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Development of soft skills while learning numerical analysis

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Abstract

Many authors argue that effective communication in any professional training is a factor that positively influences future job success. Based on these ideas, in the Numerical Analysis course at the Facultad Regional San Nicolás, Universidad Tecnológica Nacional from Argentina decided to design didactic sequences that try to promote the development of communicative competence, both oral and written, while students learn the different numerical methods. The main objective of this work is to show some of the didactic sequences that were designed to contribute to the training of students in terms of communicative competence and to present the rubrics that were developed, based on the evaluation criteria that were established. Assessment instruments were also designed to analyze the degree of development of skills in students. The didactic sequences presented in this paper show what can be done from different subjects of engineering careers to contribute to the development of soft skills in students.

Keywords: Careers; Communication; Engineering; Mathematics; Soft Skills.

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1. Introduction

Nowadays, the development of soft skills at university is increasingly necessary because students need to be trained as active subjects to be able to join the labor market and face its demands when they finish their careers. In this way, it is essential to introduce teaching methodologies in the classroom that allow students to learn or strengthen these types of skills [1]. Therefore, activities where both technical knowledge and the development of skills should be taken into account.

Considering these ideas, the faculty in charge of Numerical Analysis courses at the Facultad Regional San Nicolás (FRSN), Universidad Tecnológica Nacional (UTN) from Argentina, decided to incorporate in their teaching didactic sequences that allow the development and consolidation of such skills. Effective communication is one of the most valued soft skills. This ability refers to the ability to make statements that are not only grammatically correct but also socially appropriate [1].

1.1. Related studies

Many authors compare soft skills to interpersonal skills, but the former is only a facet of soft skills [2]. Regarding this, Sutton [3] states that soft skills are so important that employers recognize them as a key factor for those who aspire to a job regardless of the type of industry or profession. Soft skills are the intangible, nontechnical, personality-specific skills that determine one's strengths as a leader, facilitator, mediator, and negotiator [2].

Some of the most highly valued soft skills with the greatest positive effect in terms of productivity are [4] :

- Communication
- Teamwork
- Resilience
- Respect
- Negotiation
- Creativity
- Responsibility
- Integrity and ethical values
- Initiative
- Empathy and a positive attitude

1.1.1. Effective communication

In the workplace, one of the most valued skills is effective communication. Labrador and Morote [5] consider that this skill refers to the ability to transmit knowledge and express ideas and arguments in a clear, rigorous, and convincing manner, both orally and in writing, using the appropriate resources and means, depending on the characteristics of the situation and the audience.

Koontz and Weihrich [6] argue that to achieve effective communication, the sender must be sure about what he/she wants to communicate, being useful to draw up a plan to reach the desired goal.

1.1.1.1. Oral and written communication

When people speak or write, they are building texts. To do so, it is necessary to master certain skills that have to do with textual properties. These skills, for example, refer to the ability to structure information, use punctuation marks correctly or utilize spelling and grammar rules properly [7]. Table 1 shows the properties of a text along with some indicators to analyze each of them.

TABLE I
TEXT PROPERTIES

Text property	Indicators
Adequacy (Textual property that refers to the adaptation of the text to the communicative situation)	• Communicative intention (purpose intended with the text: inform, give opinions, entertain, convince...) • Approach to the topic (treatment to be given to the information transmitted: general, specific, informative, technical...)
Coherence (Textual property that refers to the transmission of information in a clear, orderly, and understandable way)	• Amount of information (selection of important information to organize it in a way that is clear and logical to the recipient) • Structuring of information (organization of discourse to avoid disorder of ideas) • Information quality (the arguments do not contradict the thesis…)
Cohesion (Textual property that refers to the correct relationship of ideas from the point of view of lexicon and grammar)	• Correct use of punctuation marks. • Use of discourse connectors to relate ideas (connectors of time, space, exemplification, explanatory, cause, consequence...) • Appropriate use of verbal mode. • Appropriate use of grammatical agreement relations (agreement between subject-verb and between noun – adjective).
Correction (Textual property that consists in respecting the rules that govern the correct use of the language)	• Correct use of the lexicon. • Proper use of spelling and grammar rules.

1.2. Purpose of study

The main objective of this work is to show the didactic sequences developed to strengthen both written and oral communication in Numerical Analysis courses, to be applied during the 2022 cycle.

