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# DESIGN AND IMPLEMENTATION OF A NOVEL DIDACTIC STRATEGY USING LEARNING STYLES FOR TEACHING CONTROL THEORY

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**Abstract**

This paper explains the design and implementation of a novel didactic strategy based on learning styles for teaching automatic control theory in engineering. Traditional research on engineering education has worked to develop teaching methodologies, educational resources, and assessment tasks without considering the learning styles of the students. However, it is important to consider the learning styles of students to increase the number of useful tools that aid students in understanding abstract ideas and difficult concepts. To demonstrate that it is possible to design excellent courses of automatic control by using class activities concerning the learning styles of students. The proposal includes knowing the learning styles of students that enable professors to design appropriate didactic strategies based on the student needs. The proposed didactic strategy is appropriate and enhances the understanding of difficult concepts related to automatic control.

***Keywords –*** Active methodology, Control theory, Engineering education, Learning styles.

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## 1. Introduction

In engineering education, research on new teaching strategies has focused on three major aspects, namely, teaching methodologies (Coelho & Vega, 2019; Forcael, Garcés & Orozco, 2021; Heywood, 2005; Prince, 2004; Samacá & Ramirez, 2011; Sánchez-Azqueta, Celma, Aldea, Gimeno & Cascarosa, 2019), teaching resources for example. electronic media and simulators (Chevalier, Dekemele, Juchem & Loccufier, 2021; Franzoni, Cervantes-Pérez & Robles, 2013; Soares & Wagner, 2011), and assessment strategies (Hassan, 2011). These studies promote active learning, as it improves the understanding of abstract concepts, such as those involved in automatic control theory (Chevalier et al., 2021; Forcael et al., 2021; Samacá & Ramirez, 2011).

Specifically, the teaching of automatic control theory requires not only active learning but also the inclusion of learning styles. Rojas-Palacio, Arango-Zuluaga and Botero-Castro (2022) defines learning styles as a useful tool to identify students' learning preferences and to adapt educational methodologies to benefit these preferences. For example, according to Felder and Silverman's learning style model (Felder & Silverman, 1998), people with a reflective learning style prefer activities centered on theory and mathematical issues, whereas people with a sensitive learning style prefer hands-on activities. Including learning styles has been a controversial issue for some authors such as those presented in Dinsmore, Fryer and Parkinson (2022), Kirschner (2017), Riener and Willingham (2010), and Yan and Fralick (2022) who believe that learning styles are not appropriate to be taken into consideration in teacher training, lesson planning and design new content. On the other hand, the topic of learning styles continues to be a topic of current study as can be seen in Agarwal, Mishra and Kolekar (2022), Almasri (2022), Balgan, Renchin and Ojgoosh (2022), Marosan, Savic, Klasnja-Milicevic, Ivanovic and Vesin (2022), Pardamean, Suparyanto, Cenggoro, Sudigyo and Anugrahana (2022), and Troussas, Giannakas, Sgouropoulou and Voyiatzis (2023), where the authors in Agarwal et al. (2022), Marosan et al. (2022), and Pardamean et al. (2022) use Felder and Silverman's learning styles model for their research which is characterized by having a direct relationship with didactics and allows its applicability in the engineering environment. Also, there are a few authors who considered including learning styles for teaching automatic control (Budiyanto, Fitriyaningsih, Kamal, Ariyuana & Efendi, 2020; Franzoni et al., 2013; Mahmoud & Nagy, 2009; Mastascusa & Hoyt, 1999; Moor & Piergiovanni, 2003; Muñoz-Ochoa, 2018; Rusk, Resnick, Berg & Pezalla-Granlund, 2008; Samacá & Ramirez, 2011; Staehle & Ogunnaike, 2014) in their studies do not cover a complete learning styles model. Those studies select one or two learning styles from a model and therefore focus on the design of one type of didactic resource.

According to the above, to benefit the largest number of students, it is necessary to use a combination of active educational methodologies that allow the design of several activities for the same topic based on student learning styles which was done in Rojas-Palacio et al. (2022) as the first part of this study.

Otherwise, it is important to take into account the design of the general planning of the teaching-learning process, which is defined as a didactic strategy. According to (Feo, 2010) the process of designing a didactic strategy includes designing teaching methodologies, didactic resources, didactic sequences and assessment strategies. These components must aim at achieving skills related to the topics to be taught. In this context, there are studies about teaching automatic control theory in which a fragment of a didactic strategy is developed as in Budiyanto et al. (2020), Franzoni et al. (2013), Khan, Jaffery, Hanif and Asif (2017), Mahmoud and Nagy (2009), Mastascusa and Hoyt (1999), Moor and Piergiovanni (2003), Muñoz-Ochoa (2018), Rasouli, Weissbach and Yeung (2017), Rusk et al. (2008), Samacá and Ramirez (2011), and Staehle and Ogunnaike (2014), but the process of designing a full didactic strategy is not frequently addressed and does not include a full learning style model.

