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Development of Communication Skills in a Capstone Project Course

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***Abstract*– Communication skills play a pivotal role in the professional activities of engineers. This article delineates activities designed to enhance communication skills of engineering students within the framework of a capstone project course. These activities foster the development of verbal and non-verbal communication skills for diverse audiences. Statistics from the last three years reveals satisfactory results in overall communication skill development, while highlighting a need for further enhancement in written communication abilities.**

***Keywords*—Communication skills, capstone project.**

I. Introduction

Communication skills play a crucial role in the professional lives of engineers. Training in these skills can increase professionals' self-efficacy in this field [1]. Additionally, a study among engineering graduates found a significant relationship between the verbal and non-verbal components of communication skills and employability [2].

It is important to note that verbal communication encompasses a variety of strategies, such as oral expression and active listening. On the other hand, non-verbal communication includes gestures, facial expressions, eye contact, and body language [1].

Some strategies for developing communication skills include discussions, both individual and group presentations, as well as project teamwork. It is also highlighted that the use of electronic portfolios is an effective tool for students to improve their effective communication skills [3].

One way to assess the impact of communication skills training is through self-efficacy, defined as the perception of one's own performance in this area. Self-efficacy promotes critical self-assessment of changes in performance and communicative behavior. This concept has been widely used to assess the outcome of communication skills development [1].

A study found a positive and significant relationship between communication skills, time management, and student motivation [4]. On the other hand, a comparison between self-assessment of communication skills by a group of students and evaluations by faculty consistently found that self-assessments were lower than evaluations by teachers [5].

The Project Oriented Learning (POL) methodology fosters the development of hard and soft skills. Studies conducted at several universities have shown evidence of a wide range of skills developed in higher education courses in which this methodology is implemented [9]. In the classroom and during teamwork, the discussion of scientific issues in teams helps to develop diverse communication skills, such as understanding others' ideas, valuing others' perspectives, developing active assertions, and fostering shared understanding [7].

The purpose of this article is to describe the activities that have been implemented in a Capstone Project course that promote the development of communication skills and the results obtained, in order to serve as a basis for the design of activities in similar courses, and that this be the starting point in an improvement process.

In order to achieve this goal this article is organized as follows. First, the methodology used and the activities implemented are described. The results obtained are then described using a statistical analysis, through which areas for improvement are identified. Finally, the conclusions are presented and specific actions are proposed aimed at obtaining better results in the aspects that require improvement.

II. Methodology

This article describes the implementation of activities carried out in a Capstone Project course in a Mechatronics Engineering educational program, in which POL has been implemented, from the point of view of the development of communication skills. It also describes the results obtained in the development of these skills.

It is essential to remember that success in creating a quality prototype does not constitute a reliable indicator of the success of the Project-Oriented Learning (POL) process. Measurements focused on the development of skills because of POL application need to be conducted.

The POL methodology began to be implemented in the previously mentioned course in 2011, and various improvements have been made to its design during these years. In this course, students design and build a prototype to help solve a real-life problem.

The project development process is carried out over a period of 15 weeks. During the first three weeks, the teacher, taking on the role of facilitator, presents topics related to the project development process. In those same weeks, students form teams, select a project from a previously approved catalog, and develop the team contract and the preliminary project.

In week 4, students present the preliminary project in an auditorium. Starting in week 5, the teacher's role changes to supervisor. During weeks 5 to 9, students present the progress

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of the project, and the teacher supervises progress. The supervision process is described in [6].

In week 10, students make a second presentation in an auditorium, this time presenting the progress of their project. During weeks 11 to 14 the supervision process continues. In week 15 there is a presentation before an evaluation panel and an exhibition of projects open to the public.

It is important to note that the comprehensive design of the course aims to strengthen a wide range of competencies, so the activities are not explicitly described as aimed at the development of communication skills. Rather, the development of communication competencies in multiple modalities is intrinsically integrated into the overall design of the course activities.

Fig. 1 presents the different stages in which these activities are carried out, from the point of view of the development, assessment, and evaluation of communication skills. The components of the course that contribute to the promotion, assessment and evaluation of communication skills are detailed below.

A. Team Contract

Each team drafts a contract that establishes the rules and guidelines that team members must follow during the project's development. This contract is based on a format similar to legally valid contracts, which includes detailed statements and clauses.