2. Materials and Methods

Assessment instruments were designed to analyze the degree of development of skills in students. First, the changes carried out in the way of developing the subject will be described, then the activities making up the designed didactic sequences will be presented, the objectives pursued by them, and finally, the rubrics designed to analyze the degree of concretion of the established evaluation criteria.

2.1. Changes in the way of teaching Numerical Analysis

Although since 2019 the team of teachers of the Numerical Analysis courses have been working with issues related to effective communication in students, only in the 2021 cycle substantial changes have been made in the way of teaching the subject. One of the first was the change of the activity booklets used in the subject, adding problematic situations where the student, appealing to the given theoretical framework, must justify or explain different situations. Figure 1 shows some of the designed activities.

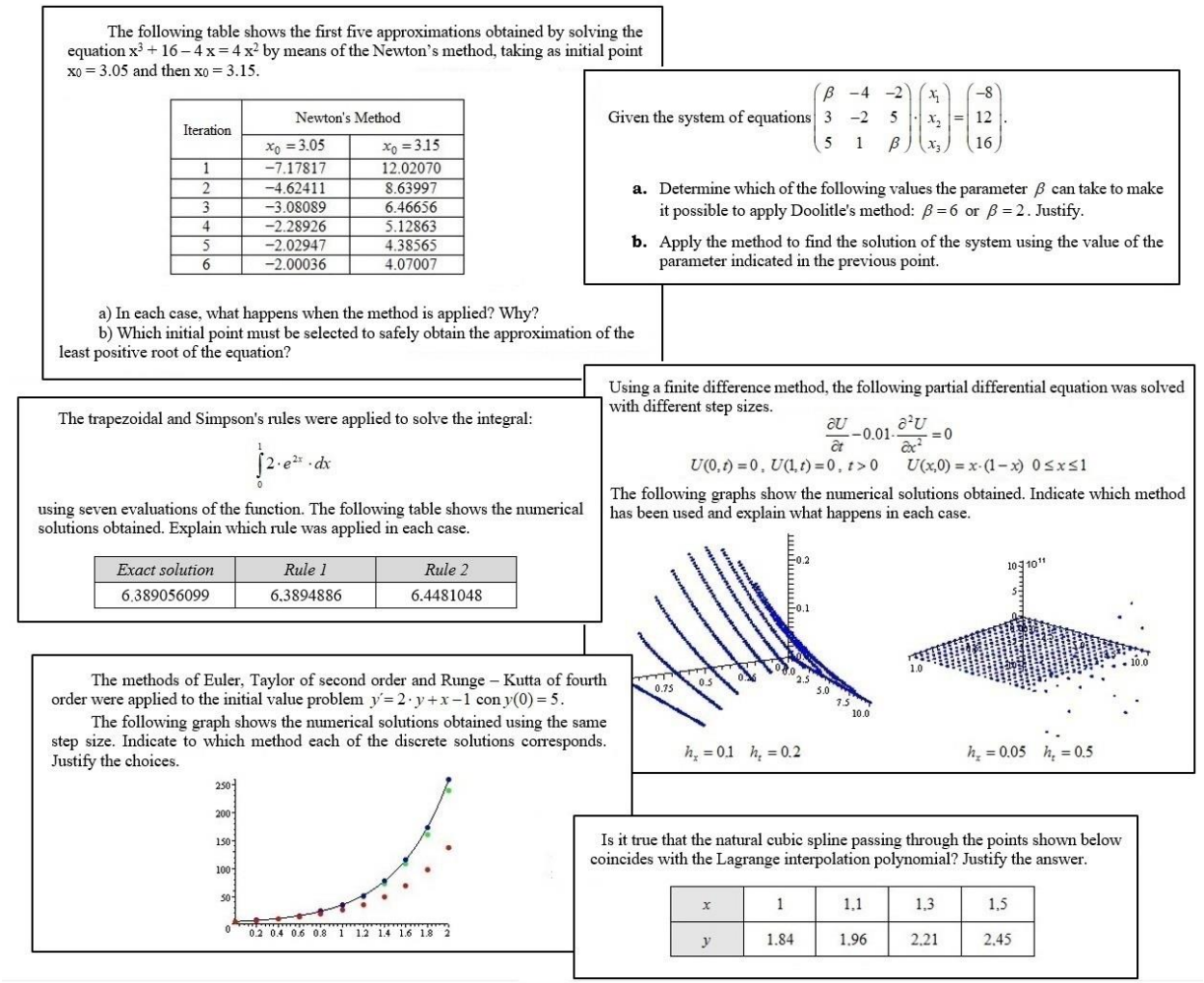


Fig. 1. Activities designed to strengthen or develop written communication

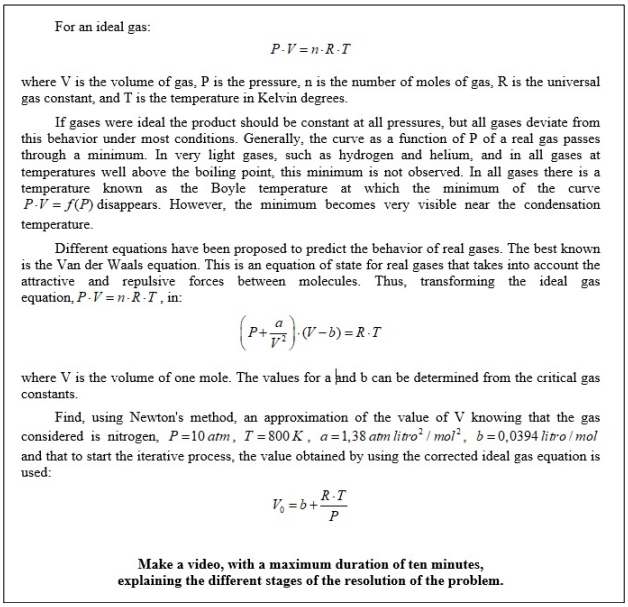
Two practical assignments were also proposed to students. In the first practical work, students had to solve a problem and record a video explaining the steps taken to obtain its solution. Besides, in the second, they had to make a report describing in detail the different stages of the resolution of the proposed problem. Figures 2 and 3 show the statements of the problems proposed in each of the practical works.

It should be noticed that, for the organization of both the oral presentation and the report, the faculty indicated the main aspects that students had to consider. They were:

- statement of the mathematical model that governs the problem.
- identification of the type of mathematical problem to determine the numerical methods that can be applied.
