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# Identification of Non-Technical Competency Gaps of Engineering Graduates in Chile*

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A study was performed to identify the non-technical competencies needed by engineering graduates in Chile. A list of abilities and knowledge attributes were derived from similar studies and the expectations expressed by professional organizations. Input was received from managers of 75 different companies across a broad range of industries and sizes and 116 engineering graduates regarding the importance and preparation for 57 abilities and knowledge attributes in 10 categories. Each competency was given a priority based on one of three criteria: 50% or more of managers reporting it to be of the highest level of importance, an average rating greater than a cutoff, and a weighted measure of priority incorporating the importance and gap between graduate preparation and needs. The results suggest that, to managers in Chile, the most important non-technical competencies are in the areas of project control, ethics, communications, teamwork, innovation and budgeting. The competencies identified as important were similar to those seen in studies in other countries, but with a greater emphasis on ethics and innovation and less emphasis on quality and customer focus. A method for prioritizing the important competencies was also presented. Many initiatives were proposed to improve specific non-technical competencies that graduates need for competing in the Chilean job market. This paper presents the methodology, the findings, the comparisons with results from similar studies in other countries, and the strategies developed as a result of the findings.

**Keywords:** engineering education; non-technical competencies; soft skills; management

## 1. Introduction

Engineers need leadership, team work, communications, and other non-technical competencies or soft skills to be effective in industry. The purpose of this study was to understand to what degree the various soft skills are needed by engineering graduates entering industry in Chile. In addition, the gaps between the needs expressed by industry managers and the knowledge and skills possessed by engineering graduates were assessed.

Several noteworthy studies provided the basis for this study. Palmer performed a study to determine the management skills relevant to engineering graduates in Australia [1]. The study included a survey of engineering graduates to rate the importance of 45 management skills. He found that the highest rated items were communication skills, project management, supervision and leadership, time management, decision making, teamwork, project evaluation and cost estimation. These results were generally consistent with an earlier study by Palmer in which academics from different universities in Australia were surveyed [2]. That study concluded that the five most important management skills for Australian engineering graduates are: communication skills, project management, supervision and leadership, economic evaluation of projects, and operations and quality management. In the latter study, graduates were also asked to rate their general preparedness with respect to management skills upon graduation (not on an item-by-item basis). Australia has included a strong management component in its engineering programs for at least two decades. The study concluded that engineering graduates appreciate the need for management studies. However, they suggest the inclusion of "more 'real world' examples of engineering management, including case studies, hands-on activities, industry visits, more in-depth coverage of topics, and presentations from practicing professionals."

Two studies that assessed specific non-technical knowledge gaps were performed by Meier *et al.* [3] and Fisher *et al.* [4]. Both studies used surveys of managers in companies in the U.S. Using two study groups, one that included small businesses



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(<50 employees) and the other medium-sized businesses (50 to 250 employees), Meier *et al.* identified the following themes: contemporary business concepts, communication, customer-focused quality, problem solving, teamwork, cultural values, and technology. To prioritize the specific skills for gap closure, the following formula was used: *Priority* = (*Importance* + (*Importance*-*Preparation*)) / 2. This formula factors in the need (*Importance*) and preparation of graduates (*Preparation*) and the gap between the two. The results suggested that engineering students in the U.S. should develop the following competencies: customer expectations and satisfaction, commitment to doing one's best, listening skills, sharing information and cooperating with co-workers, team working skills, adapting to changing work environments, customer orientation and focus, and ethical decision making and behavior.

Fisher *et al.* applied the survey and prioritization methodology of Meier *et al.* to engineering technology graduates in the U.S. Respondents were asked to rate the importance and preparedness of recent graduates and those that had three to five years' experience. The data were initially reduced using the formula of Meier *et al.* given above. They further reduced the number of items as follows: "Skills lying above the midpoint of the ranked order were considered of greatest interest and these rankings were normalized to give the top ranking a value of 100. The individual skills were then arranged into logical groups and those groups having a significant number of skills with a ranking above 65 were noted." The most critical areas were found to be project management, communications and team skills, business ethics and legal issues, and quality management practices. Of the individual skills, professional conduct had the highest priority for entry-level engineers. The need for an increasing number of specific skills was identified for 3- to 5-year level engineering technologists, particularly in ethics, economics, finance, management and organizational behavior.

This study extends the methodology used by Meier *et al.* and Fisher *et al.* and applies it in Chile. Compared with the engineering programs in the U.S., engineering programs in Chile generally include significantly more management related coursework (e.g., finance, accounting, and project evaluation). Therefore, this study was undertaken to ascertain if the results of previous studies and industry surveys by professional organizations are applicable in Chile. The rest of this paper details the methodology, findings and proposed curriculum improvements. The study clearly identified the non-technical competencies needed by engineering graduates in Chile.

## 2. Methodology

The methodology included development of the list of competencies and preparation, testing, and administration of the survey, which are described below. The competencies and survey information have been translated from the Spanish for presentation in this paper.

