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Assessing Pedagogy in Bioengineering Classrooms: Quantifying Elements of the “How People Learn” Model Using the VaNTH Observation System (VOS)

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ABSTRACT

One goal of the VaNTH Engineering Research Center is to estimate the effects of the “value added” to bioengineering student learning as a result of “How People Learn” (HPL) framework interventions. A necessary step in that process is to assess pedagogical differences in both lecture-based and HPL-oriented courses. Data from 28 bioengineering courses, over five semesters, were analyzed using a newly developed HPL Index. This index, developed from the Classroom Interaction Observation portion of the VaNTH Observation System, reports levels of HPL-inspired pedagogy, traditional pedagogy, and classroom organization within a class using codes for different types of faculty and student interactions assigned by an observer in real time. Results confirm the HPL Index’s ability to distinguish pedagogical practices based on HPL principles and pedagogical practices based on traditional, non-HPL pedagogy.

Keywords: classroom assessment, engineering pedagogy, observation systems

I. INTRODUCTION

As the demand for innovative technology increases within the United States, the number of highly qualified engineers must also increase. ABET requires that engineering graduates demonstrate several skills, such as the ability to solve engineering problems, to apply science-based, engineering, and mathematics knowledge, and to effectively work in interdisciplinary teams (Herkert, 1999). These requirements affect over 2,700 engineering programs at approximately 550 colleges and universities nationwide.

In an effort to address these requirements within engineering, researchers have begun conducting empirical studies to identify pedagogical practices intended to optimize these desired skills in the next generation of engineers. Teaching and learning within

engineering differs from teaching and learning within other disciplines because engineering is a “hard/applied” field of study, focusing on inquiry strategies, mastery of the environment, and the development and application of products and processes (Lodahl and Gordon, 1972; Biglan, 1973; Neumann, Perry and Becher, 2002). In-class student collaboration within engineering classrooms increases students’ critical thinking skills and has positive effects on student achievement, persistence, and attitudes compared to lecture-based engineering classroom environments (Cooper and Robinson, 1998; Cudd and Wasser, 1999; Springer, Stanne, and Donovan, 1998). In addition, engineering classes with greater emphases on faculty-student interactions and faculty guidance have positive effects on student learning (Cabrera, Colbeck, and Terenzini, 2001).

To meet the educational standards of ABET and to increase the quality of the students’ educational experience within engineering classrooms, valid assessments of current engineering classrooms are needed. One such discipline-specific instrument, the VaNTH Observation System (VOS), was developed to capture pedagogical practices in bioengineering classrooms (Harris and Cox, 2003). It has been used to observe over thirty bioengineering courses at two research universities. Although the VOS captures the nature and quality of faculty and student interactions within engineering courses, its use to date has not been optimized because of the absence of an algorithm for combining the distinct observation segments into a coherent index that can be used to register the quality of pedagogy exhibited in courses.

This paper describes the development and application of a newly developed index that parses data collected from one portion of the VOS into categories representing traditional and nontraditional instruction and distinguishes pedagogical style from other activities associated with classroom organization or management. Overviews of VOS studies are described, and the criterion contrast of the index is examined. Differences between traditional and HPL-oriented courses within one biomedical engineering program (at Vanderbilt University) are explored and presented, and connections to practice are discussed. The next section provides an overview of the VaNTH Engineering Research Center (ERC).

A. The VaNTH ERC Model of Learning and Instruction

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. The VaNTH ERC is the only Center funded by NSF devoted solely to bioengineering educational technologies. 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 (VaNTH, 2003). These curricular changes were guided by the “How People Learn” (HPL) framework (Bransford, Brown, and Cocking, 1999), a synthesis of research on learning that complements other pedagogical practices (e.g., constructivist, problem-based learning) that have been found to be effective within many classroom environments.

The HPL framework encourages teachers to diversify their teaching by incorporating the four lenses of knowledge-, learner-, assessment-, and community-centeredness into their current class lessons. A *knowledge-centered* environment emphasizes making academic connections around foundational concepts across courses within a discipline and using these concepts to understand and solve problems (Bransford, Vye, and Bateman, 1999). Within a *learner-centered* environment, an instructor explicitly incorporates the learning styles, preconceptions, skills, prior experiences, knowledge, and beliefs that students bring into a classroom and recognizes the challenges that novice learners may experience within a classroom environment. *Assessment-centered* environments allow students to make their thinking and learning visible through the use of both summative and formative techniques. A *community-centered learning environment* encourages students to develop a professional identity in class and out of class and to become lifelong learners via connections and collaborations that they have with faculty and students who share norms that value learning and high standards. Successful implementation of HPL framework principles should result in the transfer of learning from students’ previous academic experiences so that students become adaptive experts in their areas of study (Cordray, Pion, Harris, and Norris, 2003; Harris, Cordray, and Harris, 2002; Jansen et al., 2003; Roselli and Brophy, 2001 and 2003).

II. RESEARCH QUESTIONS AND SIGNIFICANCE

A. Research Questions

Criterion contrast explores “the degree to which an instrument’s scores are related to external criteria believed to measure the attribute of interest” (Doherty et al., 2002, p. 83). The study described in this paper examines the criterion contrast of a newly developed HPL Index derived from the Classroom Interaction Observation portion of the VOS. Within the Department of Biomedical Engineering at Vanderbilt University, there are courses that are known to be using the HPL framework. Observations have also been taken in courses that are known to follow traditional pedagogical practices. If the HPL Index adequately captures true HPL practices, it should be sensitive enough to register pedagogical differences in these two types of courses. Being able to distinguish between two contrasting groups yields evidence of criterion contrast within the Index. It is hypothesized that higher HPL instructional scores (on average) will be found within HPL courses and that lower HPL instructional scores (on average)

will be found within traditional courses. For this reason, the main question for this study asks, “Is the HPL Index sensitive enough to capture HPL-related differences in courses that are known to employ HPL-based or traditional pedagogy?” Additional information about this HPL Index is detailed in a later section.

B. Significance of the Research

This research is significant for several reasons. First, it examines ways of quantifying the amount of HPL-oriented instruction within VOS-observed classes using code strings that sum up to 100 percent of classroom instruction. The current method of indexing the amount of HPL-oriented instruction in courses relies on the simple percentage of individual HPL dimensions that are present within Classroom Interaction Observation data. This study introduces a method of indexing HPL that improves upon current practices by grouping code strings into categories that take into account the connection of these HPL lenses to classroom interactions, pedagogical methods, and technology use within the classroom. Second, this research examines differences within and across faculty in their use of HPL and traditional pedagogy, thereby setting the stage for faculty development programs targeted at improving pedagogy within engineering classrooms.

