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This chapter discusses the effectiveness of an HPL framework used in a laboratory-based, tissue-engineering module designed in part to improve students' written communication skills. It illustrates a successful implementation of written communication instruction that does not compromise content knowledge instruction.

Teaching Writing in a Laboratory-Based Engineering Course with a “How People Learn” Framework

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Experts from academia and industry agree that subject-matter competence is only one necessary goal for professional success; communication competency is critical as well—for writing grants, publishing research results, working in teams, and so on. As collaboration and interdisciplinarity become increasingly common, future engineers and scientists must be increasingly skilled in communication. Thus, engineering educators must find ways to teach the professional skills, such as communication and ethics, endorsed by the Accreditation Board for Engineering and Technology (ABET) Engineering Criteria 2000 (Shuman, Besterfield-Sacre, and McGourty, 2005).

During the last twenty years, much work has been done on engineering writing by faculty engaged in Writing Across the Curriculum (WAC) and Writing in the Disciplines (WID) (Babin and Harrison, 1999; Poe and Freeman, 2004). However, most engineering and science courses still concentrate on merely teaching their domains instead of integrating the related professional skills.

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VaNTH (<http://www.vanth.org>) aims at improving students' content understanding along with the related skills. As part of this mission, we were interested in seeing whether the HPL learning environment used in many VaNTH classes to promote content mastery, as in Tissue Engineering, simultaneously could improve the teaching and learning of communication skills. Therefore, in this study we investigated the effect of an instructional strategy aligned with the *How People Learn* (HPL) framework (Bransford, Brown, and Cocking, 1999), focusing on students' written communication skills as they acquired content understanding in a laboratory-based, tissue-engineering course.

Research has shown that an HPL-informed instructional strategy promotes student learning of content (Greenberg, Smith, and Newman, 2003; Pandey, Petrosino, Austin, and Barr, 2004), not only in science and engineering, but also in literacy and the social sciences (Cammack and Holmes, 2002; Williams, Nix, and Fairweather, 2000). Researchers even have begun to explore the effect of HPL on core competency instruction (for example, Troy, Hirsch, Smith, and Yalvac, 2004; Hirsch, McKenna, Shwom, and Anderson, 2004). However, studies have not explored the extent to which a fully utilized HPL framework and instructional strategy can influence the quality of student-generated reports in a course whose major objectives are the teaching of science.

The HPL Framework: A Review

Using the whole HPL framework means that the instructional design must encompass all four of its teaching principles. The pedagogy must be knowledge-centered, learner-centered, assessment-centered, and community-centered (Bransford, Brown, and Cocking, 1999), the characteristics of which are as follows:

In a knowledge-centered approach, the goal is to present knowledge to students so that they acquire not only specific details but also an overall understanding of the domain.

The learner-centered principle recognizes students' preinstructional skills and knowledge as a base for acquiring new knowledge. It helps students make conceptual linkages to their knowledge corpus.

Assessment-centeredness means that assessment becomes part of the teaching strategy—not merely a means of measuring learning after the instruction has ended.

Community-centeredness focuses on students' collaborating with one another and with the public, both in and after class. It includes students working in groups, engaging in class discussions, making presentations, attending conferences, and so on. These activities help students apply their newly learned skills and enter the community of engineers.

These HPL centers are all interconnected. For example, an assessment-centered learning environment requires both content knowledge and student input, and student input exemplifies learner-centeredness, as students make their knowledge visible to the instructor. In this study we suggest that the interconnectedness and complexity of an HPL framework benefits core competency instruction because it fully engages students in their inquiry-based learning tasks.

The Study Context: A Tissue-Engineering Module

Tissue engineering, a rapidly evolving field, was chosen for this implementation. The targeted student population was senior and graduate biomechanical engineering (BME) majors specializing in biotechnology. The course comprised one lecture period and one lab period per week. Class size was limited to about thirty students grouped into three lab sections.