- selection of the most suitable numerical method taking into account the characteristics of the problem.
- obtaining a valid solution using the chosen method.
- presentation of the solution to the proposed problem.

Despite having obtained favorable results, in terms of the impact that this type of activity had on the consolidation or development of communication in students, the teachers proposed to carry out a more

important intervention. To do this, they developed didactic sequences where students not only had to apply the different concepts learned in the subject but also display their skills concerning both oral and written communication.



For an ideal gas:

$$P \cdot V = n \cdot R \cdot T$$

where V is the volume of gas, P is the pressure, n is the number of moles of gas, R is the universal gas constant, and T is the temperature in Kelvin degrees.

If gases were ideal the product should be constant at all pressures, but all gases deviate from this behavior under most conditions. Generally, the curve as a function of P of a real gas passes through a minimum. In very light gases, such as hydrogen and helium, and in all gases at temperatures well above the boiling point, this minimum is not observed. In all gases there is a temperature known as the Boyle temperature at which the minimum of the curve $P \cdot V = f(P)$ disappears. However, the minimum becomes very visible near the condensation temperature.

Different equations have been proposed to predict the behavior of real gases. The best known is the Van der Waals equation. This is an equation of state for real gases that takes into account the attractive and repulsive forces between molecules. Thus, transforming the ideal gas equation, $P \cdot V = n \cdot R \cdot T$, in:

$$\left(P + \frac{a}{V^2}\right) \cdot (V - b) = R \cdot T$$

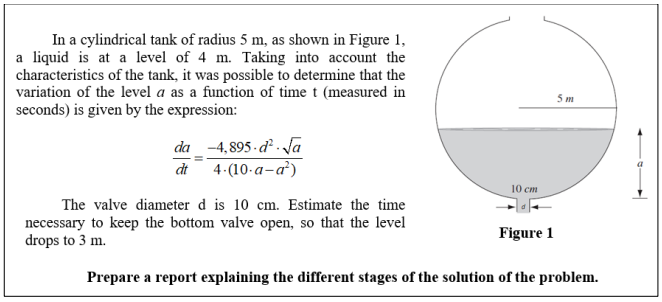
where V is the volume of one mole. The values for a and b can be determined from the critical gas constants.