III. OVERVIEW OF THE VANTH OBSERVATION SYSTEM (VOS)

A. Development of the VaNTH Observation System

In an effort to assess the presence or absence of HPL-inspired pedagogical practices within postsecondary engineering classrooms and to give bioengineering instructors feedback about their teaching, Dr. Alene Harris and her colleagues within the VaNTH ERC created the VaNTH Observation System (VOS), a direct observation system that could be used within bioengineering classrooms. The VOS was developed from the Stallings Observation System (Stallings and Kaskowitz, 1974; Stallings, 1977, 1978, 1980, and 1986; Stallings and Frieberg, 1991), which consisted of three components that registered the presence and absence of over 600 in-class student and teacher behaviors and activities (Stallings, 1977, 1978, and 1980; Adolf, 1983).

Similar to other classroom observation systems used at both the K-12 and postsecondary levels (Stallings, 1977; Piburn et al., 2000; Knight, 2001; Moran et al., 2003), the VOS provides information about the types of pedagogy and interactions occurring within a class along with information about levels of student engagement. Unlike these previous observation systems, however, the VOS contains a category that explicitly measures the presence of the four HPL framework lenses and the interactions of these lenses within observed courses. 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).

B. Observer Training and Data Collection Cycle

Since fall 2000, training of VOS observers has occurred via observations of real-time and videotaped classroom sessions. To date, eight observers at Vanderbilt University (one research assistant professor of education, three education graduate students, and four bioengineering graduate students) have been trained to use the VOS. In 2003, the VOS team developed a training CD that accompanies a training manual developed by Dr. Alene Harris. Before becoming a certified trainer, new VOS observers must code several videotaped vignettes that have been coded previously by trained observers and must achieve an overall inter-rater reliability score of 85 percent or higher across these vignettes. When new observers joined the research team, inter-rater reliability was calculated again across all observers. If reliability was less than 85 percent, all observers discussed the coding system and practiced using classroom vignettes. When reliability of 85 percent or greater was achieved, observers resumed classroom observations.

Within a semester, observed courses were selected and classified as either lecture-based or HPL-oriented. Observation dates were selected randomly throughout the semester. Depending upon the number of observers available per semester, each trained observer conducted a minimum of six observations per course (Harris and Cox, 2003).

Collecting data with the VOS requires that an observer sit in a classroom for an entire class period, start coding at the beginning of class, and stop coding when class is dismissed. The first three parts of the VOS (Classroom Interaction Observation, Student Engagement Observation, and Narrative Notes, respectively) record data in a cyclic pattern using a keyboard and a hand-held Personal Data Assistant (Figure 1). The CIO records data for three consecutive minutes, the SEO collects data for approximately thirty to sixty seconds, and the NNs record typewritten notes between one and two minutes. At the end of a class period, GRs are taken once. This data is then transferred from the handheld Personal Data Assistant to a VaNTH-designed data management program (Norris, Harris, and Washington, 2004).

C. The Classroom Interaction Observation (CIO) Portion of the VOS

Of the four components of the VOS, the Classroom Observation Interaction portion is the only portion that explicitly records faculty-student interactions, in real-time, within classes, using the four dimensions of the HPL framework. For this reason, the CIO is the primary focus of this research. Each CIO coding session is three minutes. As such, VOS observers record approximately thirty to forty-five code strings at the speed of speech during a typical

class session. These interactions are grouped into code strings of *who* – *to whom* – *what* – *how* – *media* (Figure 2) (Harris and Cox, 2003).

Who and *to-whom* categories note who is initiating or responding to in-class interactions. Interactions within both categories may occur among the following: a professor or instructor (P), all students in the class (E), one student (F), the same student as the previous interaction (S), a small group of students representing more than one but not over half the class population (g), a large group of students representing half to all but one student in the class (G), a visitor (V), or media (M).

The *what* category describes 12 types of in-class interactions that may occur during the CIO cycle. These interactions identify the presence of questions, responses, acknowledgements and/or praise, guides, corrections, or professor-initiated student monitoring. More specifically, the *what* categories note the following: the initiation of a lower-level fact-based question (1), the initiation of a higher order question (2), the response to a question (3), in-class instruction (4), social comments (5), activity-related comments not directly related to academic content (6), acknowledgements or praises by the professor (7), a guide by the professor (8), correction by the professor (9), no response to a question asked by the professor (0), active monitoring such that the professor walks among students during in-class activities (A), and passive monitoring such that the professor is standing at the front of the room and is watching students during in-class activities (P).

The content of the *how* category within the VOS differs from CIO portions of other instruments in its identification of present and absent HPL framework lenses along with classroom organization/management activities. More specifically, in the VOS, observers record activities using the lenses of the HPL framework—knowledge-centered (K), learner-centered (L), assessment-centered (A), and community-centered (C). Recognizing that not all class activities relate to classroom instruction, an additional category of organization (O) has been added to the *how* category. Of the *how* category components, VOS creators made only the knowledge-centered and organization codes mutually exclusive. Other combinations of the four HPL dimensions can co-occur in any given observation window.

To understand additional information about the types of media that an instructor is using during an observed class session, a *media* category was created. The seven types of media noted within the CIO are the board (B), the overhead projector (O), computer (C), simulation (S), demonstration (D), video (V), and a personal response system (R). Observers may also note the absence of media (N). All media categories are mutually exclusive.

Figure 1. Observation cycle for the VaNTH Observation System.

Who	To Whom	What	How	Media
Professor	Professor	1 factual question	Knowledge-centered	Board
Everyone	Everyone	2 higher order question	Learner-centered	Overhead
First student	First student	3 response	Assessment- centered	Computer
Same student	Same student	4 instruction	Community-centered	Simulation
Small group	Small group	5 social comment	Class Organization	Demonstration
Large Group	Large Group	6 activity-related comment		Video
Media	Media	7 acknowledge or praise		Response system
Visitor	Visitor	8 guide		None
		9 correction		
		0 no response		
		A active monitoring		
		P passive Monitoring		

Figure 2. VaNTH Observation System Classroom Interaction Observation (CIO) codes (Harris and Cox, 2003).

For example, if a professor asks a student a higher order question about a diagram displayed on the board, the corresponding CIO code string would be “P-F-2-K/L/A-B” such that “P” represents the professor who is initiating the question (*who*), “F” represents the student to whom the professor is asking the question (*to whom*), and “2” represents the higher order question that was asked (*what*). HPL dimensions represented are knowledge-centered (K), learner-centered (L), and assessment-centered (A) (*how*). The use of the board is represented by “B” (*media*). Additional code string examples are presented in section V.

IV. PRIOR ANALYSES OF THE “HOW PEOPLE LEARN” FRAMEWORK USING THE VANTH OBSERVATION SYSTEM

A. Reliability

Every semester since fall 2000, two to three observers have collected CIO data within a sample of classrooms and have compared coding patterns across these courses. Using the CIO *how* category as a measure, comparisons across observers for the sample of observations reported an overall inter-rater reliability of 85 percent or higher across observers during each semester that the VOS has been used (VaNTH, 2002; Cox, 2005 and 2006). Field-based reliability tests were also conducted throughout the semester. Brief descriptions of the prior studies along with results from these studies are listed below.