### *2.1 Competencies*

Competencies were selected on the basis of the references mentioned in the Introduction [1, 3, 4] and on competencies identified by professional organizations in their codes of ethics and bodies of knowledge. In particular, the National Society of Professional Engineers' (NSPE) code of ethics [5], the American Society for Quality (ASQ) Quality Engineer Certification Body of Knowledge (CQE-BOK) [6], the American Society for Mechanical Engineering (ASME) Guide to the Engineering Management Body of Knowledge (EM-BOK) [7], and the PMI (Project Management Institute) Project Management Body of Knowledge (PMBOK) [8]. A final set of attributes were added based on the Test of English as a Foreign Language (TOEFL), namely reading, listening, speaking, and writing in the English language. A matrix of 140 abilities and knowledge attributes was generated by combining all of the competencies. To make the survey a reasonable length, redundancy was eliminated and items were grouped by category and further condensed. The resulting categories and competencies, which formed the basis for the survey, were as follows:

1. Project Management Competencies
   a. Control project performance
   b. Manage project risk
   c. Manage project costs
   d. Manage time and project deadlines
   e. Use project management software
2. Communication and Teamwork Competencies
   a. Communicate effectively orally
   b. Communicate effectively in writing
   c. Listen to others
   d. Communicate with workers from other disciplines
   e. Negotiate
   f. Build networks
   g. Interview job applicants
   h. Train workers and customers
   i. Work effectively in teams
3. Quality Practices Competencies
   a. Manage quality
   b. Be aware of quality standards
   c. Use quality diagnostic tools
   d. Ensure quality standards

   e. Continuously improve processes
   f. Perform statistical process control
   g. Orient quality to customer requirements
4. Ethics and Legal Issue Competencies
   a. Have professional ethical standards
   b. Have a sense of environmental responsibility
   c. Be aware of the responsibility for workplace safety
   d. Recognize and avoid conflicts of interest
   e. Be aware of intellectual property rights
   f. Have a sense of social responsibility
5. Finance and Accounting Competencies
   a. Estimate costs
   b. Perform an economic evaluation
   c. Make a budget
   d. Have knowledge of financial accounting
   e. Allocate indirect costs
   f. Perform risk analysis
6. Supervision and Leadership Competencies
   a. Form teams
   b. Empower people
   c. Coach and motivate
   d. Conduct performance evaluations
   e. Conduct meetings
   f. Manage conflict
   g. Manage change
   h. Make decisions
7. Creativity Competencies
   a. Innovate in the workplace
   b. Be entrepreneurial
   c. Make a proposal
   d. Solve problems creatively
8. Strategy Competencies
   a. Perform a competitive analysis
   b. Make a strategic plan
   c. Plan resource usage
9. English Communication Competencies
   a. Speak in English
   b. Understand spoken English
   c. Write in English
   d. Read in English
10. Other Competencies
   a. Have professional attitudes
   b. Have the ability to relate to people
   c. Be punctual
   d. Organize and prioritize multiple tasks
   e. Have an interest in more professional training

Given this list of competencies, the survey was designed, tested and administered.

### 2.2 *The survey*

The design of a survey can affect the number and accuracy of responses. Rogers [9] proposed three steps for maximizing the utility of surveys:

1. Develop a survey plan that defines the objectives of the survey and how it will be administered.
2. Construct the survey using the most suitable format based on characteristics of the intended recipients.
3. Conduct a pilot survey with people that have the same characteristics as the final survey group and modify the survey if necessary.

The surveys were designed to be given to company managers and graduates. The surveys included the list of competencies followed by fields for rating the level of importance and preparedness for each competency. In Chile, grades for coursework are given in the range 1 to 7, so the same scale was used on the surveys. For example, in the case of graduates, the instructions and answer procedure were as follows: "In the first column indicate the level of importance of the skill when you entered your first job. Using a scale of 1 to 7, where 1 is 'not important' and 7 is 'very important'. In the second column, indicate the level of preparation you had when entering your first job."

Similarly, for business managers, the instructions were as follows: "In the first column indicate the level of importance (on a scale of 1 to 7) to entry-level engineering graduates working in your company, with 1 indicating 'not important' and 7 indicating 'very important.' In the second column, indicate the level of preparation of engineering graduates from the Universidad de los Andes where 1 indicates 'not prepared' and 7 indicates 'fully prepared.' Leave the space blank if you have not known entry-level engineers from the Universidad de los Andes working in your company." The managers' survey also asked for the company name and their title.

### 2.3 *Survey pilot test*

The survey was filled out by five recent graduates and two managers to verify the clarity of the instructions and assess the response time. The average time for completing the survey was six minutes. The format and readability were also assessed and deemed acceptable by all respondents. Therefore, no changes were made to the survey.