Find, using Newton's method, an approximation of the value of V knowing that the gas considered is nitrogen, $P = 10\,atm$, $T = 800\,K$, $a = 1{,}38\,atm\,litro^2/mol^2$, $b = 0{,}0394\,litro/mol$ and that to start the iterative process, the value obtained by using the corrected ideal gas equation is used:

$$V_0 = b + \frac{R \cdot T}{P}$$

Make a video, with a maximum duration of ten minutes, explaining the different stages of the resolution of the problem.

Fig. 2. Statement of the problem proposed in the first practical work



In a cylindrical tank of radius 5 m, as shown in Figure 1, a liquid is at a level of 4 m. Taking into account the characteristics of the tank, it was possible to determine that the variation of the level a as a function of time t (measured in seconds) is given by the expression:

$$\frac{da}{dt} = \frac{-4{,}895 \cdot d^2 \cdot \sqrt{a}}{4 \cdot (10 \cdot a - a^2)}$$

The valve diameter d is 10 cm. Estimate the time necessary to keep the bottom valve open, so that the level drops to 3 m.

Figure 1

Prepare a report explaining the different stages of the solution of the problem.

Fig. 3. Statement of the problem proposed in the second practical work

2.2. New didactic sequences

According to Díaz Barriga [8], the didactic sequences constitute an organization of the learning activities that will be carried out with the students and for the students to create situations that allow them to develop meaningful learning.

Based on these ideas, for the teaching of the topics "Numerical solving of nonlinear equations" and "Numerical integration", didactic sequences were elaborated to promote the development of effective communication. In the following subsections, as an example, some of the activities of the didactic sequences that were elaborated on will be presented.

2.3. Numerical solving of nonlinear equations

Figure 4 shows some of the activities that were designed in the unit "Numerical solving of nonlinear equations" to strengthen or develop written communication. All the activities try to make students not

only demonstrate their knowledge regarding the different numerical methods studied but also show that they know how to:

- explain, in a clear way, how a certain method works to calculate an approximation of the solution of a nonlinear equation.
- substantiate precisely why a certain method is not efficient for numerically solving a particular nonlinear equation.
- justify the choice of the necessary information to be able to start the iterative process using any of the numerical methods studied.
- explain in detail whether pseudocode is appropriate to obtain an approximation of the solution of a given nonlinear equation.