During the study, one of the authors taught one lab section by following an HPL-inspired pedagogical sequence, the Legacy cycle (Schwartz, Lin, Brophy, and Bransford, 1999). The other faculty member taught the two other lab sections (control groups) using traditional, non-HPL methods. Both instructors had similar experience in teaching the course. In the HPL group, the module led students through several guided-inquiry laboratory exercises described elsewhere (Birol, Liu, Smith, and Hirsch, 2003). Each laboratory assignment was presented as a challenge and taught using the Legacy cycle. Here, we describe how the same Legacy cycle was used to create a learning sequence for the communication instruction required by the lab.

A Legacy cycle begins with a challenge and then proceeds through several steps during which students create new ideas, glean knowledge from the instructor and each other, research and revise their work, and then “go public” with the results. In the HPL module, each laboratory exercise started with a discussion session to introduce students to the learning goals and expected outcomes of that specific laboratory. To help students generate ideas, questions promoted discussion about why the required technique is important, how to perform the lab, what kind of data to collect, and how to analyze those data. A short lecture on the exercise was included, which allowed students to research and revise their ideas. During the hands-on laboratory, the instructor continued the discussion informally. Consistent with WAC-WID ideas, each laboratory ended with a report being assigned, along with specific writing instructions. Students were then left to do their work, or test their mettle. Students went public in the next session when they submitted the reports. The instructor went over the previous week’s reports and provided written feedback on both unique and common mistakes in the reports and suggestions on how to improve the writing.

Thus, students in the HPL group received continuous, prompt feedback from their instructor on the content, style, and structure of the laboratory

reports. This feedback and the in-class discussions aimed to uncover difficulties and remedy students' misconceptions of a well-written paper. The instructor focused on higher-level writing and thinking challenges, such as synthesizing the previous research, providing an argument, and drawing meaningful conclusions.

The traditional group did not follow a Legacy cycle, and their laboratory exercises and writing assignments were not informed by the four centers of the HPL framework. Each laboratory exercise started with the instructor's short lecture and continued with the hands-on experiment. Students received the same assignments as those handed out in the HPL group; that is, they were expected to hand in a laboratory report each week. However, students did not receive additional guidelines about their writing or feedback from the instructor. They did not discuss the writing as a group. Reports were graded by teaching assistants who had no HPL training. Students' writing difficulties or misconceptions of a well-written paper were not explicated through in-class discussions or corrected by instructor feedback.

Research Methods

Overall Design. For this study we used a quasi-experimental, nonrandomized control group pre- and posttest design (Campbell and Stanley, 1966). Since the study participants were students enrolled in the tissue-engineering course, they were all self-selected. They were also self-grouped into the traditional and HPL sections. All thirty-three students were invited to participate voluntarily, and all agreed.

Instruments for Data Collection. To collect our data, we used three instruments: a student communication survey, a rubric for assessing content knowledge in the take-home paper, and a rubric for written communication in the lab report.

Student Communication Survey. To capture knowledge about students' previous instruction in written communication, we designed a thirteen-item, five-point Likert scale. The first two items asked about students' experiences in writing reports and the effectiveness of their previous instruction. The next eleven items asked students to rate their abilities in specific communication areas. These items, listed in Exhibit 5.1, were grouped under three main categories, similar to those in the written communication lab report rubric discussed in the following sections. Students from both groups completed this survey in the beginning of the quarter.

Rubric for Assessing Content Knowledge in the Paper. To measure the domain knowledge students gained by the end of the quarter, we developed a rubric for scoring the take-home paper assignments. For the assignment, students were asked to imagine they were writing a grant application and to include points such as the appropriate gene transfer technique, the critical factors for implementing that technique, and the ethical issues involved. We

Exhibit 5.1. Student Communication Survey Items 3 to 13

Content

3. Writing an abstract
4. Writing background and integrating
5. Conveying an understanding of literature
6. Writing concisely
7. Explaining ideas clearly

Organization

8. Effectively using transitions
9. Effectively using headings

Mechanics and Grammar

10. Using words carefully and precisely
11. Avoiding errors in spelling and punctuation
12. Avoiding usage errors
13. Consistently describing data

used a rubric developed by the domain experts and other study team members to probe student understanding of key course concepts.

After the course was completed, the HPL instructor used the rubric to blind score pre- and postcourse papers from both groups. For each question listed in the rubric, the instructor assigned a score from one to five, depending on the extent to which the student-generated papers aligned with the rubric criteria, shown in Exhibit 5.2.