B. Analysis of CIO Data Using the Four Lenses of the HPL Framework

Prior to the current study, CIO data were analyzed using only the codes associated with the *how* portion of the CIO (i.e., knowledge-centered, learner-centered, assessment-centered, community-centered, and organization) (Figure 2). Specifically, to obtain an HPL instructional score, the percentages of CIO observation cycles that were coded as knowledge-, learner-, assessment-, and community-centeredness were added together to derive a cumulative index of HPL-based pedagogical practices for each course (across 4–9 observations per course). Using data from 182 observations within 28

bioengineering courses at Vanderbilt University, the cumulative percentage of HPL-oriented pedagogy for both traditional and nontraditional bioengineering courses is shown in Figure 3 (Cox, 2005).

Not surprising, knowledge-centered instruction dominated both traditional and HPL-based courses (81–85 percent of observation periods). Assessment-centered pedagogy was present in 8 to 29 percent of the observations. Both learner- and community-centered pedagogy were less prevalent (5–22 percent and 2–12 percent, respectively). As shown in Figure 3, the HPL-oriented courses showed higher cumulative levels of HPL-based pedagogy compared to courses organized around traditional pedagogical practices.

This method of indexing HPL-oriented instruction has its limitations. First, it displays individual percentages of knowledge-, learner-, assessment-, and community-centeredness that equal more than 100 percent when summed across the four dimensions. Without benchmarks indicating the optimal percent of each dimension needed to enhance classroom environments, comparisons of effective teaching across various types of classroom settings proves difficult. Second, the current reporting of individual HPL dimensions does not represent the interdependencies of the four HPL framework dimensions. By just noting individual HPL dimensions, other aspects of classroom instruction (e.g., group work, higher order questioning, and guidance by the professor) are not reported in the analysis of data. Finally, in practice, coders did not distinguish knowledge-centeredness as defined by HPL framework authors from the routine transmittal of information. As such, every activity that was not classroom organization was coded as “knowledge-centered” (Cox, 2005).

C. Content Validity Study

Because of the limitations found in indexing HPL-oriented instruction, the authors examined the extent to which eleven content experts familiar with the HPL framework agreed with the current classifications of the four dimensions of the HPL framework as defined within the VOS training manual. Across 20 classroom vignettes, the percent agreement between experts’ ratings and the VOS manual’s operationalization of the HPL framework dimensions was examined. The agreement across observers for individual HPL dimensions was less than 80 percent, and the agreement for

Figure 3. Comparisons of traditional and HPL-oriented classes adding individual HPL dimensions to create an index.

combinations of the dimensions was even lower (Cox, 2005). This means that rating the four dimensions independently does not appear to capture the HPL experience reliably. The low levels of agreement across observers within this study justify the creation of a new HPL index or assessment method that not only looks at one part of a CIO category, the *how* category (i.e., knowledge-centeredness, learner-centeredness, assessment-centeredness, community-centeredness, and organization), but uses an entire CIO code string category to determine the amount of HPL-oriented instruction that is present within a class session.

V. DEVELOPMENT OF THE HPL INDEX FROM CLASSROOM INTERACTION CODE STRINGS

A. Development of a New HPL Index

Because of the limitations of the existing cumulative index, a new index for assessing the presence of HPL-oriented classroom activities was developed that incorporates more information from the CIO. Specifically, this index of HPL uses specific CIO code strings that are classified as representing HPL-based or traditional instruction, along with classroom organization or management activities. In this way all possible code strings (across all HPL, traditional pedagogy, as well as classroom organization) sum to 100 percent of the observed class time. Unlike the prior assessment method, which categorizes the amount of HPL-oriented pedagogy within a class using only the *how* category within the CIO, the new HPL index reports the amount of HPL-oriented instruction within a class using code strings representing all five CIO categories (i.e., *who* – *to whom* – *what* – *how* – *media*). Despite this added complexity in depicting pedagogy, the new integrated index actually simplifies the interpretation of the data, allowing for a single index from which to compare pedagogical styles in traditional and nontraditional engineering classrooms. More importantly, it better represents the interplay of the four HPL dimensions and the integration of other HPL-oriented behaviors such as higher order questioning and group work.

B. Translation of CIO Code Strings into an Overall HPL Index and Subcategories

Given that there are five categories within the CIO component of the VOS that comprise one code string and various interactions among the categories, permutations of these categories could produce at least 24,500 potential code string combinations. However, most of the combinations are not meaningful or feasible. To create a workable index, members of the VOS assessment team classified possible CIO code string combinations (i.e., *who* – *to whom* – *what* – *how* – *media*) as representations of either HPL-oriented instruction, traditional instruction, or classroom organization. The end product

of this review and assessment was the specification of 135 selected code strings. These are present in the appendix.

Code strings associated with HPL-oriented instruction and traditional instruction were further grouped into eleven and seven subcategories, respectively (Table 1). When combined with code strings representing classroom organization, the sum of all code strings equals 100 percent of recorded activities in each classroom observation period. All courses were observed multiple times (4–15) per semester.

C. How People Learn (HPL) Pedagogical Subcategories

Descriptions of the 11 HPL pedagogical subcategories within the HPL Index, and the reasons for these subcategories' classifications as HPL are described below. Refer to Figure 2 for the CIO code string categorizations (in the form of *who* – *to whom* – *what* – *how* – *media* categories). Note that although a class may be designated as lecture-based, it can contain the HPL-oriented elements described below.

- *Higher-order questioning by the instructor and higher-order questioning by the class* represent open-ended questions that are asked within the observed class. These questions are more thought-provoking than fact-based, yes-or-no questions. Higher order questioning is a tenet of the HPL framework. Example #1: *Higher-order questioning by the instructor* occurs when an instructor asks the entire class a higher order question that incorporates both knowledge-centered and assessment-centered dimensions as the professor uses the board (CIO Code String: P-E-2-K/A-B). Example #2: *Higher-order questioning by the class* occurs when an initial student asks an instructor a higher-order question about the same academic content that is written on the board (CIO Code String: F-P-2-K/A-B).
- *Guidance by the instructor* occurs when an instructor guides students to correct answers that they are trying solve within an observed class. Professor guidance is a tenet of the HPL framework, since it allows students to refine their thinking about academic content. Example: An instructor gives the entire class a hint about a problem solution when no one responds to a knowledge-centered, learner-centered, and assessment-centered question that is displayed on an overhead (CIO Code String: P-E-8-K/L/A-O).
- *HPL-oriented lecture* occurs when an instructor lectures using multiple HPL dimensions (knowledge-, learner-, assessment-, and community-centered). Example: An instructor uses PowerPoint to lecture to an entire class of students about academic content that incorporates knowledge-centered, learner-centered, and community-centered dimensions (CIO Code String: P-E-4-K/L/C-C).

