

An Innovative Method for **DEVELOPING COMMUNICATION SKILLS IN ENGINEERING STUDENTS**

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Although a student's knowledge of chemical engineering remains the most important part of his or her professional training, the ability to communicate is also pivotal and has a decisive role in a chemical engineer's professional life. In Chile, there is a growing recognition of the importance of developing communication skills for engineering students. Ayarza, *et al.*,^[1] have identified skills that graduating engineering students should have, based on a profile that considers international standards. They emphasize that a future engineer should be able to work well on multidisciplinary teams and should be able to communicate effectively. Furthermore, another Chilean academic, Schewember,^[2] has noted that every engineer who reaches a certain professional level is required to make complex, high-quality presentations. He adds that an engineer not only needs to be able to speak well in the rhetorical sense, but he must also dominate active communication, which implies an efficient and effective use of language.

The Chilean National Undergraduate Accreditation Commission (CNAP), together with the engineering deans of the principal Chilean universities, have elaborated an evaluation criteria for undergraduate engineering programs, where the standards of the U.S. Accreditation Board for Engineering and Technology (ABET) have been especially influential. Included in the CNAP's engineering student profile are the abilities to be creative and innovative, to communicate effectively with third persons, and to solve problems with a holistic, systemic approach. Although academic leaders emphasize the importance of these abilities, there are only a few cases where activities that permit engineering students to develop these communication skills have been incorporated into the curriculum.

During the evaluation of student performance, chemical engineering professors at the Universidad de Concepción noted a deficit in students' communication ability—a number of them had difficulty with oral and written expression when communicating results to their peers and professors. This inability to communicate effectively could negatively influence their

future job possibilities.

These deficiencies could be due to any one of several causes. First, chemical engineering students have few opportunities to develop communication abilities as part of their university education. Second, a significant number of engineering students at the University of Concepción come from a low socioeconomic and cultural background, further limiting development of communication abilities on their own and requiring support programs to overcome the deficiency. For example, in 2002, 72% of the students came from subsidized or public

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education (public education in Chile has deteriorated greatly), and 47% of them received financial aid scholarships because of their family's low incomes. This socio-economic distribution could be indicative of fewer opportunities to develop language performance and interpersonal communication skills.

Third, engineering student in general have better mathematical than verbal skills, which can be observed in their average scores for university admission tests. The average math score in 2003 was 739 points, while the language score was 625 out of 845 points. These scores can be compared with the national results. The 80th percentile nationally was 615 point and 593 points for mathematical and verbal admission tests, respectively. For the verbal skills, the national average was 500 points, with standard deviation of 122.2; in mathematics, the average was 500 points, with standard deviation of 140.

The introduction of new activities designed to strengthen communication abilities in a strongly scientific discipline breaks with the traditional teaching curriculum and raises a series of challenges for professors. Delors^[3] asserts that people possess attributes that they can use creatively and positively to communicate with others. He also states that to better communicate, students need to understand their role in social life as part of their professional success. Thus, a program can be developed where students can acquire communication skills that will permit them to control how to present themselves and to relate with others in an academic, as well as social, environment.

The Chemical Engineering Department at the University of Concepción recognizes that one of its weaknesses is the "significant preponderance of subjects and methodologies that

do not contemplate nor promote team work, effective technical communication (either written or oral) and other issues that permit a more integral, functional student formation". As a result, one of the objectives of the Department is to "promote an integral, highly competent professional formation" and specifically to "improve oral and written communication abilities, social participation, and ethical and moral values".

Consequently, the Department developed a "Communication Skills Development Workshop" as part of the Chemical Processes Laboratory class for fourth-year students. The principal objectives of this class are to strengthen the students' understanding of fundamental chemical engineering principles and to introduce them to laboratory work. In this class, the students carry out experiments in areas such as reactor design, fluid mechanics, and heat transfer. They work in groups of five and present oral and written reports. This paper presents and analyzes the results of the workshop.

METHODOLOGY

A pilot experience was held with a representative sample of thirty chemical engineering students in the Chemical Processes Laboratory. The students attended workshops for two hours a week during two 14-week semesters. Table 1 presents the workshop themes.