Thereby, according to a review of the above, this study proposes updating the design of a didactic strategy by including learning styles and connecting theory with practice for teaching automatic control concepts using the methodology developed in Rojas-Palacio et al. (2022).

Therefore, this study presents a design for a student-centered didactic strategy, which includes the elements that compose it and integrates one of the models of learning styles using active methodologies to improve the understanding of the linearization and operation point concepts by employing a practical laboratory approach. Additionally, this study presents the necessary steps to design a didactic strategy in a general way with the aim of using it in a different field of engineering and not only in the automatic control field.

This paper is organized as follows. First, presents the definition of terms related to the design of the strategy. Second, presents the didactic strategy and its application to automation control theory. Third, analyzes the results obtained from an engineering course. Finally, presents the conclusions.

## 2. Didactic Strategy Design

### 2.1. Definitions Related to the Design of the Didactic Strategy

To generate the didactic strategy that considers the learning styles of students, it is necessary to clarify the theory and application of the models of learning styles as well as their link with active methodologies.

First, to construct an appropriate definition of didactic strategy that was aligned with the field of engineering education, it was necessary to have the definitions of learning, learning styles and active methodologies. Rojas-Palacio et al. (2022) presented the definitions of these concepts in the specific area of automatic control and engineering education. Therefore, these definitions were adopted for this study. Then, different definitions of didactic strategy were searched to adapt a definition that was relevant to the field of engineering education.

The literature provides several definitions for didactic strategy, as in Avanzini (2004), Campusano-Cataldo and Díaz-Olivos (2017), Feo (2010), Ferreiro-Gravié (2003), Kozulin and Barberán (2000), and Muñoz-Ochoa (2018). A few of these definitions are presented to provide another definition within the framework of this research.

According to Kozulin and Barberán (2000), didactic strategies are instruments that enhance learning activities and problem-solving, whereas Ferreiro-Gravié (2003) defined the didactic strategy as mediation tools between an apprentice who learns, and the teaching content used by an educator to achieve a certain level of learning.

In addition, Avanzini (2004) explained that the didactic strategy denotes a set of procedures supported by teaching techniques that aim to achieve learning objectives. Alternatively, Feo (2010) defined it as procedures that professors and students employ to organize actions to achieve goals in the teaching-learning process and adapt to the needs of students in a significant manner. Conversely, Campusano-Cataldo and Diaz-Olivos (2017) defined it as organized procedures with a clear definition of their stages and intended to achieve the expected learning outcomes.

Based on the above definitions, this study defines a didactic strategy as a result of planning the teaching-learning process, including the selection of techniques and activities, to achieve learning objectives.

Additionally, this paper used the components of a didactic strategy presented by Feo (2010) and Ferreiro-Gravié (2003): problem, objectives, contents, theoretical support, didactic sequence, context, resources, total duration, and assessment strategy, because these components integrate the procedures that allow students to build their knowledge step by step.

### 2.2. Didactic Strategy Based on Learning Styles

To design this didactic strategy based on learning style, it is necessary to choose a learning styles model. For this study, the model selected was the Felder and Silverman model (Felder & Silverman, 1998). This model was selected because Rojas-Palacio et al. (2022) mentioned that this model facilitates the structuring of the didactic strategy because its approach is derived from didactics.

The proposed didactic strategy consists of nine steps. The steps were structured in a general manner, such that they are applicable to any engineering context as well as to other areas of knowledge. In addition, it is possible to return to the previous steps if adjustments during the design process are needed.

Figure 1 represents the process of creating the didactic strategy as an assembly of nine steps that are executed, where each step depends on all the previous steps.

Step 1 consists of performing a search for concepts to be taught, including their levels of difficulty and importance. Thus, this study suggests that professors perform a literature review of the topics to be taught to select the most appropriate concepts according to the current global needs.

Step 2 verifies the contents or subtopics selected in Step 1. A concept should cover many subtopics to enhance understanding. Therefore, the subtopics should be identified based on course needs. For example, to teach the feedback concept in automatic control theory, it is necessary to teach the subtopics block diagrams and closed loops.