The contract covers various aspects of teamwork. In the initial section, the scope and duration of the contract are defined, while in the statements section, students provide their general information. In the clauses, students explicitly agree to assume the responsibilities and commitments necessary for the project's development, as well as their willingness to be flexible in its execution. Furthermore, the allocation of three key roles in the team is specified: the leader, the secretary, and the treasurer, along with their respective responsibilities.

Students agree on incentives for those who demonstrate outstanding performance, as well as the selection process to determine who will receive such incentives. They also establish penalties for those who fail to comply with the contract agreements.

A significant penalty is the possible removal of a team member, which can only be applied if the conditions set out in the contract are met and the required evidence is provided according to the course guidelines. To avoid ambiguities, the contract is drafted clearly and precisely, ensuring that no team member is penalized if there is no specific clause allowing it.

B. Personal Portfolio

Students manage two types of portfolios: an individual one and a team one. Starting from the fifth week, each student presents a weekly report describing their activities as part of the team during the previous week. This report is integrated into the personal portfolio and includes the following points:

a) Knowledge acquired in the period: Specific knowledge developed or acquired related to disciplines relevant to the project, whether engineering or other related fields, is detailed.

b) Personal contribution to the team: The individual student's contribution to the team's progress in the project is described. Evidence of this contribution is provided, which may include theoretical foundations, analysis, diagrams, calculations, code snippets, drawings, photographs of the development process, among others.

c) Contribution received from team members: Any contribution received from other team members that has impacted the project's development or supported other team members is described.

d) Team situation: The team's challenges are identified, the emotional state of the members is described, and an opinion on the level of efficiency of the team's work overall is provided.

e) Reflection on improving individual contribution: Reflection on the work method, time spent, and efficiency in the activities performed as part of the project is carried out. An opinion on how the student can improve his individual contribution as a team member is included.

f) References: All consulted sources of information are listed using the APA reference format.

The content of individual reports can serve as a basis for the team report.

C. Team Portfolio

Starting from the fifth week, team members present a weekly project progress report, which is incorporated into the team portfolio. This report includes the following:

a) Project progress: The actual progress of project activities is graphically displayed using a Gantt chart or a similar tool, comparing the progress with the initial plan.

b) Team members' activities: A record of the activities carried out by each team member is detailed, including the hours dedicated to each task individually, as well as the team's total dedication in hours.

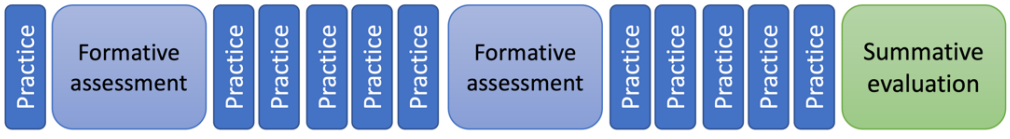


Fig. 1 Organization of activities related to communication

c) Summary of activities performed: This section is fundamental and includes a detailed report of the activities carried out during the period, along with evidence of the work done. This can include the components selection process, theoretical foundations, results of consultations made to sources, calculations, and the design process, among others.

d) Cost analysis: A report on project costs to date is presented, comparing them with the initial budget and providing an adjusted projection of the final project cost.

e) Problems and solutions: The problems encountered by the team during the project's development are identified, as well as the solutions implemented or proposed to solve them.

f) Scheduled activities: The planned activities for the following week are listed, providing a clear guide for the team.

g) References: The main sources consulted by team members during the period are included, following the APA format for citations and bibliographic references.

These sections allow for detailed monitoring of project progress, as well as continuous assessment of activities performed and resources used.

D. Weekly Presentations

Every week, each team meets with the course professor to present the project's progress, using previously prepared material. During these meetings, team members select the most relevant information and present it clearly and concisely, using both visual and oral means.

During these sessions, students can practice oral communication skills using visual and/or audiovisual tools, as described by González et al. [6]. The design of the dynamics of these meetings aims at developing various competencies. Students are challenged to explain and justify their decisions using solid foundations, while the professor provides feedback and asks questions to inquire about the work done and the decision-making processes.

This communication process is bidirectional, allowing students to express their ideas and defend their decisions effectively. Although it is not explicitly stated in Fig. 1, the professor provides feedback to the students about their performance, including the way they communication their ideas, which makes it a part of the formative assessment. As these weekly meetings take place, an improvement in students' communication ability and a decrease in stage fright associated with exposure to the group are observed.