### 2.4 *Survey administration*

The graduates' survey, was sent via e-mail by the alumni association to Universidad de los Andes (U. Andes) engineering graduates from the 11 year period prior to the study (2000 to 2010) and was accompanied by a brief letter of justification. To encourage responses, 12 premium white wines were offered as prizes in a draw of respondents and the students were promised anonymity. The 355 grad-

**Table 1.** Industry segments of graduates and managers

| Industry segment | SIC | Grads | | Managers | |
|---|---|---|---|---|---|
| Ag., Forestry, Fishing | 01–09 | 21 | 6% | 4 | 5% |
| Mining | 10–14 | 28 | 8% | 5 | 7% |
| Construction | 15–17 | 58 | 16% | 7 | 9% |
| Manufacturing | 20–39 | 6 | 2% | 15 | 20% |
| Transportation, Utilities | 40–49 | 41 | 12% | 10 | 13% |
| Retail Trade | 52–59 | 80 | 23% | 5 | 7% |
| Finance, Ins., Real Estate | 60–67 | 43 | 12% | 5 | 7% |
| Services | 70–97 | 62 | 17% | 24 | 32% |
| Government | N/A | 17 | 5% | 0 | 0% |
| Total | | 355 | 100% | 75 | 100% |

uates were distributed among eight Standard Industrial Classification (SIC) codes and government employers as shown in Table 1. The managers' survey was sent via e-mail to the alumni association's current list of employers that offered jobs to graduates. Managers were promised confidentiality with regard to their specific data and that data would only be reported in aggregate. Graduates and managers who did not answer the survey promptly received a follow up e-mail and a telephone call.

## 3. Results and analysis

Of the total of 355 graduates surveyed, 116 (33%) valid responses were obtained. Of the 90 surveys sent to company managers, 75 (83%) valid responses were obtained. The managers were distributed among the eight SIC codes shown in Table 1. Most (92%) of the companies did not qualify for the level of preparedness of graduates. The reason for this was that many of the managers surveyed had no direct contact with engineers from U. Andes.

Three criteria were used to analyze the results for gaps and prioritize the competencies for instructional improvement. The first criterion identified all competencies for which at least 50% of managers rated the importance as a 7 (the highest score). The second criterion identified any competency having a statistically significant average importance rating of 6 or above. The third criterion was essentially that of Meier *et al.* [3] but used weighted averages of graduate and manager responses. The results of applying these three criteria to the survey data are given in the following subsections.

### *3.1 Criterion 1: High scoring median*

Competencies that received the highest possible score by at least 50% of the managers were distributed among 7 categories as shown in Tables A.1 through A.10 in the appendix. The percentage of managers who indicated the highest rating for the competency is shown in the criteria column labeled 1. Having professional ethical standards was given the highest rating by 90% of the managers. No competencies were identified in the categories of Quality Practices, Strategy or Other using this criterion.

### *3.2 Criterion 2: Hypothesis test*

The second criterion used a hypothesis test to identify those competencies that had an average rating of 6 or higher with 95% confidence. This criterion produced a larger list of competencies that included all of the competencies identified by the first criterion as shown in Tables A.1 through A.10. The average rating for each item is shown in the criteria column labeled 2. The only category missed by this criterion was Quality Practices.

### *3.3 Criterion 3: Priority*

The third criterion, which was based on the priority calculation from Meier *et al.* [3], is shown in Equation (1) where $I$ denotes "importance" and $P$ denotes "preparation":

$$Priority = \frac{I + (I - P)}{2}. \quad (1)$$

However, in the studies of Meier *et al.* [3] and Fisher *et al.* [4], only company manager data were available, whereas in this study, graduate data were also available. Therefore, a weighted average of "importance" was used to compute the priority as shown in Equation (2). The subscripts 'm' and 'g' indicate data from the manager and graduate groups, respectively. The scale factor, $\alpha$, was set to 0.75 to give more weight to the managers' input. Changing the weighting by as much as 25% had no affect on the findings. Given the low response from managers about the preparation of graduates, those data were not used. The items having the upper 50% of priority values were retained in the list. The results of applying this criterion are shown in Tables A.1–A.10. The criteria column labeled 3 contains the computed priority:

$$I = \alpha I_m + (1 - \alpha) I_g. \quad (2)$$

## 4. Discussion

The competencies identified using the three aforementioned criteria were prioritized into three mutually exclusive priority levels:

1. Competencies identified by all three criteria.
2. Competencies identified by criterion 2 and criterion 3 and not criterion 1.
3. Competencies identified only by criterion 3.

The results of these classifications are shown in the rightmost column of Tables A.1–A.10. The competencies identified as important were similar to those of Meier [3], Palmer [1, 2] and Fisher [4] but with a heavier emphasis on ethics and innovation and less emphasis on quality and customer focus.

Graduates were presumed to have sufficient preparation for the competencies identified by criteria 1 or 2 but not by criterion 3. Proposal writing, prioritizing multiple tasks, and communication in English were examples. A final screening of the competencies based on the level of preparation reported by the graduates confirmed this assumption. Graduates rated their preparation for communication in English as relatively high (average rating of 5.8). Therefore, changes to the English language program, which consists of nine courses, was not recommended. Graduates also felt prepared to be able to organize and prioritize multiple tasks (average rating of 5.7). Incidentally, they also felt prepared for punctuality (average rating of 5.7), which was not identified by the criteria.