After defining the concepts and contents, Step 3 establishes the specific objectives that students must achieve, which will be useful when preparing an assessment.

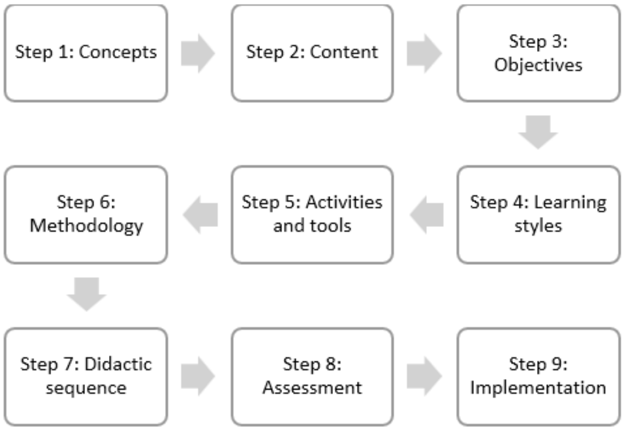


Figure 1. Summary of the steps of the didactic strategy

Step 4 consists of applying the diagnostic instrument of the Felder and Silverman model of learning styles to the students. This allows professors to determine the learning style specific to each student and later generate didactic material according to the needs of the selected concepts. The instrument is available online at https://www.webtools.ncsu.edu/learningstyles/. Students are instructed to take a screenshot of the results and send it to the professors for analysis.

Step 5 selects the activities and tools required for each learning style. It is suggested that professors conduct a review of the learning style model and the specific needs of each style.

Step 6 requires a review of the literature on educational methodologies in the area to be taught and the adaptation of such methodologies to the learning style model.

Step 7 consists of designing the components of the didactic strategy, and it is also necessary to consider the place where the didactic strategy will be implemented. To do that, this study suggests following the guidelines proposed by Ferreiro-Gravié (2003), which provides a detailed review of didactic strategy components, such as methodology, theoretical support, and the didactic sequence.

Step 8 points to the need to create an assessment strategy. This study recommends two types of evaluation: qualitative and quantitative. For example, a rubric with numerical values (quantitative) and a perception survey (qualitative) can be used for evaluation.

Finally, Step 9 implements the didactic strategy. To this end, a small group of students is recommended because it facilitates the implementation of personalized activities and the monitoring of the learning process for each student.

## 3. Methodology

The main objective of this study was to design and implement a didactic strategy using a complete model of learning styles and the methodology proposed by Rojas-Palacio et al. (2022) to improve the understanding of the linearization and operation point concept.

The application of the steps designed in Section 2.2 is shown below.

### 3.1. Data Collection Procedure

First, ethical approval to conduct this study was obtained from the Universidad Nacional de Colombia Ethics Committee. The proposed didactic strategy was applied across the second semester of 2023 distributed as follows: a control group of 11 students and a test group of 16 students. All participants filled a consent form to participate in the study. No participant was asked to provide personal information like name, gender or email addresses, and the surveys were anonymous.

### 3.2. Case study Control: Input-Ouput Course

The didactic strategy from this study was established for one automatic control concepts of the Control: Input-Output course at the Universidad Nacional de Colombia. This course is part of the undergraduate degree in Control Engineering.

For step 1, it was analyzed the review of the literature performed by Rojas-Palacio et al. (2022), and it was obtained a list of the most important automatic control concepts. Then, the most important concepts worldwide and the concepts taught in the Control: Input-Output course were compared to select the topics to teach (Step 2). The concept comparison was made on the basis of the level of difficulty of each concept. The high Level includes concepts that require differential equations, integrals, the Laplace transform, and the derivatives and interpretations of a complex plane. The medium level includes concepts that require only the Laplace transform and differential equations, whereas the low level includes concepts that do not require complex mathematical calculations. Table 1 presents the levels of difficulty associated with each concept of the course. Eight concepts of a high level of difficulty, four of medium level of difficulty and two of low level of difficulty were identified.

| Concept | Difficulty | | |
|---|---|---|---|
| | **High** | **Medium** | **Low** |
| Control history | | | X |
| Closed loop | | X | |
| Transfer function | | X | |
| Block diagram | | | X |
| State space | X | | |
| Linearization and operating point | X | | |
| Frequency response | X | | |
| Time response | X | | |
| Stability analysis | X | | |
| Feedback effects | X | | |
| Effects of PID control actions | X | | |
| Controller design methods | | X | |
| Simulation of controllers | | X | |
| Discretized systems | X | | |