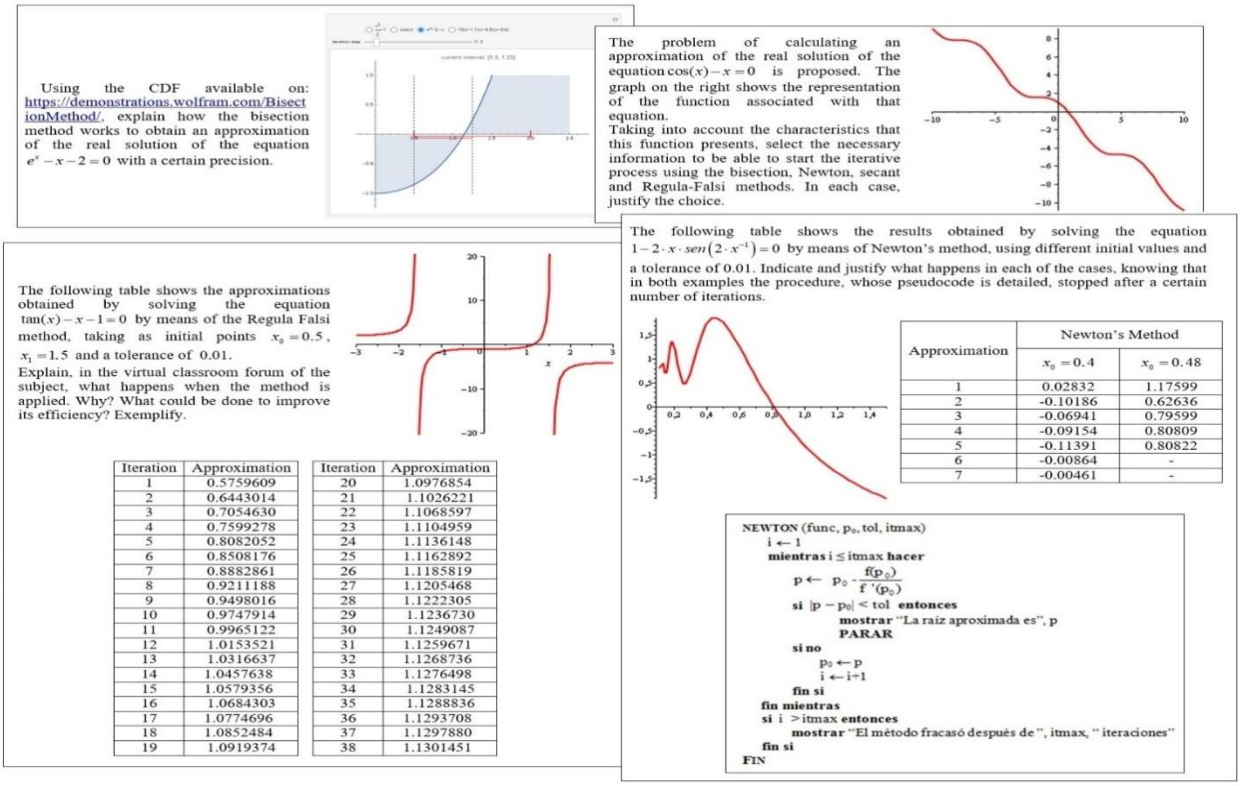


Fig. 4. Activities of the didactic sequence "Numerical Solving of Nonlinear Equations"

2.4. Numerical integration

Similarly, in the unit corresponding to "Numerical integration", a sequence of activities was designed to strengthen or develop oral communication in students. Figure 5 shows some of the activities that were developed. All of them try to make students not only apply the different concepts learned in the unit but also know how to:

- communicate, using language relevant to the context of the situation, the most important steps in the process of solving a numerical integration problem.
- explain, clearly and concisely, the advantages and disadvantages of the different numerical methods studied to solve a definite integral.
- expose and defend, before an audience, the research carried out on a certain engineering problem.

1) The teacher will randomly select six students from the class group.
2) Each selected student must explain to their classmates, according to their criteria, what are the main advantages and disadvantages of the numerical methods studied to solve a definite integral:
   - Trapezoidal Rule.
   - Simpson's Rule.
   - Simpson's 3/8 Rule.
   - Gauss – Legendre quadrature.
3) Each speaker will have a maximum time of five minutes to do their presentation.
4) The teacher, as moderator, will communicate to the rest of the students the topic that is going to be treated and will indicate the rules that will be followed. In addition, it will be the person in charge of giving the floor to each of the exhibitors and of controlling the time that each of them uses to make their presentation.
5) Once the presentations are finished, the teacher will make a summary on the blackboard of the advantages and disadvantages mentioned by the different exhibiting students and will highlight the most notorious differences and coincidences that have been mentioned.
6) Finally, the teacher will invite the class group to ask questions to the student speakers. Each one can make a single intervention.

1) Form groups of no more than five students.
2) Each group will investigate some engineering problem, of their specialty, that requires the numerical resolution of a definite integral. They will have a term of 20 days to solve that problem applying one of the studied numerical methods. The students will be able to make the necessary queries to the faculty during the resolution process.
3) Each group will make an oral presentation lasting between 15 and 20 minutes to explain the proposed problem and the way in which it was solved. In order to carry out the presentation, students may use digital presentations and/or blackboard. The oral presentation must be made by all the members of the group.

1) Form groups of four students.
2) Each group must solve the problematic situation shown below.

If the velocity distribution of a fluid through a pipe is known, it is possible to calculate the flow rate Q (that is, the volume of water passing through the pipe per unit of time) using the integral:

$$Q = \int_0^{r_0} v \cdot (2\pi r) \cdot dr$$

where r is the radial distance measured from the center of the pipe. If the velocity distribution is given by:

$$v = 2 \cdot \sqrt{1 - \frac{r}{r_0}}$$

where r_0 is the total radius, approximate the value of Q considering $r_0 = 2$ cm.

To do this, students can use the customized application available on the website corresponding to the issue.

3) Each group must prepare a document detailing the problem resolution process and select a representative.
4) Each representative must show and explain to their classmates the process of solving the problem carried out by their group.
5) The proffesor, as moderator, will allow the members of the other groups to ask the group that is presenting a maximum of three questions. These questions will be answered by the other three members of the exhibiting group.
6) Among all the members of the different groups, a summary of the most important aspects of the process of solving the proposed problem will be drawn up on the blackboard.