Each session progressed inductively from personal experience to conceptualization, emphasizing the capacity of each student to internalize concepts based on his or her own experience. The didactic intervention model has three levels:

- *Personal development to recognize the strengths and weaknesses as a person who interacts maturely, proactively, and*

TABLE 1
Communication Skills Development Workshop

<i>Module Name</i>	<i>Activities</i>
Satisfaction Survey	<ul style="list-style-type: none"> • Presentation of workshop objectives • Sensitization • Diagnostic
<i>Personal Development</i>	
Proactive attitude and process of change	• Development of a proactive and positive attitude with respect to change
Commitment	• Development of an attitude to participate with others in the achievement of goals
Maturity	• Development of an attitude to make a decision and stick with it
Negotiation	• Development of an attitude of collaboration and flexibility in dealing with differences (leadership and supervision)
<i>Verbal/Nonverbal Communication</i>	
Credibility	<ul style="list-style-type: none"> • Development of the ability to channel audience intentions by orator behavior • Good orator qualities
The art of listening	<ul style="list-style-type: none"> • Development of the ability to retain participants' attention to what is said • Recognition of why it is important to know how to listen
Audience analysis	• Ability to detect audience characteristics
Use of nonverbal elements	• Development of the ability to control one's voice and body to emphasize the message's meaning
<i>Planning Oral and Written Discourses</i>	
Discourse purpose	• Ability to identify the objective of the discourse
Outline design of an oral or written presentation	• Outline design of an oral or written discourse
Verbal and visual support	• Ability to use support materials to emphasize and make explicit one's ideas before a group
Satisfaction survey	• Workshop evaluation

- committed with others
- Development of body skills and spatial movement to support public presentations
- Development of communication skills to elaborate oral and written presentations, enabling the students to communicate effectively and efficiently

The students were evaluated before and after the didactic intervention for their

- Personal satisfaction
- Ability to present a theme orally and in a precise time
- Use of audiovisual material as support for the oral presentation

The instruments used to evaluate these issues were a personal satisfaction survey (self-evaluation), video tapes of the presentations (performance evaluation), and team evaluations (co-evaluation).

EVALUATION INSTRUMENTS

Self-Evaluation

To measure student satisfaction with respect to the semester's work, self-evaluations were incorporated to stimulate student feedback and student reflection of their class performance. The self-evaluations took place twice during the first semester of 2002—halfway through the course and at the end of the semester. The first evaluation permitted us to correct certain issues of class work and to program the second-semester academic activities.

The evaluated issues were the

- Degree of participation
- Degree of responsibility in assignment completion
- Level of comprehension
- General participation

The second self-evaluation also included the students' perception of their performance in verbal and nonverbal communication. On both occasions, open questions were included to gather student opinions and suggestions, which allowed us to generate modifications when necessary to plan future activity.

The value scales (categories) used to evaluate the opinion with respect to the distinct affirmations contained in the evaluation tool were

1. I believe that the statement is highly exact.
2. I believe that the statement is exact in general.
3. I believe that the statement is minimally exact.

Oral Performance Evaluation

To evaluate the initial student conduct, during the first session each student was asked to do a three-minute video, an unprepared presentation, on any theme. The evaluation guide considered the following performance evaluation scale:

- Above average: Fully satisfied all the requirements
- Satisfactory: Partially satisfied the requirements
- Minimally Satisfactory: Satisfied the minimal requirements

- Deficient: Did not satisfy minimum requirements

The issues that were evaluated were

- Actions to catch the audience's attention (induction)
- Clear and precise presentation on a theme, in an orderly manner
- Use of vivid language
- Voice use
- Space administration

At the end of the first semester's workshops, the students were asked to prepare (within a week) a three-minute presentation on a technical theme related to chemical engineering laboratories. The presentations were individually videotaped and were evaluated using the first evaluation's criteria, with an additional evaluation on audiovisual use.

Co-Evaluation: Feedback on the Experience

During the second semester of 2002, previously defined work teams held meetings with supervision by both the communications and the chemical engineering professor. The following co-evaluation was carried out in each session:

- Two video presentations of each group member were presented
- Each student received an evaluation guide noting the area that was effectively achieved (effective area) and the area where improvement was required (opportunity area)
- Each student indicated the effective and opportunity areas for each member of their group
- Each student recognized his/her strengths and weaknesses in front of the team
- The professor facilitated constructive dialogue between the students

This stage permitted recognition, both at an individual level and before the group, of the students' strengths and weaknesses, which allowed the teaching team to plan the topics that should be reinforced in short workshops.

RESULTS AND DISCUSSION

Self-Tests

A summary of survey results with respect to attendance and participation from the students' self-tests can be seen in Figure 1. In the first survey, the majority of the students perceived that the best-achieved activities were related to their classroom performance and with their care and dedication to complete the required activities in each workshop (82% and 64%, respectively). The less-achieved activities were associated with the performance of out-of-class activities in the assigned time, which was associated with the lack of time available for workshop activities with respect to other classes.