HPL-Oriented Instruction Subcategories	Traditional Instruction Subcategories
<ul style="list-style-type: none"> • Higher-order questioning by the instructor • Higher-order questioning by the class • Guidance by the instructor • HPL-oriented lecture • HPL-oriented comments • HPL-oriented praise • HPL-oriented monitoring • HPL-oriented question and response • HPL-oriented correction • Use of a Personal Response System • HPL no response 	<ul style="list-style-type: none"> • Instruction by media • Traditional question and response • Traditional lecture • Traditional comments • No response in a traditional manner • Traditional praise • Traditional correction

Table 1. Subcategories of HPL-oriented instruction and traditional instruction.

- *HPL-oriented comments* occur when an instructor or students make in-class comments about academic content using multiple HPL dimensions. Example: An instructor uses no media as she makes a comment that is tangentially related to academic content that incorporates knowledge-centered and learner-centered dimensions (CIO Code String: P-E-6-K/L-N).
- *HPL-oriented praise* occurs when an instructor praises students after they respond to an HPL-oriented question or HPL-oriented comment. Example: An instructor compliments a small group of students who have developed a solution to a higher-order question asked by the instructor earlier in the class period (CIO Code String: P-g-7-K/L/A/C-N).
- *HPL-oriented monitoring* occurs when an instructor observes students or walks among students as they work on in-class activities that represent multiple HPL dimensions. Much of this monitoring occurs when students are working in groups. Example: An instructor stands at the front a classroom and watches students as they work on seatwork that requires them to develop a solution to a problem that incorporates knowledge-centered, learner-centered, and assessment-centered dimensions (CIO Code String: P-E-11-K/L/A-N).
- *HPL-oriented questions and responses* are lower-level (yes or no) questions and responses to questions that represent multiple HPL dimensions. Example: An initial student in a class asks the instructor a question that incorporates knowledge-centered, assessment-centered, and community-centered dimensions (CIO Code String: F-P-1-K/A/C-N).
- *HPL-oriented correction* occurs when an instructor corrects students after they respond to an HPL-oriented question or HPL-oriented response. Example: An instructor solves a problem on the board after a student incorrectly answer a question that incorporates knowledge-centered, learner-centered, and assessment-centered dimensions (CIO Code String: P-S-9-K/L/A-B).
- *Use of a Personal Response System* occurs when an instructor uses a wireless response unit to obtain formative feedback from students. The wireless response unit used within VaNTH-observed classes is called a Personal Response System (PRS). Every interaction that occurs while a PRS is in use is placed in this subcategory, since the purpose for using the PRS is to make students' thinking visible about their

understanding of academic content. Example: A student uses her PRS unit to reply to a higher-order question asked by an instructor (CIO Code String: F-P-3-K/L/A-R).

D. Traditional Pedagogical Subcategories

Using the five CIO categories within the VOS as a guide, all possible traditional code strings can be classified into one of seven traditional pedagogical subcategories. Relative to the HPL dimensions, traditional instruction is characterized by in-class instructional behaviors that are typically noted within classrooms such that there is limited integration of all HPL dimensions within instruction. Specifically, this involves the use of the knowledge-centered dimension (since VOS coders assigned this code to every activity that was not classroom organization) or the use of only the knowledge-centered and assessment-centered dimensions. General descriptions of each subcategory and reasons for these subcategories' classifications as traditional are described below. Note that although a class may be designated as HPL-oriented, it can contain the traditional elements described below.

- *Instruction by media* represents media-led classroom instruction (e.g., video) that represents the knowledge-centered dimension. Example: A video presents lecture material to students (CIO Code String: M-E-4-K-V).
- *Traditional question and response* are lower-level (yes or no) questions and responses that represent only the knowledge-centered and assessment-centered dimensions. Example: An instructor replies to a student's question that incorporates both knowledge-centered and assessment-centered dimensions (CIO Code String: P-S-3-K/A-N).
- *Traditional lecture* occurs when an instructor lectures using only the knowledge-centered dimension or the knowledge-centered and assessment-centered dimensions. Example: An instructor writes mathematical equations on the board (CIO Code String: P-E-4-K-B).
- *Traditional comments* occur when an instructor or students make in-class comments about academic content using only the knowledge-centered dimension or knowledge-centered and assessment-centered dimensions. Example: An instructor presents the class with a comment about academic content (CIO Code String: P-E-6-K-N).
- *No response in a traditional manner* relates to students not responding to a professor's question that uses only the

knowledge-centered dimension or knowledge-centered and assessment-centered dimensions. Example: No students within a class reply to the instructor's lower-level question that incorporates knowledge-centered and assessment-centered dimensions (CIO Code String: E-P-10-K/A-N).

- *Traditional praise* occurs when an instructor praises students after they respond to a lower-level "yes" or "no" question or to a question that does not represent the integration of multiple HPL dimensions. Example: An instructor praises a student after he answers a lower-level question that integrates knowledge-centered and assessment-centered dimensions (CIO Code String: P-S-7-K/A-N).
- *Traditional correction* occurs when a professor corrects students after they respond to a question that uses only the knowledge-centered dimension or knowledge-centered and assessment-centered dimensions. Example: An instructor corrects a student who incorrectly answers a lower-level question that incorporates knowledge-centered and assessment-centered dimensions (CIO Code String: P-F-9-K/A-N).

VI. METHODS

A. Research Sample

The analyses using the new HPL Index are based on 182 classroom observations in 28 bioengineering courses at Vanderbilt University. Seventeen of these courses were designated as experimental (primarily implemented HPL-oriented pedagogical practices) classes, and eleven were designated as control (primarily used traditional, or nonHPL, engineering practices) classes. Although faculty teaching the HPL-oriented courses received no formal pedagogical training within their classes, they helped to design and to implement curricula that incorporated elements of the HPL framework within their courses. Indirectly, these faculty gained some understanding about the HPL framework lenses. Traditional faculty, on the other hand, were given no HPL-oriented materials to use in their classrooms and were informed to teach their courses in their usual manner. Both groups of faculty gave VOS observers permission to observe their classrooms at various times throughout each semester. Data were collected by trained VOS observers during five academic semesters between spring 2002 and spring 2004. Some of the observers were aware of the designation of courses as either traditional or HPL-oriented, and some of the observers were not. Table 2 lists the courses observed each semester along with the number of classes observed within each course.

B. Data Analysis

Based upon VaNTH ERC researchers' designations of the 28 courses within the sample as either HPL or nonHPL, the first author grouped the sample of courses accordingly. Microsoft Excel files containing CIO data for each class session were created, and incomplete rows and columns of data were removed from each data file. Excel files for each observed session were imported into SPSS, and the SPSS syntax, created by the first author, representing HPL and traditional subcategories within the HPL Index was run. (A copy of the SPSS syntax for constructing the index is available from either author.) From here, the frequencies of all CIO code strings within each subcategory were reported. All frequencies representing

the seven traditional subcategories were summed to create a traditional pedagogical instruction percentage, and all frequencies representing the 11 HPL subcategories were summed to create an HPL pedagogical instruction percentage. Individual class profiles of average percentages of traditional and HPL instruction and classroom organization were then created.