Fig. 5. Activities of the didactic sequence "Numerical integration"

3. Results

The expression learning outcomes refer to what students are expected to be able to do as a result of a learning activity [9]. In the didactic sequences developed, regarding communication, the following learning result was proposed: *Identifies the relevant results of the work carried out in order to communicate them, both in writing and orally, in a language relevant to the context of the situation and communicative intention.*

Table 2 shows the evaluation criteria considered in the didactic sequence "Numerical solving of nonlinear equations", while Table 3 shows those corresponding to "Numerical integration". Using this criterion, it is possible to analyze the concreteness degree of the established learning outcome.

Table II
Evaluation criteria considered in the didactic sequence "numerical solving of nonlinear equations"

	Evaluation criteria
EC.1	Presents the information to communicate in an organized manner.

EC.2	Explains in an understandable and orderly manner the steps taken to solve the proposed problem.
EC.3	Makes a complete and detailed explanation of the resolution process of the proposed problem.
EC.4	Uses in the report a vocabulary appropriate to the context of the situation and communicative intention.
EC.5	Uses appropriate language in the written presentation according to the rules of cohesion.
EC.6	Prepares a report using the correction rules appropriately.

TABLE III
EVALUATION CRITERIA CONSIDERED IN THE DIDACTIC SEQUENCE "NUMERICAL INTEGRATION"

	Evaluation criteria
EC.1	Presents the information to communicate in an organized manner.
EC.2	Explains in an understandable and orderly manner the steps taken to solve the proposed problem.
EC.3	Makes a complete and detailed explanation of the resolution process of the proposed problem.
EC.4	Uses a vocabulary appropriate to the context of the situation and communicative intention.
EC.5	Uses appropriate language in the presentation according to the rules of cohesion
EC.6	Explains the resolution process of the problem with a proper diction
EC.7	es a tone of voice and rhythm in the explanation that maintains the interest of the viewer.
EC.8	akes a presentation with a duration according to the established time.

4. Discussion

4.1. Rubrics elaborated to evaluate the didactic sequences

Rubrics, as Torres & Perera [10] say, are assessment tools to be considered in a context different from the one of conventional evaluation. Using a rubric not only students´ knowledge is evaluated, but they are also useful as a reflection tool to be aware of what has been learned. In a rubric, evaluation criteria are placed in rows and the domain levels, in columns.

Tables 4 & 5 show the analytic rubrics designed to evaluate the activities of the didactic sequences developed.

Table iv
analytic rubric designed to evaluate the activities of the didactic sequence "numerical solving of nonlinear equations"

	Beginner (2 points)	**Basic (6 points)**	**Proficient (8 points)**	**Advanced (10 points)**
EC.1 (20%)	Doesn´t make a well-structured presentation of the resolution process of the problem.	Makes a poorly structured presentation of the resolution process of the problem.	Makes a weakly structured presentation of the resolution process of the problem.	Makes a well-structured presentation of the resolution process of the problem.

EC.2 (30%)	Doesn´t make a clear and well-organized explanation of the resolution process of the problem.	Makes an unclear and not-so-well-organized explanation of the resolution process of the problem.	Makes a clear but not well-organized explanation of the resolution process of the problem.	Makes a clear and well-organized explanation of the resolution process of the problem.
EC.3 (30%)	Doesn´t provide a thorough and detailed explanation of the steps used to resolve the problem.	Provides a non-exhaustive and not-so-detailed explanation of the steps used to resolve the issue.	Provides a thorough but not detailed explanation of the steps used to resolve the problem.	Provides a thorough and detailed explanation of the steps used to resolve the problem.
EC.4 (10%)	Doesn´t use pertinent and technical vocabulary in the explanation	Uses pertinent but not technical vocabulary in the explanation.	Uses pertinent but not very technical vocabulary in the explanation.	Uses pertinent and technical vocabulary in the explanation.
EC.5 (5%)	Does not correctly use the rules of cohesion (relations of grammatical agreement, tense and verbal mode, discourse connectors to relate ideas, unnecessary repetitions of words).	Very limited use of the rules of cohesion (relations of grammatical agreement, tense and verbal mode, discourse connectors to relate ideas, unnecessary repetitions of words).	Limited use of the rules of cohesion (relations of grammatical agreement, tense and verbal mode, discourse connectors to relate ideas, unnecessary repetitions of words).	Correctly uses the rules of cohesion (relations of grammatical agreement, tense and verbal mode, discourse connectors to relate ideas, unnecessary repetitions of words).
EC.6 (5%)	Does not use correction rules properly (spelling and grammar rules).	Uses correction rules very inappropriately (spelling and grammar rules).	Uses correction rules inappropriately (spelling and grammar rules).	Properly uses the correction rules (spelling and grammar rules).