The comprehension results are presented in Figure 3. It is interesting to note that a considerable percentage of students did not perceive the positive value their contributions had in stimulating others in the learning process (57%). This result could be related to their prior experiences in teamwork. As can be seen, for attendance and participation, a high percentage (82%) did not have a clear perception of the value their

own work had for others. The students perceived that the importance of the workshop and the self-test were highly achieved activities (75% and 71%, respectively). A conclusion that can be drawn from this first survey is that the students were unaware of the importance of teamwork and consequently did not value it.

When students were asked to evaluate their participation with a general grade for their participation in all the workshop activities at this time (on a scale from 1 to 7), the largest percentage, 82%, perceived that they had good participation (between 6 and 7), with only 18% classifying their participation between 4 and 5.

In relation to the general usefulness of the workshop and suggestions, the students were satisfied with the activities. With respect to its personal usefulness for professional life, the students mentioned that it provided an opportunity to communicate and to learn more about themselves and their classmates. The suggestions were oriented toward increasing the workshop time in order to deepen some of the topics and incorporating it as a required activity in the engineering program in order to ensure continuity and the ability to dedicate the required time.

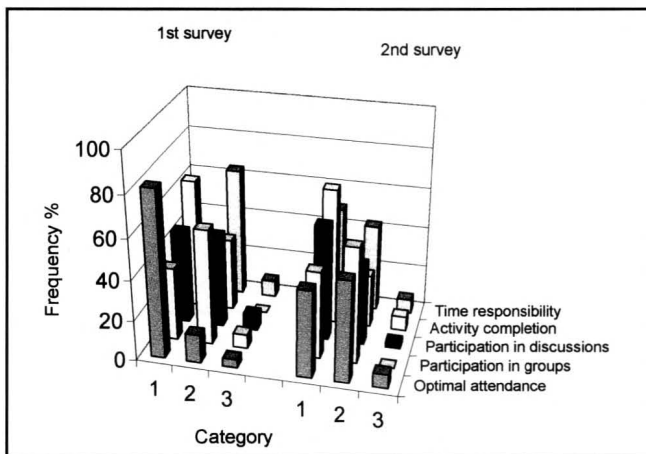


Figure 1 Results of self-evaluations: attendance and participation.

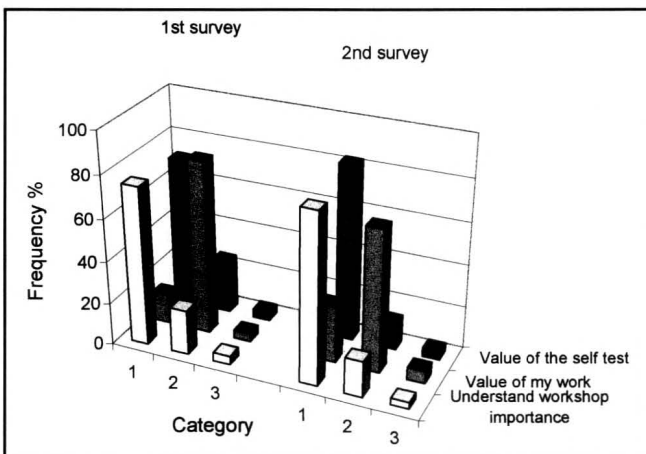


Figure 2. Results of self-evaluation: comprehension.

Additionally, the results of the second self-test are presented in Figures 1 and 2 for comparison. It can be noted that the students changed their perception with respect to certain items and to their dispersion. The percentage of highly achieved increased (from 28% to 50%) with respect to the first self-test. The perception of active participation in front of others increased 11%, which could be a product of the participatory methodology used in activity development. This result is consistent with the increase of the students' perception that their contributions could stimulate others' participation.

Between the first and second self-tests, there is a drop (from 82% to 43%) in the percentage of students who thought their attendance and optimal participation were highly achieved. This result could be due to the growing consciousness of the commitment and individual responsibility required to fulfill the requirements and that they prioritized their other curricular demands.

With respect to the value to others that the students place on their own work, those who felt they highly achieved this value increased from 14% to 27%. The percentage of students who felt that the self-evaluation process was highly achieved increased from 71% to 83%.

Table 2 presents the responses to the questions on verbal and nonverbal communication that were included only on the second self-test.