Rubric for Written Communication in the Lab Report. We designed another rubric to assess students' written communication performance on the laboratory report. We generated items through discussion with the engineering instructor, a learning scientist, and a writing instructor. Our criteria consisted of characteristics of well-written professional papers in engineering drawn from other engineering writing courses at the university, surveys given to our engineering faculty, and industry workshops (Hirsch and others, 2005). Writing abilities were grouped under three categories

Exhibit 5.2. Summary of Items from the Rubric Assessing Content Knowledge Reflected in the Paper

- 1A. Student identifies the factors involved in the proposal.
- 1B. Student discusses the factors involved in the proposal.
- 2A. Student identifies an appropriate gene transfer technique and possible cellular target site.
- 2B. Student provides a rationale for choosing an appropriate gene transfer technique and possible cellular target site.
3. Student devises a plan to implement the technique.
4. Student identifies and discusses the critical factors related to the specific gene transfer technique.
5. Student identifies and discusses ethical issues relating to the design.

chosen by the engineering instructor, shown in Exhibit 5.3. As before, each subcategory was scored on a five-point scale.

Analysis

Pre- and posttest data from all three instruments were analyzed using a repeated measures analysis of variance (ANOVA) procedure; in some cases, gain scores were compared with an independent samples *t* test to simplify presentation of findings. Specifically, we investigated whether HPL-based instruction had an impact on students' views of their written communication skills and effectiveness of the instruction they received, students' content knowledge performance, and students' written communication performance.

Exhibit 5.3. Rubric Items for Evaluating Written Lab Reports

- A. Content
 - A1. Abstract
 - A2. Opening: states background and purpose
 - Abstract (if called for in assignment)
 - Introduction states purpose of report (not just purpose of experiment)
 - A3. Reflects literature
 - Is complete
 - Has depth
 - Includes citations
 - A4. Explains ideas clearly
 - Highlights key points
 - Uses figures and equations when appropriate
 - Uses words precisely
 - Is consistent regarding numerical significance
 - A5. Makes good arguments
 - Draws appropriate inferences and conclusions
 - Backs up assertions with evidence and reasoning
 - A6. Has a useful conclusion
- B. Organization
 - B1. Has good overall organization
 - B2. Divides information into useful categories or paragraphs
 - Includes useful headings, topic sentences, transitions
 - Subdivides long sections
 - B3. Has logical, coherent paragraphs
- C. Writing Quality
 - C1. Explains ideas concisely
 - Avoids repetition and narrative
 - Avoids discussion of mistakes
 - C2. Has a coherent voice—sounds like one writer
 - C3. Structures sentences so they're easy to read
 - Subjects and verbs early in sentences; lists at end
 - Sentences of reasonable length or broken by punctuation into chunks
 - Appropriate use of active or passive voice
 - C4. Avoids errors in spelling and punctuation
 - C5. Avoids errors in usage and grammar

Findings

Students' Views: Personal Experience with Writing and Effectiveness of Instruction. The student communication survey asked students to rate their past experiences in writing laboratory reports in BME classes. After the course was completed, students in both groups rated their report-writing experiences significantly higher than prior to the course, $F(1, 21) = 4.31, p < .05$. The means of the HPL group and the traditional group were 2.75 (.95) and 3.83 (.85), respectively. Indeed, students in both groups completed seven reports, so it was expected that both groups would increase their responses to this item. As shown in Figure 5.1, no group differences were detected.

When student rating of the effectiveness of their previous communication, shown in Figure 5.2, was considered, a marginally significant interaction was detected; this included a trend toward the HPL group's rating the effectiveness of instruction higher than that of the traditional group after the course, $F(1, 21) = 2.91, p = .052$. The HPL group showed a considerable increase, whereas in the traditional group students actually rated the instruction to be less effective after the course.