Pizarro proposed 37 initiatives affecting the curriculum, courses and university life to improve the preparation of engineering graduates of U. Andes in the competencies identified above [10]. The recommendations are summarized in the following subsections. They are listed with the category and priority most aligned to the initiative, although some would improve competencies in more than one category and more than one priority level. The support of references is indicated for many of the proposed initiatives. The initiatives were proposed to the faculty administration for consideration during its curriculum development and strategic planning activities. As indicated below, some of the initiatives were implemented immediately following the study and the others are still under consideration.

### *4.1 Project management initiatives*

Two competencies were identified in the Project Management category, one with a priority of level 1 (controlling project performance) and the other with level 3 (use of project management software).

#### *4.1.1 Priority 1: Control project performance*

Two approaches were identified for improving the preparation for controlling project performance, adding more projects in courses and a project management course. The first requires no change to the curriculum, whereas the second would require shifting priorities in an already full 6-year undergraduate curriculum. Therefore, it was concluded that a significant project should be assigned in at least one course per semester of the curricula. The projects should be applied to contemporary industry problems and students should be evaluated using authentic evaluations [11]. Projects should require the students to make decisions, write reports, give presentations of progress and develop analytical skills. Where appropriate, team projects and projects across more than one course, level or in common courses with interdisciplinary teams should be used [3, 12, 13] to enhance teamwork and communication abilities. As a result of this study, formal project planning was incorporated into the pre-thesis preparation course. Other courses, both common and discipline specific, were also identified for inclusion of team projects.

#### *4.1.2 Priority 3: Use of project management software*

Students should be exposed early to formal project management concepts and software and be expected to use it for projects throughout the curriculum [12]. Formal team projects exist in several courses including Introduction to Engineering and Project Evaluation. In addition, at U. Andes, an undergraduate thesis project must be submitted in order to receive the title of engineer. These projects commonly last from 4 to 12 months.

### *4.2 Communication and teamwork initiatives*

Most of the competencies in the Communication and Teamwork category were identified by one or more criteria. Teamwork and oral communications were identified as top priorities. Written communication and communication with people of other disciplines were in the second priority. The ability to negotiate was a third priority.

#### *4.2.1 Priority 1: Oral communications and listening*

A key to developing and improving oral communications abilities is practice and feedback. Presentations should be integrated in courses throughout the curriculum. A standard rubric should be used for all written and oral communication throughout the curriculum beginning with diagnostic evaluations upon entry into the university [14]. Accumulating the evaluation results in a web format that is accessible to the students can help them track progress and enable the faculty to recommend targeted remediation. Depending on the level of proficiency, students may have to attend courses or workshops or to repeat the diagnostic evaluations.

In some cases, it is not feasible for all team members or all individuals to give an oral presentation in a given class due to the length of time required. In this case, all students should be required to prepare a presentation and the professor should "randomly" choose students to present. This method was very successful in the Operations Management course. Alternatively, the students should be required to submit a recording of their presentation for evaluation. In the Introduction to Engineering course, the teams were required to submit a recorded presentation, evaluate their presentation relative to a standard rubric and ultimately revise the presentation for resubmission. The presentations were also graded by teaching assistants, who reported a significant improvement between the first and second presentations.

The student organization or faculty should organize public speaking workshops throughout the year. The workshops should include expert speakers and speech writers providing guidance to improve oratorical skills. These may include such topics as vocalization, modulation, diction, voice projection, breathing and word selection. A speaking club like Toastmasters or a debating club would also encourage students (and professors) to develop and refine their oral communication abilities.

#### *4.2.2 Priority 1: Teamwork*

Often associated with projects, teamwork is also integrated into active learning classroom environments by clustering students around questions or problems [15]. The purpose of teamwork should be made clear to students [16]. Project teams should use self and peer evaluations to reduce shirking [17] and increase the students' ability to provide and receive constructive criticism [14]. When self and peer evaluations are formally introduced and their purpose clarified, they can promote enthusiasm and engagement by creating reflective learners [18].

Teams should be assigned, rather than self-selected to ensure teams are diverse. Students were allowed to choose their own teams in the Introduction to Engineering class one semester before this study. The students tended to group themselves according to prior friendships and the entire cohort of new students did not mix as well as it did the following year when teams were assigned by the professor. In addition, on peer evaluations, there was more of a tendency to inflate the contributions of friends than teammates who had previously been unknown.

Games and competitions provide a good framework for exercising team dynamics. An example introduced into the Introduction to Engineering course was a team activity in which large teams were required to build a model to given specifications. The time to build the model was recorded at the end of each build for three cycles giving teams a spirit of competition. Then a second design was built three consecutive times. Through this activity, students learned how to develop and improve the team processes. Analysis of videos of the fastest and slowest teams was used to emphasize the difference between effective and ineffective team dynamics.