It is interesting to note that the issues perceived by the students as less achieved are all related to nonverbal communication (body movement, voice use, and physical space control). The students' self-evaluation on nonverbal communication is in agreement with the professor's evaluation of the students' video performance, which is discussed in the following section.

PERFORMANCE EVALUATION

The professors evaluated student performance considering the areas that were effectively achieved and the areas where improvement was needed, using the categories of above average, satisfactory, and minimally acceptable. In general terms, students performances before and after the pedagogical intervention, evaluated according to the predetermined categories, improved substantially, as can be seen in Figure 3.

The video registration of the presentations permitted identification of the principal weaknesses in both verbal and nonverbal communication during the students' oral presentations. The evaluation results are presented in Table 3. The highest frequencies are concentrated in the opportunity area—in those issues that students need to improve in order to equilibrate their personal capacities and skills, especially with respect to their ability to structure their presentation from a communicational point-of-view. There are accumulated frequencies of 71% in each of the indicated issues.

In the effective area there is a greater frequency in the non-verbal communication items, fundamentally in the following issues: maintaining visual contact with the audience (48%), voice use (38%), and stage control (36%).

Based on the students' self-tests and the professors' evaluations, the following weaknesses needed to be strengthened during the feedback sessions:

- Voice use with respect to volume and modulation
- Use of common language vices and crutches
- Presentation structure from a communicational point-of-view

The continuous evaluation of the video presentations permitted identification of each student's achievements. In the following section, we describe in detail the changes for three students. Initially, these students presented similar performance levels with significant communication difficulties, and after the pedagogical intervention they presented distinct achievement levels.

First Student: Radical Change • Table 4 presents the radical changes in this student's performance before and after the communication workshops. In the surveys, this student indicated

I have learned to have more confidence when speaking in public and to recognize the defects of others as well as my own when working in a group . . . In my case, I learned that there is an attitude of my personality, idealism, that bothers others who work with me.

Second Student: Incorporation of Elements Taught in Class • The second student made use of all the elements taught in the workshop, incorporating them into the oral presentation, as can be seen in Table 5. The student commented

Among all the things that I learned in class, I would like to identify the one that is the most important for me . . . I learned to recognize that I am afraid that others think that I am "stupid" and I do my best to demonstrate the opposite.

Third Student: Continued with Difficulties Despite Efforts to Improve • The third student had difficulties in effectively communicating. The greatest difficulties were observed in voice control and diction (see Table 6). Despite the difficulties, the student demonstrated perseverance and enthusiasm during the workshops. This student commented

...this workshop has helped me understand my capacities in other fields. ... it has enabled me to better communicate with others. . . . I have learned to

recognize the potentials of each person and to respect their defects.

FEEDBACK (CO-EVALUATION)

The feedback activity was considered highly valuable by the students, who highlighted and recognized the importance of peer evaluation, the constructive environment generated during team work, and the added value for personal learning once they could visualize their performances, recognize their weaknesses and strengths, and accept the opinions of others.

In response to students' comments, during the second se-

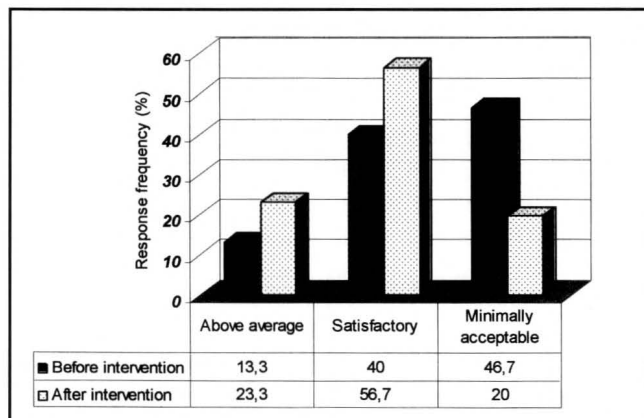


Figure 3. Effect of intervention on student performance.

