitator who taught the Introduction to Engineering Design course during the Spring and Fall 2008 semesters. This feedback has enabled them to know what their strengths and weaknesses are in their use of the HPL framework, in order to improve for future courses.

The process of collecting data from directly observing most of the EI-100 class sessions for nearly a year has also enabled us to compile a great deal of qualitative information, which is providing us a basis for an ethnographic analysis which is underway.

Future Actions

The VaNTH Observation System is a very complex set of instruments, a considerable amount of time was needed to become familiar with the instruments, its observational framework, as well as to adapt some of the items and cycle of data collection to another country and language setting prior to train the observers before their observations could be validated. Therefore since at UDLAP engineering school are several courses that are known to be using the HPL framework, VOS needs to be utilized to assess them. Observations need also to be taken in courses that are known to follow traditional pedagogical practices to capture HPL-related differences in courses that are known to employ HPL-based or traditional pedagogy, while identifying the advantages and disadvantages of each of these pedagogies in the teaching and learning of engineering.

A second group of future actions that are important to point out are related to the need of setting the stage for faculty development programs targeted at improving pedagogy within engineering classrooms[10]. We also need to promote the importance of making use of the HPL framework in several engineering courses at UDLAP, so that EI-100 will neither be the first nor the last course in which students learn under this framework. Students need to be knowledgeable, learn and adapt to the new framework before being successful with it. We cannot expect students to be HPL-centered the very first time they encounter this approach. Thus we are using the VOS in a second semester engineering course to follow up on students who took EI-100 last semester in order to observe their achievements and disadvantages.

Acknowledgments

We acknowledge financial support from HEWLETT-PACKARD (HP), through the HP Technology for Teaching Higher Education Grant Initiative for Latin America for the project "High-Quality Learning Environments for Engineering Design: Using Tablet PCs and Guidelines from Research on *How People Learn*". Author Gazca acknowledges financial support for her PhD studies from the National Council for Science and Technology of Mexico (CONACyT) and *Universidad de las Américas Puebla*.

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