Teamwork workshops should be conducted throughout the year. Attendance should be mandatory for select groups, like students of Introduction to Engineering, and optional for others. These workshops should help participants to understand that everyone can make a valuable contribution and show how to generate open and respectful communication between members.

#### *4.2.3 Priority 2: Written communications*

Written communication should be representative of the memos, reports, plans and specifications that are common in industry [11]. These should be required and use a standard rubric throughout the curriculum. Templates and formal instruction on professional writing help ensure that students understand the professors' expectations. Team teaching collaboration with engineering and English professors to provide students with the necessary depth of feedback can help improve their communication skills [14]. Formal communication instruction and grading by teaching assistants from the English department is another option [19]. Providing consistent feedback and requiring resubmission of corrected works reinforces the necessity of professionalism and precision in writing [20]. A teaching assistant from the school of journalism provided corrections for the communications aspects of reports in the pre-thesis course. The feedback was incorporated into later reports resulting in finished products of a much higher quality than had been the case the previous year.

#### *4.2.4 Priority 2: Interdisciplinary communications*

Specific minors and general education courses should be promoted when advising students to encourage opportunities for interdisciplinary communication. For example, the Organizational Psychology minor provides an understanding of how to contribute to and stimulate the successful development of teams within a company, reconciling the objectives of the institution with personal and professional people at work. This and other minors can help students to broaden their connections to a diverse group of students.

Social work projects also expose engineering students to an interdisciplinary environment and it gives them a sense of social responsibility. At U. Andes, there are annual social projects organized by the engineering student association and by the university life organization in which engineers participate. During the annual "solidarity week," student social work accomplishments are highlighted and non-profit social organizations show opportunities for student involvement in their work.

#### *4.2.5 Priority 3: Negotiation*

Regular workshops to cover topics in negotiations and interpersonal relations should be available to students in an extracurricular speaker series. These workshops should include the dynamics of conducting meetings and negotiating with customers and suppliers. Speakers from industry should provide examples and advice relevant to engineering.

### *4.3 Quality practices initiatives*

The general topic of quality management was identified as important by criterion 3. This is a topic already emphasized from an ethics perspective and in the marketing course. Short of adding a quality management course to an already full curriculum, workshops and additional emphasis on quality should be added to courses throughout the curriculum.

### *4.4 Ethics and legal issues initiatives*

In the category of 'Ethics and legal issues', professional ethical standards and avoiding conflicts of interest were identified as priority level 1 competencies. Environmental responsibility and workplace safety were identified at priority level 2.

#### *4.4.1 Priority 1: Professional ethics and conflict of interest*

Whereas ethics is covered many times in specific courses, ethics cases should be included in many courses throughout the curriculum. Beginning with the Introduction to Engineering course, the basis for ethical decision making was defined and student teams were required to analyze various ethics cases. For each case, students wrote recommendations and their justification and their positions were discussed in a larger group. The cases were considered on the basis of morality, professional ethics and criminal and civil legal implications.

An engineering ethics course can have a sustained positive influence on the moral reasoning skills of students [21]. At U. Andes, it was recommended that the existing general ethics course be replaced with an engineering ethics course or that sections be specifically tailored to engineering students. The course should have applications from each engineering major and general subject area of the faculty to sensitize them to the ethical considerations in a wide range of engineering and business environments. Presentations by working engineers on ethics topics should be interspersed in courses or organized in the lecture series hosted by the engineering student organization. Exhibitors should be experienced engineers. They should recount situations where ethics and professional standards were the keys to the success or failure of an endeavor.

Many students entering universities in Chile have cheating and copying habits. It is most desirable to develop a sense of ethical responsibility in students. However, in the short-term, it is also desirable to help students break these habits. Two measures were proposed for curtailing cheating by students. The first was to provide more rooms for examinations and tests so that students have more distance between them and thus preclude plagiarism. This is challenging, given the shortage of large classrooms on campus. The second measure was to use portable monitoring systems and separating walls to isolate students during tests. This could prevent students prone to cheating from having access to the work of their friend or neighbor. Ultimately, the crutch of cheating can give way to a sense of responsibility and confidence. Given removable walls, an ordinary classroom can readily be transformed into an evaluation room and vice versa.

#### *4.4.2 Priority 2: Environmental responsibility and workplace safety*

Environmental responsibility and workplace safety are typically addressed in industrial and environmental engineering programs. Engineers usually need to rely on companies to provide job-specific training programs for these topics. Presentations by industrial safety engineers and government regulators in relevant courses and extracurricular lecture series could sensitize all engineering students to the need for ensuring the safety of workers and the environment.

### *4.5 Finance and accounting initiatives*

Important competencies in the Finance and Accounting category included the ability to make a budget at priority level 1 and being able to estimate costs and perform economic analysis and risk analyses at priority level 2.