E. Plenary Presentations

During weeks 4 and 10 of the semester, students make plenary presentations in an auditorium in front of a panel of examiners and members of other teams. In week 4, each team presents its preliminary project, while in week 10, they present their project's progress.

The number of examiners may vary depending on the availability of teachers, generally ranging between 8 and 15. These examiners evaluate various technical and non-technical aspects of the presentations, including written and verbal communication and body language.

Each team has eight minutes for their presentation, followed by four minutes allocated for questions and answers. Students must organize their presentation effectively, using resources that allow them to express the main ideas clearly and highlight the positive aspects of their preliminary project or progress within a limited time. During the question-and-answer session, examiners question students about theoretical foundations, decision-making, design, and other project-related topics.

These sessions challenge students to overcome stage fright and stress associated with presenting to authority figures and peers, preparing them to face similar situations in their professional lives.

An important part of this process is the feedback provided by the examiners. Examiners use rubrics to evaluate the students' presentation, and students can review these rubrics when preparing their presentation to know what the examiners will review. Optionally, the reviewers write recommendations and additional observations. This feedback constitutes formative assessment. Additionally, students have access to video recordings of their presentations to review their performance and identify areas for improvement.

F. Project Report and Manual

Team members prepare a project report covering theoretical foundations, feature definition process, and the design and development of the prototype. This document has a maximum length of 70 pages, excluding appendices, requiring students to describe their project concisely and accurately. In addition to the report, a user manual and a maintenance manual for the prototype are prepared.

Before submission, these documents are reviewed by the team advisor, who provides authorization by signature for them to be presented to the professor and to the synodal, a member of the evaluation committee described below. The report and manual are required to be submitted one week before the final project presentation, allowing them to be reviewed in advance before the presentation begins.

G. Final Project Presentation

In week 15 of the semester, students conduct the final presentation of their project before an evaluation committee composed of three panel members: the professor, the team advisor, and the synodal. The synodal is an additional panel member who has not been involved in the development of the project. At the time of the presentation, the professor and the advisor have known details about the project during the duration of the course; the synodal has only seen the two presentations in the auditorium. The final project presentation lasts 90 minutes and consists of the following parts:

a) Project Presentation: Students present their project to the evaluation committee using audiovisual means.

b) Questions and Answers: Panel members ask questions to the students, which can be directed to a team member or

open to be answered by any member of the group. In both cases, the evaluation of the answer affects the entire team.

c) Prototype Demonstration: Students demonstrate the functioning of the prototype to the evaluation committee.

d) Deliberation: The members of the evaluation committee deliberate on the fulfillment of the Capstone Project course requirements, taking into consideration the project report, the user manual and the maintenance manual, the oral presentation, and the demonstration of the functioning of the prototype.

e) Feedback: Panel members provide feedback to the students on the results of their work and their performance in the presentation. Occasionally, this feedback also includes aspects of oral and written communication.

After the presentation, panel members provide project evaluation using rubrics developed for this purpose, which assess aspects of technical and non-technical competencies, including oral and written communication. These rubrics are provided to the students at the beginning of the course.

Additionally, on the same day as the final project presentation, an exhibition of the projects of all participating teams in the Capstone Project course is held. During this event, a competition is conducted where projects are evaluated, and teams excelling in different aspects of the project are awarded. This exhibition provides students with a final opportunity to practice their communication skills before judges and the general public. The results of this competition are not included in the final course evaluation.

H. Self-Assessment

At the end of the semester, students assess the development of their competencies using specific rubrics. These rubrics cover the assessment of technical and non-technical competencies, including the ability to communicate effectively. This self-assessment is not used in the final course evaluation to avoid possible distortions caused by students seeking to improve their results. An objective of this self-assessment is for students to reflect on their own progress and identify areas of improvement for their personal and professional development.

The assessment of effective communication is carried out during the final presentation of the project, described previously. The components of this assessment are shown in Fig. 2.

The professor, the advisor, and the synodal, as members of the evaluation committee, assess the project report, the user manual, the maintenance manual, and the final project presentation using rubrics.

The results of some items of these rubrics are mapped to assess four factors of effective communication. These factors are communication to the public, written communication, tools for communication, and wording, spelling, and vocabulary. Additionally, each student conducts a self-assessment of their communication skills for each of the four factors. Finally, the average scores obtained in each factor by both evaluators and students are calculated to determine the final effective communication score.