Students' Views: The Specifics of a Written Report. Students were also asked to rate their abilities on specific aspects of report writing. Table 5.1 shows significant gains across the majority of items, implying that students in both groups thought their experiences in the tissue-engineering course improved their written communication abilities. Group differences were detected on only one item. Gains for the students in the HPL group

Figure 5.1. Students' Pre- and Posttest Responses (Means): Their Writing Experiences

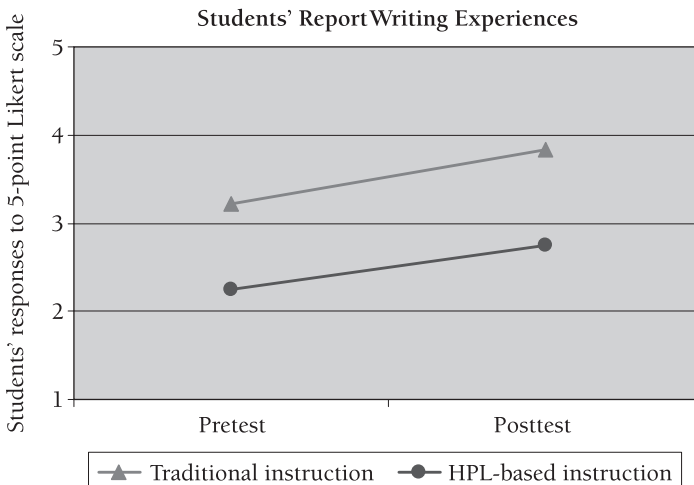
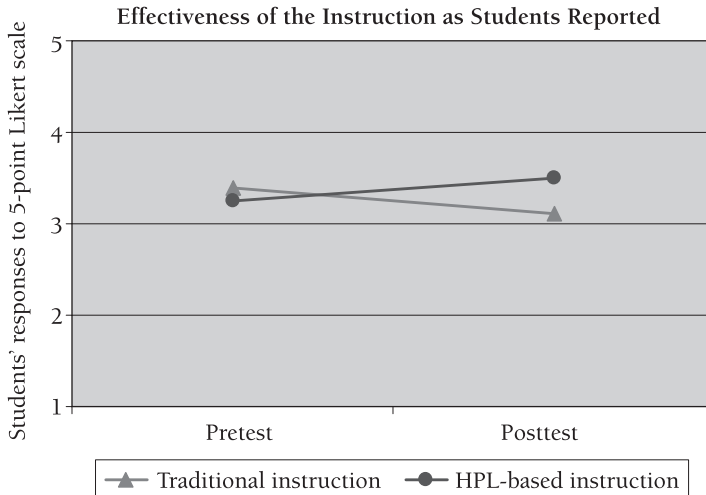


Figure 5.2. Students' Pre- and Posttest Responses (Means): Their Views on the Effectiveness of Previous Instruction in Written Communication



were significantly higher than those of the traditional group on “Writing an Abstract,” $t(21) = 2.2, p < .05$. Trends in the data showed that students in the HPL group reported more gains than did those in the traditional group on all other items, except two: “Explaining ideas clearly” and “Using words carefully and precisely.”

Students' Content Understanding. Students in both groups demonstrated gains over the course in all categories but one. The analysis of students' content understanding revealed no statistically significant differences across groups.

Students' Lab Report Writing. To analyze the students' written communication performance, we used the written communication lab report rubric, resulting in a matched total of six students from the HPL group and twenty-two from the traditional instruction group. Reports were blind scored. The students' pretest scores were compared across groups; students from the HPL group performed significantly higher than did those in the traditional group on all of the rubric items except two. The exceptions were the last two items of the rubric: “Avoids errors in spelling and punctuation” and “Avoids errors in usage and grammar.”

Content. Figure 5.3 represents students' gain scores in the content component of the communication rubric. The data showed that HPL-based instruction had an impact on the students' reports in several content areas, including “Makes a good argument,” $t(28) = 2.3, p < .05$; “Explains ideas clearly,” $t(28) = 2.3, p < .05$; and “Abstract,” $t(28) = 10.6, p < .01$.