VII. RESULTS

Using the HPL Index to categorize all 36,188 code strings across 28 observed courses, independent sample *t*-tests were run within SPSS. The *t*-test was used to compare the HPL Subcategory Sum and the Traditional Subcategory Sum using HPL-oriented or traditional course classifications as a grouping variable. Mean occurrences and *t*-test results for both instructional sums are displayed in Table 3. A Levene's test for equality of variances was run. At a family $p < 0.05$, a Bonferroni correction was used to calculate an individual $p < 0.025$, since two independent hypotheses on the same data were tested. Results reveal statistically significant differences between HPL-oriented and traditional courses for both the HPL Subcategory Sum and the Traditional Subcategory Sum. Compared to lecture-based courses, HPL-oriented courses reported a higher HPL Subcategory Sum ($\bar{x} = 17.81$ and $\bar{x} = 12.66$, $p < 0.025$), and compared to HPL-based courses, lecture-based courses reported a higher Traditional Subcategory Sum ($\bar{x} = 70.63$ and $\bar{x} = 65.38$, $p < 0.025$) (Table 3).

Since the HPL Subcategory and Traditional Subcategory Sums were found to be statistically significant for both HPL-oriented and traditional courses, additional independent *t*-tests were run on the 18 subcategories (Table 4). A Levene's test for equality of variances was run. At a family $p < 0.05$, a Bonferroni correction was used to calculate an individual $p < 0.003$, since 18 independent hypotheses on the same data were tested. Five HPL subcategory items and four traditional subcategory items were found to be statistically significant. Compared to traditional, lecture-based classes, HPL-designated classes reported higher occurrences for the following five HPL subcategories: guidance by the instructor ($\bar{x} = 0.99$ and $\bar{x} = 0.69$, $p < 0.003$), comments ($\bar{x} = 2.94$ and $\bar{x} = 1.74$, $p < 0.003$), praise ($\bar{x} = 1.06$ and $\bar{x} = 0.58$, $p < 0.003$), monitoring ($\bar{x} = 2.32$ and $\bar{x} = 0.69$, $p < 0.003$), and question and response ($\bar{x} = 3.56$ and $\bar{x} = 1.65$, $p < 0.003$). Compared to HPL-designated classes, lecture-based classes reported higher occurrences for the following three statistically significant traditional subcategory items: instruction by media ($\bar{x} = 0.99$ and $\bar{x} = 0.69$, $p < 0.003$), lecture ($\bar{x} = 0.99$ and $\bar{x} = 0.69$, $p < 0.003$), and no response ($\bar{x} = 0.99$ and $\bar{x} = 0.69$, $p < 0.003$). The fourth statistically significant traditional subcategory item, praise, had a higher occurrence in HPL-oriented courses than within traditional courses ($\bar{x} = 0.99$ and $\bar{x} = 0.69$, $p < 0.003$).

VIII. DISCUSSION

The HPL Index described in this paper provides information about the frequencies (percentages of observed instances) in which each of the HPL and traditional subcategories occur within lecture-based and HPL-oriented courses. Although subcategory trends are similar within both HPL-oriented and traditional courses, the

Spring 2002	Fall 2002	Spring 2003	Fall 2003	Spring 2004
HPL Courses	HPL Courses	HPL Courses	HPL Courses	HPL Courses
Biomedical Optics (8,M)	Biomedical Optics (4,M)	Biomechanics (6,M)	Freshman Seminar-Electrocardiogram (2,S)	Bioethics (7,M)
Biotechnology (8,S)	Freshman Seminar-Electrocardiogram (5,S)	Biopharmaceuticals (10,M)	Biomechanics (4,M)	Biotechnology (13,S)
Biomechanics (5,M)	Freshman Seminar-Optics (4,S)		Transport (7,M)	Biomedical Optics (8,M)
	Systems Physiology (9,L)			Biomechanics (8,M)
				Medical Imaging (5,M)
NonHPL Courses	NonHPL Courses	NonHPL Courses	NonHPL Courses	NonHPL Courses
	Systems Physiology (8,M)	Biotechnology (5,S)	Senior Design (7,L)	Bioinstrumentation (5,M)
Biopharmaceuticals (7,M)	Freshman Seminar-Electrocardiogram (3,S)	Systems Physiology (7,M)	Freshman Seminar-Electrocardiogram (2,S)	Bioinstrumentation (10,M)
	Biomechanics (10,M)		Transport (5,M)	

*Small (S) = less than 25 students; Medium (M) = 25-50 students; Large (L) = greater than 50 students

Table 2. Biomedical engineering courses and the number and sizes of classes^a observed using the VaNTH Observation System.

Category	Frequencies/ Percentages across Courses	HPL-Oriented Courses (N = 17)	Traditional Courses (N = 11)	p value
HPL Subcategory Sum	5790 (16.00%)	4178 (17.81%)	1612 (12.66%)	0.000***
Traditional Subcategory Sum	24328 (67.23%)	15335 (65.38%)	8993 (70.63%)	0.000***
Organization	6070 (16.76%)	3942 (16.81%)	2128 (16.71%)	
Total	36188	23455	12733	

Family $p < 0.05$

Corrected individual $p < 0.025$

Table 3. Distribution of HPL and traditional categories of instructional practices and organization.

Index confirms that HPL courses promote supportive classroom environments so that instructors are more likely to praise their students when they answer questions correctly and are more likely to guide their students to correct answers instead of automatically correcting their answers or asking another student for a correct answer. In addition, group work (in the form of monitoring) is an occurrence within HPL courses that allows students to interact with one another during class time.

Results from the Index also show that although lecture is more prevalent within traditional courses than within HPL courses, it is the most frequently used pedagogical practice within both course types. Although faculty may think that they are introducing innovative curricula and pedagogy into their courses, without formal training in pedagogical innovations and strategies, the majority of engineering faculty members rely upon lecture-based instruction as their primary method of instruction within engineering courses (Rugarcia et al., 2000). This is not surprising, since many engineering faculty receive little or no teaching experience within their graduate programs prior to accepting university positions (Ruscio, 1987; Boice,

1991; McDermott, 1990; Reinarz, 1991; Shea and Taylor, 1990; Stice et al., 2000; Seymour et al., 2005). With the added service and research responsibilities, by the time many engineering faculty enter the professoriate, they have little or no time to develop into "expert teachers"—those faculty who excel in their content areas, possess pedagogical knowledge, and understand the integration of their disciplinary areas and pedagogy (Fink, Ambrose, and Wheeler, 2005).