#### *4.5.1 Priority 1: Making a budget*

The ability to set a budget is required in the comprehensive project courses of every engineering major at U. Andes. In addition, students of the Project Evaluation course, which is required of all majors, develop cost estimates and budgets for a team project. As a result of this study, a costing and budgeting activity was added to the Introduction to Engineering course to introduce the topic earlier in the curriculum.

#### *4.5.2 Priority 2: Cost estimation and economic and risk analyses*

Cost estimation and economic and risk analyses are integral components of the Project Evaluation course required of all students of engineering at U. Andes. Therefore, this course was reviewed for the depth of coverage and effectiveness of its evaluations.

### *4.6 Supervision and leadership initiatives*

In the Supervision and Leadership category, competencies at all three levels of priority were found. The ability to form teams was found at priority level 1. The abilities to empower others, manage conflicts and make decisions were found at priority level 2. The ability to conduct meetings was a level 3 priority. The competencies at priority levels 1 and 2 could be addressed by the same initiatives.

#### *4.6.1 Priorities 1 and 2: Team formation, empowerment, and conflict management*

Team projects are at the heart of learning team formation, empowerment and conflict management. However, students of engineering at U. Andes typically have teams assigned to them. So to the extent they form teams, it is the roles and responsibilities that they are able to decide. Given a higher number of team projects throughout the curriculum, students should be reminded of concepts such as empowerment, leadership, and task distribution before each new project assignment.

The student organization is a key factor to generate leadership and other skills that students sometimes do not learn in the classroom. The student organization should be supported through both the university life organization and the faculty so that they can generate activities such as lectures, workshops, socials, seminars, recreational activities, competitions and debates that directly support the engineering program's educational objectives. Two initiatives were recommended to support the student organization at U. Andes. The first was to generate an item in the budget of the faculty specifically for the organization to support its activities. The second was for the faculty to visibly support, encourage and even partner in the development of student activities. For example, permitting announcements in classes and co-sponsoring the speaker series. These proposals are currently being considered by the faculty administrators.

Activities, seminars and workshops geared toward strengthening leadership should be integrated into the courses and the speaker series of the university life and engineering student organizations. Speakers should be leading professionals from different areas of engineering to highlight the various leadership styles and roles. These leaders could share experiences of their own industries, and explain how various teamwork problems were addressed.

#### *4.6.2 Priority 3: Conducting meetings*

Students conduct their own team meetings for project work, generally without any formal understanding of how to conduct an effective meeting. As with team dynamics, the concept of how to conduct a meeting should be formally introduced early and reinforced throughout the curriculum.

### *4.7 Creativity initiatives*

Many facets of creativity were identified as important. The highest priority was being innovative in the workplace. The second priority was entrepreneurship. The third priority was creative problem solving.

#### *4.7.1 Priority 1: Innovation*

Increasing involvement of students in the research of professors in the faculty can improve student's abilities to innovate [22]. This can be facilitated through a comprehensive website with research summaries and brief presentations of ongoing research in courses. After this study, presentations of ongoing research were incorporated into the Introduction to Engineering course and, as a result, some first-year students have already expressed interest in participating in research. Student projects in the comprehensive project courses (e.g., Project Evaluation) also include some segments of ongoing research. In addition, research topics are often offered and accepted as options to students for their undergraduate thesis.

#### *4.7.2 Priority 2: Entrepreneurship*

One initiative resulting from this study was the formation of a leadership club, *Actúa X Chile* (i.e., Act for Chile), whose goal is to enable graduates to develop enterprises on behalf of the University in three major areas: social, business and public service. Through its Center of Public Leadership, Innovation and Entrepreneurship, the university life organization provides competitive grants for the same purpose. In the year of this study, 30 projects were proposed, of which 25% were from engineering students and a total of 12 were funded. A more focused engineering specific fund and evaluation process would enable the faculty to set priorities that support the faculty strategy initiatives.

The existing comprehensive project courses could also include business administration students, though coordination with the course objectives in the business faculty would need to be developed. This would promote entrepreneurial spirit among the engineering students and perhaps lead to projects with business potential [23].

#### *4.7.3 Priority 3: Creative problem solving*

A standard research-based problem-solving strategy should be instilled across several or all courses in the curriculum [24]. For example, scientific method was introduced in laboratory the Fluid Mechanics and the Introduction to Engineering courses as a standard approach to research and problem solving. Another approach is the use of the Socratic Method in engineering classes to ensure that students understand the often intuitive solution process, rather than just provide an answer [25]. Students should refine their ability to formulate creative solutions to problems through the use of this approach. By having to fully justify their reasoning process, students will also learn more advanced presentation and communication skills.