Table 5.1. Students' Mean Scores Across Communication Survey Items

Communication survey items	Traditional group (n = 18)			HPL group (n = 4)		
	Pretest	Posttest	Gain	Pretest	Posttest	Gain
3. Writing an abstract	3.00	3.00	0.00	2.00	3.25	1.25*
4. Writing background and integrating	3.39	4.00	0.61	3.75	4.50	0.75
5. Conveying an understanding of literature	3.61	4.11	0.50	3.50	4.50	1.00
6. Writing concisely	4.0	4.22	0.22	3.00	3.75	0.75
7. Explaining ideas clearly	3.61	4.33	0.72	3.75	4.25	0.50
8. Effectively Using Transitions	3.72	3.83	0.11	4.25	4.75	0.50
9. Effectively using headings	3.61	4.16	0.55	3.75	4.50	0.75
10. Using words carefully and precisely	3.77	4.05	0.27	4.00	4.00	0.00
11. Avoiding errors in spelling and punctuation	3.94	4.38	0.44	3.75	4.50	0.75
12. Avoiding usage errors	3.94	4.27	0.33	3.75	4.75	1.00
13. Consistently describing data	3.66	4.11	0.44	3.50	4.25	0.75

*Denotes significant difference between groups at the $p < .0$ level.

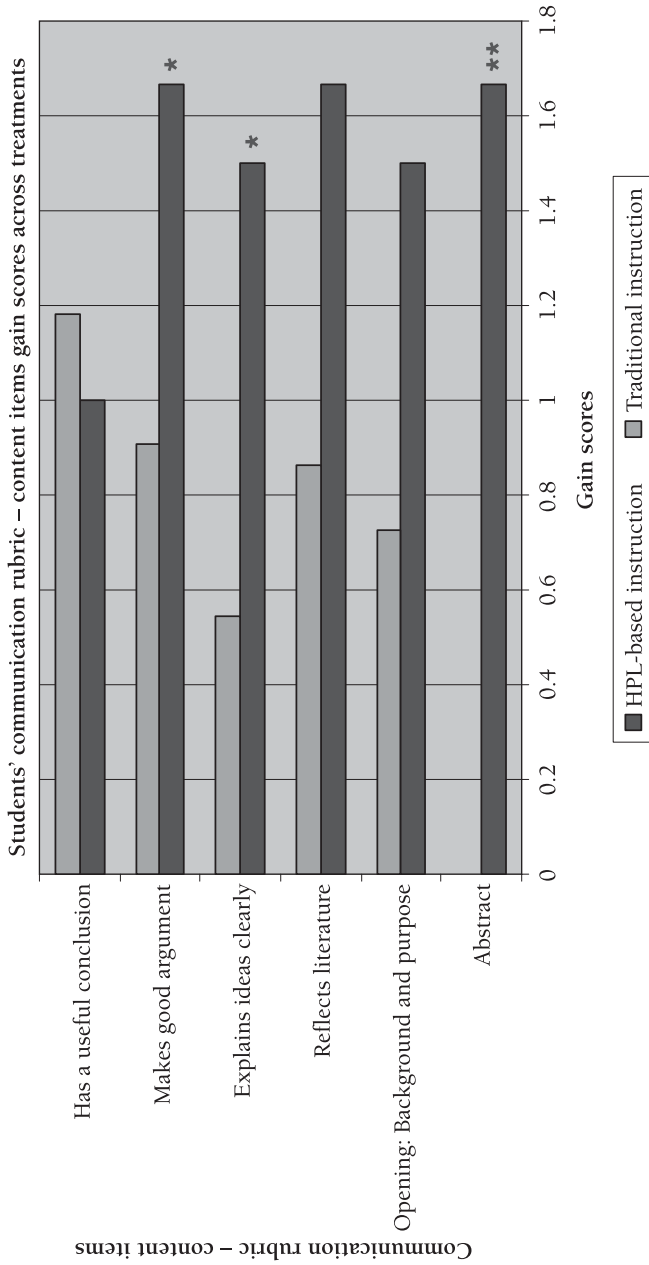
Organization. Figure 5.4 shows students' gain scores in the organization component of the communication rubric. In both groups, students performed better after instruction, but the HPL group significantly outgained the traditional group on "coherence," $t(28) = 2.9, p < .01$; "useful division," $t(28) = 3.24, p < .01$; and "overall organization," $t(28) = 2.0, p < .05$.