Future research is needed to provide details about both the frequencies and the sequence, or ordering, of code strings analyzed using the HPL Index. In this way, researchers may note whether there are instructional patterns (e.g., higher order questioning followed by monitoring) that positively impact student outcomes or if there are overall course profiles that promote desired student outcomes within a variety of learning environments (e.g., laboratories, large lecture courses). Additional research can explore whether there are certain levels of HPL-oriented instruction that connect to decreases or increases in student outcomes and whether instructors' pedagogical patterns change over time given the feedback they receive from HPL

Category	Sub-category	Frequencies/ Percentages across Courses	HPL- Oriented Courses (N = 17)	Traditional Courses (N = 11)	p value
HPL	Higher-order questioning by the instructor	621 (1.72%)	413 (1.76%)	208 (1.63%)	0.373
	Higher-order questioning by class member(s)	317 (0.88%)	222 (0.95%)	95 (0.75%)	0.043
	Guidance by the instructor	320 (0.88%)	232 (0.99%)	88 (0.69%)	0.002***
	Lecture	1051 (2.90%)	651 (2.78%)	400 (3.14%)	0.052
	Comment(s)	912 (2.52%)	690 (2.94%)	222 (1.74%)	0.000***
	Praise	323 (0.89%)	249 (1.06%)	74 (0.58%)	0.000***
	Monitoring	632 (1.75%)	544 (2.32%)	88 (0.69%)	0.000***
	Question and response	1046 (2.89%)	836 (3.56%)	210 (1.65%)	0.000***
	Correction	11 (<0.1%)	6 (<0.1%)	5 (<0.1%)	0.476
	Use of Personal Response System	518 (1.43%)	311 (1.33%)	207 (1.63%)	0.026
	No response	39 (0.11%)	24 (0.10%)	15 (0.12%)	0.668
Traditional	Instruction by media	46 (0.13%)	18 (<0.1%)	28 (0.22%)	0.002***
	Question and response	2146 (5.93%)	1372 (5.85%)	774 (6.08%)	0.381
	Lecture	18083 (49.97%)	11354 (48.41%)	6729 (52.85%)	0.000***
	Comment(s)	3365 (9.30%)	2136 (9.11%)	1229 (9.65%)	0.091
	Praise	471 (1.30%)	340 (1.45%)	131 (1.03%)	0.000***
	Correction	56 (0.15%)	33 (0.14%)	23 (0.18%)	0.356
	No response	161 (0.44%)	82 (0.35%)	79 (0.62%)	0.001***

Family $p < 0.05$

Corrected individual $p < 0.003$

Table 4. Distribution of HPL and traditional sub-categories of instructional practices.

Index data. In addition, studies may explore the role of lecture within innovative and traditional courses and the role that class size plays in the implementation of HPL-based practices.

Because of these limitations for faculty, results obtained from the HPL Index may be translated into deliverables that might give graduate teaching assistants (GTAs) within engineering disci-

plines formative feedback on their teaching so that they can revise their pedagogical practices prior to entering the professoriate and can identify and mitigate potential problems and hindrances to student learning within their courses. Often, GTAs receive little to no formal pedagogical training (White, 1993; Bomotti, 1994; Cahn, 1994; Rushin et al., 1997; Shannon, Twale, and Moore,

1998; Golde and Dore, 2001), obtain limited information within their GTA training sessions (White, 1993; Tang and Sandell, 2000), and receive no pedagogical mentoring by faculty teaching courses in which they are GTAs (Baiocco, 1998).

Finally, by examining differences within and across innovative and conventional engineering courses, this study emphasizes a need for faculty and graduate student development programs targeted at improving pedagogy within engineering classrooms and laboratories. More specifically, higher education institutions and university teaching centers may translate empirical findings from schemes such as the HPL Index into deliverables that will inform engineering faculty and engineering doctoral students pursuing careers in academia about effective classroom practices. Using the results from the HPL Index could introduce engineering GTAs to effective pedagogy and could provide them with tools that they can use beyond single semester GTA assignments.

IX. LIMITATIONS

Despite the potential merit of this work, the authors acknowledge its limitations. First, because of the intricacy and complexity of the new coding scheme, new observers may have to undergo intense training to achieve inter-rater reliability and to interpret the findings for each class session. If the intricacy of this proposed system is a concern, the authors recommend that observers consider using other validated tools that embrace the principles of the HPL framework or consider revising the CIO and the HPL Index for their research purposes. Second, since the HPL Index was created using configurations of “strings” of codes that represent a global class focus, it records information about subgroups but does not detail information about the number of these interactions and the content of the interactions. For this reason, certain characteristics of the HPL framework (e.g., small group interactions) are not explicitly reported within the classroom observation results. However, these details can be extracted from the original HPL Index code strings (see Appendix). Future subcategories might reflect such interactions so that faculty can understand the frequency in which they engage in classroom activities such as group work.

Possible observer bias might be an issue of concern. To examine the possibility of observer bias, the HPL sums and organizational sums were calculated for two observer groups- (1) observers who were aware of course designations as traditional or HPL-oriented and (2) observers who were not aware of these course designations. There were no obvious trends across both groups. HPL sums for both groups were 16.3 percent and 16.5 percent. Observers who were aware of course designations reported more time devoted to organization (17.8 percent) than observers who were not aware of course designations (12.4 percent). Given the small sample sizes, the differences in the organization sum are not significant.

X. FUTURE RESEARCH

In the future, lessons learned via the creation of the HPL Index will be used to inform the development of a formative assessment tool within a one-credit hour seminar for graduate teaching assistants (GTAs) who have significant responsibilities for undergraduate student learning (NSF #0632879). Within the course, GTAs will

- Interpret the pedagogical feedback that they receive from the HPL Index and the extent to which they are implementing HPL-based pedagogical practices into their laboratory teaching.
- Develop their pedagogical expertise through an introduction to HPL-based teaching methods and strategies that can be incorporated into their engineering laboratory courses.
- Build a support network or community with other engineering GTAs and engineering faculty through engagement in open dialogues about teaching and curricular design for undergraduate engineering courses.
- Explore the impacts of their teaching and curricular innovations on undergraduate student learning and retention.

Researchers will evaluate whether the pedagogical perceptions of GTAs enrolled within the graduate course differ significantly from the pedagogical perceptions of GTAs who are not enrolled within the graduate course. In this way, the impact of formative assessment for GTAs may be evaluated.

Since the VOS has been used exclusively within classroom settings to observe one instructor, another extension of the current research involves the piloting and possible revision of the CIO portion of the VOS for engineering laboratory environments (NSF # 0648380). Some questions that might be answered via this research include the following:

- How does instruction differ between traditional classroom environments and laboratory environments?
- Are the 18 HPL Index subcategories still present within observed laboratories? Should additional subcategories be added? What are the frequencies and sequences of these subcategories within these laboratories?
- Can the CIO and the HPL Index be used effectively within laboratory environments? What elements are and are not applicable and generalizable?