An engineering entrepreneurship minor is another approach to motivate innovation and ingenuity of engineering students as they move through the curriculum. [26]. Students' motivation is enhanced through competition. Local competitions within and outside of courses promote creativity and teamwork. An example is the pasta bridge contest. Competing teams are given a specific kit of pasta and glue and their bridges are tested for strength during engineering week. Formal competitions are also being used by prospective students who visit during weekend events. For example, prospective engineering students designed and built seismic resistant bridges, which they then drove a remote controlled car through while it was shaken. Incoming students reported that the experience affected their enrollment decision. More competitions like this should be added to extracurricular activities hosted by the engineering student organization.

### *4.8 Strategy initiatives*

Two competencies were identified at the second priority level: competitive analysis and resource planning. Competitive analysis was already part of the Project Evaluation course. Like budgeting, the more broad resource planning should be included in projects in the Project Evaluation course or thesis projects. Financial resource budgeting was addressed under the category of Finance and Accounting. Human resource planning is now emphasized in team projects, which require that a responsibility matrix be generated. This begins in the first semester Introduction to Engineering course and is carried through to more advanced courses that have team projects.

### *4.9 Other initiatives*

Two other competencies were identified as having level 2 priority: professional attitudes and personal relations. The engineering curricula at the U. Andes require three internships, which help develop the professional attitudes of its students. After students perform an internship, the companies fill out an evaluation form. An evaluation of interpersonal skills should be added to the form and the feedback should be provided to the students so they can improve their performance using the workshops and other initiatives proposed above.

Students should be encouraged to participate in extracurricular activities to improve interpersonal relationship abilities by interacting with others. The university life organization creates many opportunities for engineering students to interact with students from other departments. Their activities include art exhibitions, sports competitions, seminars and recreation. The engineering student organization should have discussion forums in which graduates can present and discuss with students the realities of the workplace. It is important for them to emphasize how they solve problems and relate to peers, managers and others throughout the organization.

### *4.10 Competencies rejected by selection criteria*

It was also useful to review the list of competencies not identified as important by any of the criteria. This list shows the material that does not need in-depth coverage in the curriculum.

- Project Management Competencies
  - Manage project risk
  - Manage project costs
  - Manage time and project deadlines
- Communication and Teamwork Competencies
  - Build networks
  - Interview job applicants
  - Train workers and customers
- Quality Practices Competencies
  - Be aware of quality standards
  - Use quality diagnostic tools
  - Ensure quality standards
  - Continuously improve processes
  - Perform statistical process control
  - Orient quality to customer requirements
- Ethics and Legal Issue Competencies
  - Be aware of intellectual property rights
  - Have a sense of social responsibility
- Finance and Accounting Competencies
  - Have knowledge of financial accounting
  - Allocate indirect costs

- Supervision and Leadership Competencies
  - Coach and motivate
  - Conduct performance evaluations
  - Manage change
- Strategy Competencies
  - Make a strategic plan
- Other Competencies
  - Be punctual
  - Have an interest in more professional training

Many traditional business manager roles were not selected by the criteria including, for example, managing risk, networking, interviewing and training workers, customer quality, intellectual property, social responsibility, financial and managerial accounting, coaching and motivation, performance evaluation, and strategic planning. Also, whereas quality management was selected as an important competency, specific details were not considered very important.

### *4.11 Implementation process*

Pizarro [10] recommended the formation of a standing committee to ensure, through the proposed initiatives or others generated by the committee, that graduates develop the most important non-technical competencies identified by this study. This committee should be composed of faculty administrators, engineering professors, members of the engineering student organization, graduates and industry representatives [27]. Furthermore, to continue responding to the constantly changing job market, this study should be repeated every five to 10 years. The methodology of this study can be generalized to other colleges and universities and other departments interested in assessing non-core or even core competencies in the curriculum.

## 5. Conclusions

The results indicate that to managers in Chile, the most important non-technical competencies are in the areas of project control, ethics, communications, teamwork, innovation and budgeting. In particular, the non-technical competencies identified as most important were the following: control project performance, communicate effectively orally, listen to others, work effectively in teams, have professional ethical standards, recognize and avoid conflicts of interest, make a budget, form teams and innovate in the workplace. These competencies were similar to those found to be most important by studies in other countries. However, in Chile, there was a heavier emphasis on ethics and innovation and less emphasis on quality and customer focus. Given the similarity in the findings, the recommendations in this paper should be relevant well beyond the borders of Chile.

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## 1. Appendix: Competencies Identified by Criteria 1, 2 and 3

The tables in this appendix show the competencies identified by the three criteria: 1) High scoring median, 2) Hypothesis test, and 3) Priority, indicated in Section 3. The column labeled "Priority" indicates the priority based on the classification described in Section 4.