TABLE 2
Results of the Second Self-Test
(n = number of students; f% = percentage response frequency)

Perception of nonverbal expression and communication	1		2		3	
	n	f%	n	f%	n	f%
I present my ideas clearly and precisely	16	(53)	14	(47)	0	(0)
I develop my ideas in a coherent, logical order	19	(63)	11	(37)	0	(0)
I make sure the audience is listening to and understanding me	18	(60)	11	(37)	1	(3)
I can develop audiovisual materials	19	(63)	11	(37)	0	(0)
I control my body movements and gestures	7	(23)	17	(57)	6	(6)
I pay attention to paralanguage	7	(23)	14	(47)	9	(9)
I control physical space	6	(20)	21	(70)	3	(3)

TABLE 3
Results of the Professors' Evaluation of the Students' Filmed Performances
(n = number of students; f% = percentage response frequency)

Communication	Effective Area		Opportunity Area			
	Above Average (7)		Satisfactory (5)		Minimally Acceptable (3)	
	n	f%	n	f%	n	f%
Induction	10	(32)	14	(45)	7	(23)
Exposition of ideas	9	(29)	16	(52)	6	(19)
Logical Order	9	(29)	15	(48)	7	(23)
Vivid Language	10	(32)	14	(45)	7	(23)
Visual Contact	15	(48)	14	(45)	2	(7)
Paralanguage use	12	(38)	16	(52)	3	(10)
Special use	11	(36)	14	(45)	6	(19)

TABLE 4
Performance Evaluations

<i>Items</i>	<i>Initial Performance Before Intervention</i>	<i>Final Performance After Workshops</i>
FIRST STUDENT		
Induction: generate audience's attention?	No, did not	Yes, well achieved
Clear and organized presentation	No	Yes, a logical order and sequence of ideas observed
Use of vivid language	Did not use vivid language Told an experience flatly	Used greater lexical richness, could explain technical themes in simple manner
Maintained visual contact with the audience	Yes	Yes—the student generated greater connection with audience and greater interaction with movement
Used paralanguage	Flat voice, without variation, intonation, or pauses; spoke quickly	Controlled voice, made less use of language crutches, used pauses, emphasized with intonation changes, gestulated to reinforce theme
Controlled the space	Was static; fallen arms	Made coordinated movement toward the blackboard and toward public
General attitude	Withdrawn, nervous, difficulty controlling respiration	Secure, calm, relaxed, scene dominance and believable attitude
Appreciation of future role in a company	Staff member	Manager
SECOND STUDENT		
Induction: generate audience's attention?	No, did not	Yes, well achieved
Presentation	Order and sequence of ideas not clearly observed	Logical order of presentation was observed. Student introduced theme, developed, and closed presentation
Maintained visual contact with audience	Yes	Yes—also coordinated it with the use of audiovisual materials
Used paralanguage	Flat voice without pauses in intonation; reiterated use of crutches; gestures uncoordinated, especially the hands	Control of voice improved with respect to intonation, with more pauses, better control of gestures with the hands
Controlled physical space	Did not make use of physical space; made swinging body movements; crossed hands/legs	This aspect still requires improvement
General attitude	Nervous, timid, low self-esteem reflected in the position of fallen shoulders, faltering voice	More relaxed, more vivid, elaborated language; conquered the audience; even introduced a certain amount of humor
THIRD STUDENT		
Induction: generate audience's attention?	No	Yes
Presentation	Central message needs greater precision; told story but did not communicate it; no transfer of ideas to audience	There was concern to do a better job; greater coherence was observed; there was an attempt to open, develop, and close the presentation
Used paralanguage	Fallen arms, brusque movements with arms and spacial movement; lack of variety in intonation and velocity of voice; spoke quickly	Partially controlled gestures and movements/ use of velocity and volume of voice did not improve, although the diction did
Controlled the physical space	Without spatial movement and with swinging body movement	Improved use and control of physical space; partially controlled gestures
General attitude	Flat	Proactive attitude, tenacious, conscious of limits and open to improvements

mester we scheduled strengthening workshops for those students who continued to present weakness in certain areas. Fifteen of them attended the workshops, and the topics developed in four sessions were: voice control, body expression, and spatial movements. The workshop results were also analyzed according to the students' educational backgrounds, socio-economic levels, and the College Admittance Exams. Students who came from private (unsubsidized) schools, without government financial scholarships, and with high scores on the College Admittance Exam performed better and did not need the strengthening workshops, which was noted when the performance of the best-evaluated students were compared with those who had more difficulties.

CONCLUSIONS

- The students' opinions and professors' evaluations indicated that the workshops were useful experiences in the students' education.
- This pilot experience should be formalized in the student academic process for two reasons: there is an observed need to generate spaces for personal and social development, and the workshop had positive effects on student attitude and performance.
- This intervention was shown to have the greatest effects on those students who exhibited the greatest difficulties in expressing themselves, partially associated with the educational background and with socio-economic factors.
- To achieve a greater impact of the described activity, a larger number of academics need to participate and the activities need to be incorporated as a habitual practice in the engineering curriculum.

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