XI. CONCLUSIONS

The criterion contrast study of the HPL Index supports the studies described in Section IV of this paper. More specifically, the criterion contrast of the HPL Index is confirmed since results from the Index distinguish pedagogy between courses based upon HPL principles and courses based on traditional, non-HPL pedagogy. HPL Index results demonstrate statistically significant differences between HPL and traditional courses for nine subcategories developed within the Index. Surprising, however, are the high uses of traditional lecture (48.41 percent and 52.85 percent) and the low occurrences of the HPL subcategories within both types of courses (17.81 percent and 12.66 percent).

Now that the HPL Index can provide a way of displaying the presence of the four HPL lenses via 100 percent of observed class time, future research might explore whether there should be a “gold standard” of HPL instruction within courses, how levels of HPL instruction vary across different learning environments (e.g., engineering laboratories, K-12 classrooms), and how the presence of the HPL Index subcategories relate to student learning within STEM courses. In addition, research might explore ways to simplify the Index so that observers can be trained more easily or so that results can be translated into profiles that might be used in conjunction with other methods of teacher evaluation, such as student ratings

and course material evaluation, to provide a more comprehensive picture about how faculty convey information to students within courses over time.

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APPENDIX

HPL- Categories	Who	To whom	What	How	Media
	Professor	Professor	1 fact question	Knowledge-centered	Board
	Everyone	Everyone	2 higher order question	Learner-centered	Overhead
	First student	First student	3 response	Assessment-centered	Computer
	Same student	Same student	4 instruction	Community-centered	Simulation
	Small group	Small group	5 social comment	Organization	Demonstration
	Large Group	Large Group	6 activity-related comment	Behavior	Video
	Media	Media	7 acknowledge or praise		Response system
	Visitor	Visitor	8 guide		None
			9 correction		
			0 no response		
			A active monitoring		
			P passive monitoring		

HPL INDEX SUBCATEGORIES

Index Subcategory	CIO Who Category	CIO To Whom Category	CIO What Category	CIO How Category	CIO Media Category	Percent of Observed Instances
HPL Higher order questioning by the professor	P or V	E	2	Any code excluding O	Any media code excluding R	513 (1.43%)
	P or V	F	2	Any code excluding O	Any media code excluding R	36 (<0.1%)
	P or V	S	2	Any code excluding O	Any media code excluding R	43 (0.12%)
	P or V	g	2	Any code excluding O	Any media code excluding R	28 (<0.1%)
	P or V	G	2	Any code excluding O	Any media code excluding R	0
	V	P	2	Any code excluding O	Any media code excluding R	1 (<0.1%)
HPL Higher order questioning by the class	E	P or V	2	Any code excluding O	Any media code excluding R	0
	F	P or V	2	Any code excluding O	Any media code excluding R	272 (0.76%)
	S	P or V	2	Any code excluding O	Any media code excluding R	38 (0.11%)
	g	P or V	2	Any code excluding O	Any media code excluding R	7 (<0.1%)
	G	P or V	2	Any code excluding O	Any media code excluding R	0
HPL Guidance by the professor	P or V	E	8	Any code excluding O	Any media code excluding R	215 (0.59%)
	P or V	F	8	Any code excluding O	Any media code excluding R	5 (<0.1%)
	P or V	S	8	Any code excluding O	Any media code excluding R	85 (0.24%)
	P or V	g	8	Any code excluding O	Any media code excluding R	15 (<0.1%)
PRS Use (HPL)	Any code	Any code	Any code	Any code excluding O	Any media code excluding R	518 (1.44%)
HPL Question and Response	P or V	g	1 or 3	Any code excluding O	Any media code excluding R	59 (0.16%)
	P or V	G	1 or 3	Any code excluding O	Any media code excluding R	0
	P or V	E	1 or 3	KAL, KAC, or KLAC	Any media code excluding R	150 (0.42%)
	P or V	F	1 or 3	KAL, KAC, or KLAC	Any media code excluding R	14 (<0.1%)
	P or V	S	1 or 3	KAL, KAC, or KLAC	Any media code excluding R	110 (0.31%)
	E	P or V	1 or 3	KAL, KAC, or KLAC	Any media code excluding R	52 (0.14%)
	E	F	1 or 3	Any code excluding O	Any media code excluding R	0
	E	S	1 or 3	Any code excluding O	Any media code excluding R	0

Index Subcategory	CIO Who Category	CIO To Whom Category	CIO What Category	CIO How Category	CIO Media Category	Percent of Observed Instances
HPL Question and Response (continued)	E	G or g	1 or 3	Any code excluding O	Any media code excluding R	0
	g or G	P	1 or 3	Any code excluding O	Any media code excluding R	325 (0.90%)
	g or G	E	1 or 3	Any code excluding O	Any media code excluding R	1 (<0.1%)
	g or G	F	1 or 3	Any code excluding O	Any media code excluding R	0
	g or G	S	1 or 3	Any code excluding O	Any media code excluding R	2 (<0.1%)
	g	G	1 or 3	Any code excluding O	Any media code excluding R	0
	G	g	1 or 3	Any code excluding O	Any media code excluding R	0
	F	P or V	1 or 3	KAL, KAC, or KLAC	Any media code excluding R	253 (0.70%)
	F	S	1 or 3	Any code excluding O	Any media code excluding R	1 (<0.1%)
	F	G or g	1 or 3	Any code excluding O	Any media code excluding R	2 (<0.1%)
	S	E, g, G, or F	1 or 3	Any code excluding O	Any media code excluding R	0
	S	P or V	1 or 3	KAL, KAC, or KLAC	Any media code excluding R	75 (0.21%)
	P	V	1 or 3	KAL, KAC, or KLAC	Any media code excluding R	1 (<0.1%)
	P or V	g or G	4	Any code excluding O	Any media code excluding R	108 (0.30%)
	P or V	E	4	KL, KC, KLC	Any media code excluding R	915 (2.53%)
HPL Lecture	P or V	F	4	KL, KC, KLC	Any media code excluding R	1 (<0.1%)
	P or V	S	4	KL, KC, KLC	Any media code excluding R	6 (<0.1%)
	F	E	4	Any code excluding O	Any media code excluding R	0
	S	E	4	Any code excluding O	Any media code excluding R	19 (<0.1%)
	g	P or V	4	Any code excluding O	Any media code excluding R	1 (<0.1%)
	g	E	4	Any code excluding O	Any media code excluding R	1 (<0.1%)
	G	P or V	4	Any code excluding O	Any media code excluding R	0