III. Results

The results of measurements from 83 students (n = 83) belonging to the Capstone Project groups of the mechatronics engineering academic program of six semesters were analyzed. The measurement results are on a 4-point scale. To carry out the statistical analysis, JASP software was employed. Table 1 presents the statistical data of the measurement scores. It is observed that the mean of the three factors is similar, with a significant difference in the factor of written communication.

TABLE I
TYPE SIZE FOR PAPERS

Statistic	Mean	Standard deviation	Minimum	Maximum
Communication to the public	3.45	0.38	2	4
Written communication	3.05	0.78	0.43	4
Tools for communication	3.45	0.49	1	4
Wording, spelling, and vocabulary	3.46	0.31	2.8	4
Effective communication	3.35	0.33	2.25	3.95

The box plots in Fig. 3 represent the distribution of scores for each of the factors. It is observed that the median of three of the factors is close to 3.5, while the median of the written communication factor is approximately 3.0.

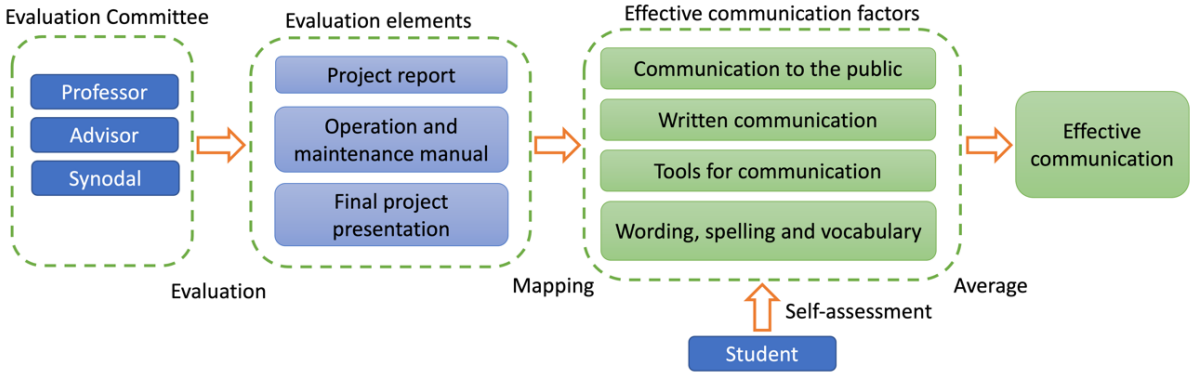
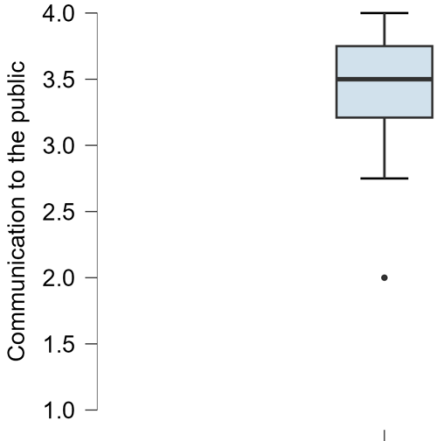


Fig. 2 Components of the effective communication assessment



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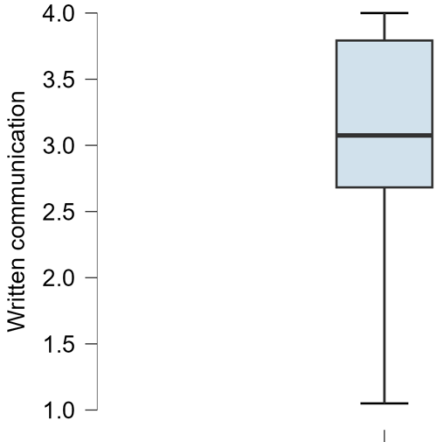

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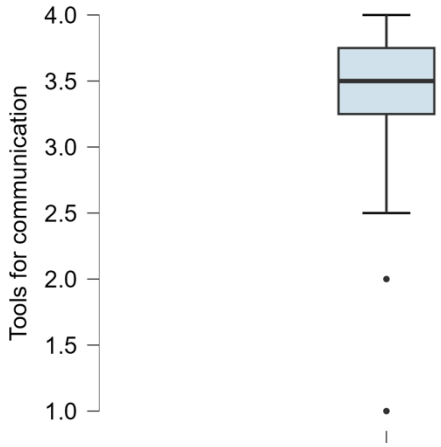
Fig. 3 Box plots of factor scores.