Writing Quality. Figure 5.5 represents students' gain scores in the writing quality component of the communication rubric. As seen previously, all students gained due to instruction, but the HPL group gained significantly more from instruction than their counterparts on four of the five items, including "Usage and grammar," $t(28) = 2.2, p < .05$; "Spelling and punctuation," $t(28) = 2.3, p < .05$; "Coherent voice," $t(28) = 2.6, p < .05$; and "Explains ideas concisely," $t(28) = 2.14, p < .05$. Analysis of the final item, "Writes easy-to-read sentences," did not indicate significant differences but demonstrated a trend toward an advantage for the HPL students.

Discussion

Findings—particularly students' gain scores—revealed that an HPL framework was effective for delivering instruction in written communication in a laboratory-based engineering course without detracting from students' mastery of engineering content. Several reasons may explain this effectiveness.

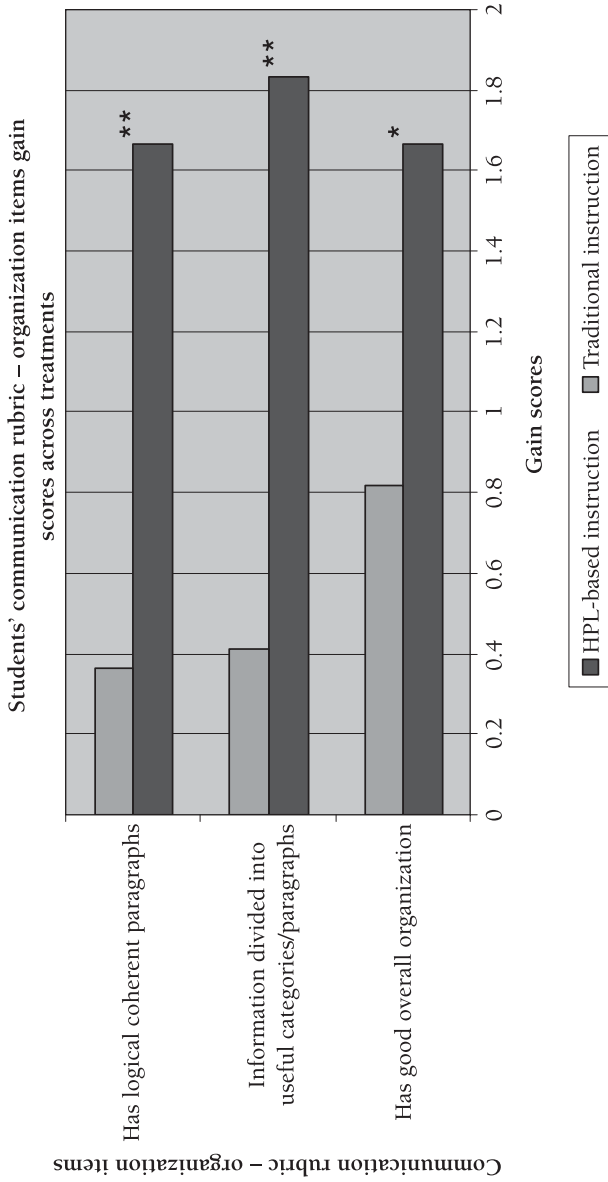
Figure 5.3. Students' Gain Scores: "Content" Component of the Communication Rubric



* Denotes significant difference between groups at the $p < .05$ level.