**Table A.1.** Project Management competencies

| | **Criteria** | | | |
|---|---|---|---|---|
| **Competency** | **1** | **2** | **3** | **Priority** |
| a. Control project performance | 55% | 60.3 | 30.94 | 1 |
| b. Manage project risk | – | – | – | – |
| c. Manage project costs | – | – | – | – |
| d. Manage time and project deadlines | – | – | – | – |
| e. Use project management software | – | – | 3.92 | 3 |

**Table A.2.** Communication and Teamwork competencies

| | **Criteria** | | | |
|---|---|---|---|---|
| **Competency** | **1** | **2** | **3** | **Priority** |
| a. Communicate effectively orally | 63% | 6.5 | 3.99 | 1 |
| b. Communicate effectively in writing | – | 6.3 | 3.91 | 2 |
| c. Listen to others | 63% | 6.5 | 4.00 | 1 |
| d. Communicate with workers from other disciplines | – | 6.3 | 3.88 | 2 |
| e. Negotiate | – | – | 4.02 | 3 |
| f. Build networks | – | – | – | – |
| g. Interview job applicants | – | – | – | – |
| h. Train workers and customers | – | – | – | – |
| i. Work effectively in teams | 68% | 6.6 | 3.97 | 1 |

**Table A.3.** Quality Practices competencies

| | **Criteria** | | | |
|---|---|---|---|---|
| **Competency** | **1** | **2** | **3** | **Priority** |
| a. Manage quality | – | – | 3.77 | 3 |
| b. Be aware of quality standards | – | – | – | – |
| c. Use quality diagnostic tools | – | – | – | – |
| d. Ensure quality standards | – | – | – | – |
| e. Continuously improve processes | – | – | – | – |
| f. Perform statistical process control | – | – | – | – |
| g. Orient quality to customer requirements | – | – | – | – |

**Table A.4.** Ethics and Legal Issues competencies

| | Criteria | | | |
|---|---|---|---|---|
| **Competency** | **1** | **2** | **3** | **Priority** |
| a. Have professional ethical standards | 90% | 6.8 | 3.93 | 1 |
| b. Have a sense of environmental responsibility | – | 6.2 | 3.91 | 2 |
| c. Be aware of the responsibility for workplace safety | – | 6.3 | 3.95 | 2 |
| d. Recognize and avoid conflicts of interest | 61% | 6.4 | 3.99 | 1 |
| e. Be aware of intellectual property rights | – | – | – | – |
| f. Have a sense of social responsibility | – | – | – | – |

**Table A.5.** Finance and Accounting competencies

| | Criteria | | | |
|---|---|---|---|---|
| **Competency** | **1** | **2** | **3** | **Priority** |
| a. Estimate costs | – | 6.3 | 3.78 | 2 |
| b. Perform an economic evaluation | – | 6.3 | 3.81 | 2 |
| c. Make a budget | 61% | 6.5 | 3.96 | 1 |
| d. Have knowledge of financial accounting | – | – | – | – |
| e. Allocate indirect costs | – | – | – | – |
| f. Perform risk analysis | – | 6.0 | 4.07 | 2 |

**Table A.6.** Supervision and Leadership competencies

| | Criteria | | | |
|---|---|---|---|---|
| **Competency** | **1** | **2** | **3** | **Priority** |
| a. Form teams | 63% | 6.6 | 3.98 | 1 |
| b. Empower people | – | 6.1 | 3.79 | 2 |
| c. Coach and motivate | – | – | – | – |
| d. Conduct performance evaluations | – | – | – | – |
| e. Conduct meetings | – | – | 4.01 | 3 |
| f. Manage conflict | – | 6.4 | 4.15 | 2 |
| g. Manage change | – | – | – | – |
| h. Make decisions | – | 6.4 | 3.98 | 2 |

**Table A.7.** Creativity competencies

| | Criteria | | | |
|---|---|---|---|---|
| **Competency** | **1** | **2** | **3** | **Priority** |
| a. Innovate in the workplace | 52% | 6.4 | 4.1 | 1 |
| b. Be entrepreneurial | – | 6.2 | 3.8 | 2 |
| c. Make a proposal | – | 6.4 | – | – |
| d. Solve problems creatively | – | – | 4.01 | 3 |

**Table A.8.** Strategy competencies

| Competency | Criteria 1 | 2 | 3 | Priority |
|---|---|---|---|---|
| a. Perform a competitive analysis | – | 6.3 | 3.94 | 2 |
| b. Make a strategic plan | – | – | – | – |
| c. Plan resource usage | – | 6.2 | 3.91 | 2 |

**Table A.9.** English Communication competencies

| Competency | Criteria 1 | 2 | 3 | Priority |
|---|---|---|---|---|
| a. Be able to speak English | – | 6.3 | – | – |
| b. Understand spoken English | – | 6.2 | – | – |
| c. Be able to write in English | – | 6.1 | – | – |
| d. Be able to read in English | 51% | 6.3 | – | – |

**Table A.10.** Other competencies

| Competency | Criteria 1 | 2 | 3 | Priority |
|---|---|---|---|---|
| a. Have professional attitudes | – | 6.4 | 3.78 | 2 |
| b. Have ability to relate to people | – | 6.6 | 3.93 | 2 |
| c. Punctuality | – | – | – | – |
| d. Be able to organize and prioritize multiple tasks | – | 6.4 | – | – |
| e. Show interest in further training professionally | – | – | – | – |

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