Index Subcategory	CIO Who Category	CIO To Whom Category	CIO What Category	CIO How Category	CIO Media Category	Percent of Observed Instances
HPL Monitoring	G	E	4	Any code excluding O	Any media code excluding R	0
	P or V	g or G	A or P	Any code excluding O	Any media code excluding R	410 (1.14%)
	P or V	E or F	A or P	KAL, KAC, KLAC	Any media code excluding R	222 (0.62%)
	P or V	g or G	9	Any code excluding O	Any media code excluding R	3 (<0.1%)
	P or V	E, F, S, or V	9	KAL, KAC,	Any media	8
	P	g	6	Any code excluding O	Any media code excluding R	114 (0.32%)
	P	G	6	Any code excluding O	Any media code excluding R	6 (<0.1%)
	g	P	6	Any code excluding O	Any media code excluding R	60 (0.17%)
	g	G	6	Any code excluding O	Any media code excluding R	0
	G	P or g	6	Any code excluding O	Any media code excluding R	0
	g	E	6	Any code excluding O	Any media code excluding R	24 (<0.1%)
	G	E	6	Any code excluding O	Any media code excluding R	0
	F	E	6	Any code excluding O	Any media code excluding R	4 (<0.1%)
	F	S	6	Any code excluding O	Any media code excluding R	4 (<0.1%)
	S	E	6	Any code excluding O	Any media code excluding R	174 (0.48%)
	S	F	6	Any code excluding O	Any media code excluding R	1 (<0.1%)
	P or V	E	6	KAL, KAC, KLAC	Any media code excluding R	48 (0.13%)
	P or V	F	6	KAL, KAC, KLAC	Any media code excluding R	18 (<0.1%)
	P or V	S	6	KAL, KAC, KLAC	Any media code excluding R	47 (0.13%)
	V	E, F, or S	6	KAL, KAC, KLAC	Any media code excluding R	0
	P or V	E	6	KL, KC, or KLC	Any media code excluding R	382 (1.05%)
	P or V	F	6	KL, KC, or KLC	Any media code excluding R	0
	P or V	S	6	KL, KC, or KLC	Any media code excluding R	0
	E	P	6	KAL, KAC, KLAC	Any media code excluding R	3 (<0.1%)

Index Subcategory	CIO Who Category	CIO To Whom Category	CIO What Category	CIO How Category	CIO Media Category	Percent of Observed Instances
HPL Comments (continued)	E	V	6	KAL, KAC, KLAC	Any media code excluding R	0
	F	P or V	6	KAL, KAC, KLAC	Any media code excluding R	0
	S	P	6	KAL, KAC, KLAC	Any media code excluding R	22 (<0.1%)
	E	P or V	6	KL, KC, or KLC	Any media code excluding R	0
	F	P or V	6	KL, KC, or KLC	Any media code excluding R	0
	S	P	6	KL, KC, or KLC	Any media code excluding R	5 (<0.1%)
	S	V	6	KL, KC, or KLC	Any media code excluding R	0
HPL No Response	V	P	6	KL, KC, or KLC	Any media code excluding R	0
	g	P or V	0	Any code excluding O	Any media code excluding R	0
	G	P or V	0	Any code excluding O	Any media code excluding R	1 (<0.1%)
	E	P or V	0	KAL, KAC, KLAC	Any media code excluding R	37 (0.10%)
	F	P or V	0	KAL, KAC, KLAC	Any media code excluding R	0
	S	P or V	0	KAL, KAC, KLAC	Any media code excluding R	1 (<0.1%)
	V	P	0	KAL, KAC, KLAC	Any media code excluding R	0
Instruction by Media (Traditional)	M	E	4 or 6	Any code excluding O	Any media code excluding R	46 (0.13%)
Traditional Lecture	P or V	E	4	K or KA	Any media code excluding R	18033 (49.65%)
	P or V	F	4	K or KA	Any media code excluding R	14 (<0.1%)
	P or V	S	4	K or KA	Any media code excluding R	36 (<0.1%)
Traditional Correction	P	E, F, S, or V	9	K or KA	Any media code excluding R	56 (0.16%)
	V	E, F, or S	9	K or KA	Any media code excluding R	0
Traditional Praise	P or V	E	7	K or KA	Any media code excluding R	30 (<0.1%)
	P or V	F	7	K or KA	Any media code excluding R	8 (<0.1%)
	P or V	S	7	K or KA	Any media code excluding R	433 (1.20%)
	P	V	7	K or KA	Any media code excluding R	0

Index Subcategory	CIO Who Category	CIO To Whom Category	CIO What Category	CIO How Category	CIO Media Category	Percent of Observed Instances
Traditional Question and Response	E	P or V	1	KA	Any media code excluding R	4 (<0.1%)
	E	P or V	3	KA	Any media code excluding R	59 (0.16%)
	F	P or V	1	KA	Any media code excluding R	264 (0.73%)
	F	P or V	3	KA	Any media code excluding R	505 (1.40%)
	S	P or V	1	KA	Any media code excluding R	49 (0.14%)
	S	P or V	3	KA	Any media code excluding R	158 (0.44%)
	P or V	E	1	KA	Any media code excluding R	483 (1.29%)
	P or V	E	3	KA	Any media code excluding R	32 (<0.1%)
	P or V	F	1	KA	Any media code excluding R	29 (<0.1%)
	P or V	F	3	KA	Any media code excluding R	6 (<0.1%)
	P or V	S	1	KA	Any media code excluding R	45 (0.13%)
	P or V	S	3	KA	Any media code excluding R	512 (1.42%)
	P or V	E	6	K	Any media code excluding R	2779 (7.72%)
	P or V	F	6	K	Any media code excluding R	19 (<0.1%)
	P or V	S	6	K	Any media code excluding R	87 (0.24%)
Traditional Comments	P	V	6	K	Any media code excluding R	14 (<0.1%)
	P or V	E	6	KA	Any media code excluding R	219 (0.61%)
	P or V	F	6	KA	Any media code excluding R	11 (<0.1%)
	P or V	S	6	KA	Any media code excluding R	32 (<0.1%)
	P	V	6	KA	Any media code excluding R	0
	E	P or V	6	K	Any media code excluding R	1 (<0.1%)
	F	P or V	6	K	Any media code excluding R	77 (0.21%)
	S	P or V	6	K	Any media code excluding R	88 (0.24%)
	V	P	6	KA	Any media code excluding R	0
	F	P or V	6	KA	Any media code excluding R	9 (<0.1%)
	V	P	6	K	Any media code excluding R	3 (<0.1%)
	E	P or V	6	KA	Any media code excluding R	0
	S	P or V	6	KA	Any media code excluding R	26 (<0.1%)
	V	P	6	KA	Any media code excluding R	0
Traditional Comments (cont.)						

Index Subcategory	CIO Who Category	CIO To Whom Category	CIO What Category	CIO How Category	CIO Media Category	Percent of Observed Instances
Traditional, No Response	E	P or V	0	KA	Any media code excluding R	148 (0.41%)
	F	P or V	0	KA	Any media code excluding R	5 (<0.1%)
	S	P or V	0	KA	Any media code excluding R	8 (<0.1%)
	V	P	0	KA	Any media code excluding R	0