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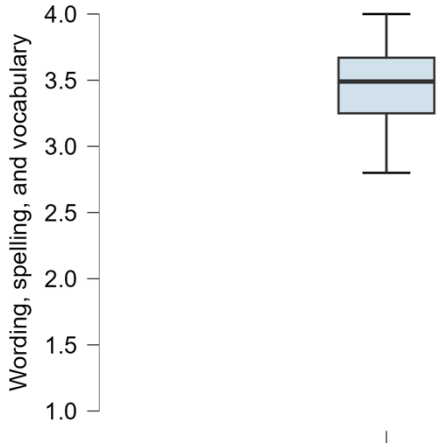
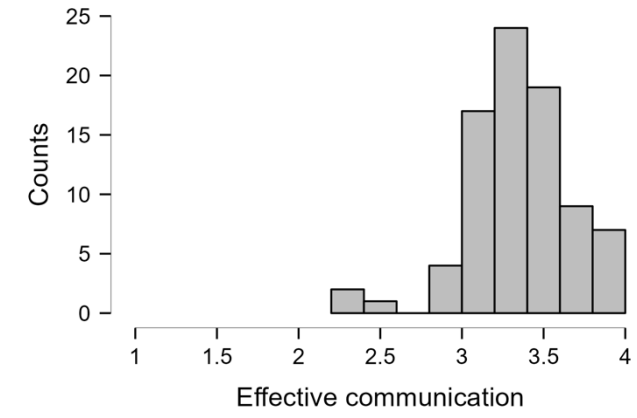


(d)

Fig. 3 Box plots of factor scores (cont.).

Similarly, in three of the factors, the upper and lower quartiles are close to the median, and the dispersion is not significant, although some outliers are observed. In contrast, the scores of the written communication factor show considerable dispersion.

Fig. 4 presents the bar graph and the box plot of the average scores of the factors. Generally, most of the evaluations of effective communication skills have a score of 3 or higher, and they do not show significant dispersion.



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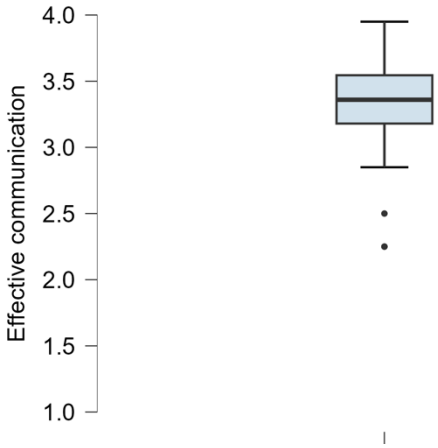

(b)

Fig. 4 Distribution and box plot of effective communication.

IV. Conclusions

The activities carried out in the course are designed to promote the development of various soft skills, including communication skills, as detailed in [6].

Some aspects of communication were measured in this study. The results of the measurements globally revealed satisfactory performance, given that most scores are equal to or higher than 3 on a scale of 4. However, the analysis of the factors highlights an area of opportunity in the realm of written communication.

Based on this analysis, the following modifications are suggested:

a) Implement a more detailed monitoring of the project report writing process throughout the semester, through periodic progress submissions. Research indicates that written communication skills can be improved through the writing of research reports in cycles, with feedback provided to students between each cycle [8].

b) Integrate the evaluation of meeting minutes. It is intended for students to learn to maintain meeting minutes properly during project development meetings, where agreements and commitments are recorded. Currently, these minutes are neither submitted nor part of the formative assessment. It is expected that weekly feedback on the minutes will contribute to reinforcing written communication skills.

At the time of writing this article, suggested modifications are in the design phase. When the design be finished, the modifications will be tested in a pilot group. The results obtained in the pilot group will be reported in a subsequent article.

This article described a set of activities that are designed, among other purposes, to develop students' communication skills in the context of a Capstone Project course. The results obtained were shown from the point of view of communication in general and from the point of view of the specific components of communication. It is expected that the analysis of these results will serve as a basis for planning activities in similar courses and as a starting point for a process of improvement of the components in which lower-scoring results were found.

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