TABLE V

Analytic rubric designed to evaluate the activities of the didactic sequence “numerical integration”

	Beginner (2 points)	**Basic (6 points)**	**Proficient (8 points)**	**Advanced (10 points)**
EC.1 (20%)	Doesn´t make a well-structured presentation of the resolution process of the problem.	Makes a poorly structured presentation of the resolution process of the problem.	Makes a weak-structured presentation of the resolution process of the problem.	Makes a well-structured presentation of the resolution process of the problem.
EC.2 (20%)	Doesn´t make a clear and well-organized explanation of the resolution process of the problem.	Makes an unclear and not-so-well-organized explanation of the resolution process of the problem.	Makes a clear but not well-organized explanation of the resolution process of the problem.	Makes a clear and well-organized explanation of the resolution process of the problem.
EC.3 (20%)	Doesn´t provide a thorough and detailed explanation of the steps used to resolve the problem.	Provides a non-exhaustive and not-so-detailed explanation of the steps used to resolve the issue.	Provides a thorough but not detailed explanation of the steps used to resolve the problem.	Provides a thorough and detailed explanation of the steps used to resolve the problem.

EC.4 (8%)	Doesn´t use pertinent and technical vocabulary in the explanation	Uses pertinent but not technical vocabulary in the explanation.	Uses pertinent but not very technical vocabulary in the explanation.	Uses pertinent and technical vocabulary in the explanation.
EC.5 (8%)	Does not correctly use the rules of cohesion (relations of grammatical agreement, tense and verbal mode, discourse connectors to relate ideas, unnecessary repetitions of words).	Very limited use of the rules of cohesion (relations of grammatical agreement, tense and verbal mode, discourse connectors to relate ideas, unnecessary repetitions of words).	Limited use of the rules of cohesion (relations of grammatical agreement, tense and verbal mode, discourse connectors to relate ideas, unnecessary repetitions of words).	Correctly uses the rules of cohesion (relations of grammatical agreement, tense and verbal mode, discourse connectors to relate ideas, unnecessary repetitions of words).
EC.6 (8%)	Doesn´t pronounce the words clearly and cleanly in the explanation.	Pronounces the words unclearly and uncleanly in the explanation.	Pronounces the words not so clearly and cleanly in the explanation.	Pronounces the words clearly and cleanly in the explanation.
EC.7 (8%)	Doesn´t use an adequate tone of voice and rhythm in his explanation to keep the attention of the viewer.	Uses a tone of voice and rhythm in the explanation that is not adequate to hold the attention of the viewer.	Uses a tone of voice and rhythm in the explanation that is not so adequate to hold the attention of the viewer.	Uses an adequate tone of voice and rhythm in his explanation to keep the attention of the viewer.
EC.8 (8%)	Gives a presentation that doesn't fit the time at all.	Gives a presentation that does not quite fit the established time but the lag is quite significant.	Gives a presentation that does not quite fit the established time but the lag is not significant.	Gives a presentation that precisely fits the time established.

5. Conclusions

One of the most important responsibilities that the teacher has is to propose sequenced activities to their students that allow them to generate an adequate learning climate. The design of a didactic sequence is not limited to the simple development of a series of activities, but rather involves the creation, by the teacher, of true learning scenarios so that the student can learn new knowledge and develop different skills.

The didactic sequences presented in this paper show what can be done from different subjects of engineering careers to contribute to the development of soft skills in students. Professors of Numerical Analysis of careers at Facultad Regional San Nicolás are and will continue working on the development and consolidation of skills related to written and oral communication. It is expected to analyze 2022 the impact on students of didactic sequences like the ones presented here, as well as to design activities to link communication with other skills, such as active listening.

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