** Denotes significant difference between groups at the $p < .01$ level.

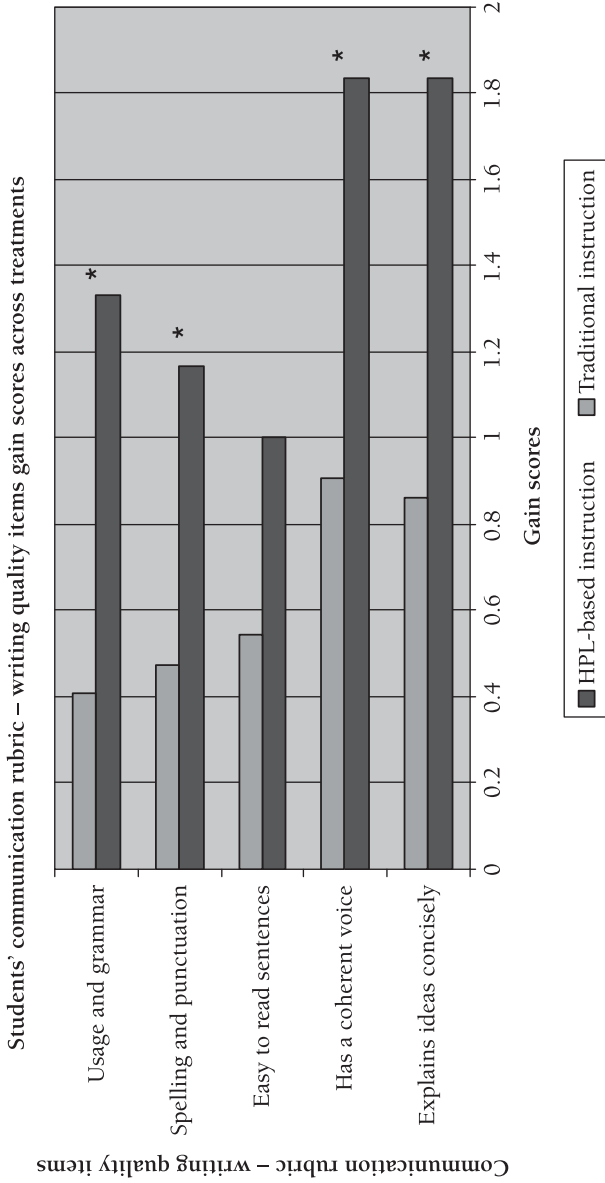
Figure 5.4. Students' Gain Scores: "Organization" Component of the Communication Rubric



*Denotes significant difference between groups at the $p < .05$ level.

**Denotes significant difference between groups at the $p < .01$ level.

Figure 5.5. Students' Gain Scores: "Writing Quality" Component of the Communication Rubric



* Denotes significant difference between groups at the $p < .05$ level.

First, challenge-based instruction might have encouraged students to communicate their positions thoroughly in the lab reports. That situation could explain why students in the HPL group scored higher in their initial lab reports than did students in the traditional group. Moreover, in-class discussions and the continuous instructor feedback might have helped students become more conscious of the characteristics of a well-written paper. Students could locate and remedy the source of difficulties in report writing. Thus, the continuous feedback, Legacy cycle, and challenge-based design all together apparently created a meaningful context for students to synthesize the literature, make an argument, and draw meaningful conclusions in their written communication.

One limitation of the study is that it does not rule out whether students received writing instruction in another class. However, as Figure 5.1 showed, both groups responded similarly on their writing experiences; thus if students received additional instruction about writing, the averages of the additional instructions would be equal across groups. Another possible limitation resides in the fact that two different instructors taught the two groups. As is often the case in applied research, this potential confounding factor was unavoidable. These differences might have influenced the outcomes of interest in this study and blurred the effects of the pedagogical intervention.

Regarding content performance, students did relatively well across groups. This finding suggests that devoting time to communication instruction in the HPL group did not interfere with the HPL instructor's ability to cover domain knowledge (a common faculty concern) or with the students' ability to focus on mastering the domain knowledge.

Conclusion

Engineering faculty often say that they do not have time to teach writing, or that if they spend time teaching writing they will have to sacrifice domain instruction (Hirsch and others, 2005). This study suggests otherwise; data show that an HPL framework used to improve science and engineering instruction can be exploited concurrently to teach written communication, including higher-level writing skills such as argumentation and coherence. Student perceptions support this idea. Students in the HPL section rated their writing instruction as much more effective at the end of the course, whereas students who wrote the same number of reports in the traditional section noted a decrease in the effectiveness of their writing instruction. Apparently, students in the traditional group did not see a benefit to writing seven reports, whereas the students in the HPL group did. Similarly, students in the HPL group made greater gains in rating their own writing abilities than did students in the traditional section. When the reports were blind scored by an independent rater, scores suggested that students in the

HPL group made greater gains in the content, organization, and quality of their writing.

The small numbers of students in the study preclude the appearance of some statistically significant differences, but the data strongly suggest that students' abilities to write lab reports can be enhanced through a pedagogy informed by the HPL framework. We conclude that the HPL framework is effective in teaching other areas than technical concepts and skills. Future research can investigate the effect of HPL-based instructions with larger groups and in related core competency areas, such as oral presentation skills and teamwork.

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