Table 1. Difficulty of concepts of control: input-output course

Now, among the concepts of a high level of difficulty, the concepts of linearization and operation point were selected because those concepts are a fundamental process that must be done to obtain the transfer function of a dynamic system and this topic has a high level of difficulty for students as also shown by the authors in Kheir, Åström, Auslander, Cheok, Franklin, Masten et al. (1996), and Roubal, Husek and Stecha (2010). Also, those concepts must also be taken up again in some courses after the Control: Input-Output course despite having been taught from a basic course such as differential calculus. Furthermore, according to the grades obtained in the theoretical part of the course, only 48.15% of the 27 students who were part of this study obtained a passing score with an average score of 2.59 where 5.0 is the maximum grade and 3.0 is the passing score. For these reasons, it was considered pertinent to strengthen this concept through a new methodology such as the one proposed in this study.

Then, specific objectives were established for the selected concept (Step 3): (1) Identify the difference between the operating point and the equilibrium point of a control system; and (2) perform the linearization process manually to obtain the transfer function of a control system.

Step 4 concerns the identification of the learning styles of the students. For this, an identification of students' learning styles in the Control: Input-Output course was made according to the Felder and Silverman model (Felder & Silverman, 1998). The most predominant styles were the visual style (90.91%), sequential style (72.73%) and sensitive style (63.64%) for the test group. It is important to mention that the didactic strategy was designed for all learning styles, not only for the most predominant styles.

For Step 5, a proposal of the teaching material was prepared (Table 2) in accordance with the model of the learning styles selected.

| Learning style | Didactic material |
|---|---|
| Visual | Graphs diagrams<br>Demonstrations |
| Verbal | Written and oral explanations during the session |
| Sensitive | Real case studies<br>Experiments |
| Intuitive | Mathematical concepts and procedures<br>Mental exercises |
| Active | Practical activities involving students, such as experiments |
| Reflective | Analysis through questions that induce internal reflection in students |
| Sequential | A learning path of the concept from the particular to the general |
| Global | A learning path of the concept from the general to the particular<br>Overview of the concept |

Table 2. Proposal of didactic material according to learning style

Then, in Step 6, it was necessary to select an educational methodology that allows us to use the teaching material generated in Step 5. For this study, it was selected the methodology proposed in Rojas-Palacio et al. (2022). The methodology proposed was a combination of: learning by doing, problem-based learning (PBL), and collaborative learning.

According to (Rojas-Palacio et al., 2022), these three educational methodologies can amplify the effect of laboratory practices to develop the skill of students to associate theoretical concepts taught in a lecture with the complexity of real study cases. Additionally, such methodologies are appropriate for generating teaching materials for all the learning styles of the Felder and Silverman model in a laboratory environment

However, it was necessary to adapt that selected methodology into a new methodology that fits with the activities proposed based on the concepts to be taught, the students' learning styles and the place in which the didactic strategy will be carried out. Figure 2 summarizes the adapted methodology.

To unify theory and practice, this study opted to work under a laboratory practice modality using vertical take-off and landing (VTOL) and heating ventilation air conditioning (HVAC) plants available in the Electronics and Control Laboratory of the Electric Energy and Automatic Department (DEEA) of the Faculty of Mines. In addition, the methodology is mainly based on face-to-face work for two hours per week. Also, students must work in teams to develop a self-contained laboratory guide, in which the professor plays the role of facilitator and guides students in solving their concerns during the sessions.

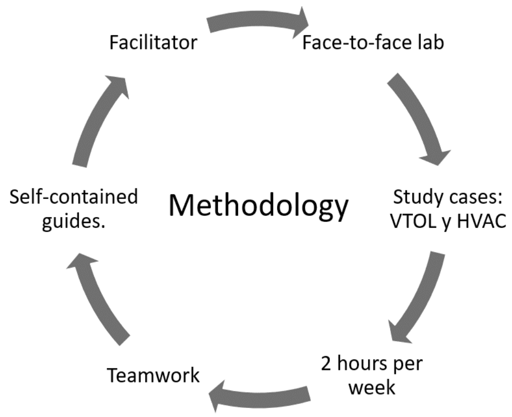


Figure 2. Designed methodology based on laboratory

Step 7 denotes the selection of a place; for this study, it was selected the Electronics and Control Laboratory of the DEEA at the Universidad Nacional de Colombia. For theoretical support, it was selected the methodology proposed in Step 6. Additionally, step 7 consists of designing the components of the didactic strategy. Figure 3 provides a summary of the beginning, development, and closing phases of the proposed didactic sequence.

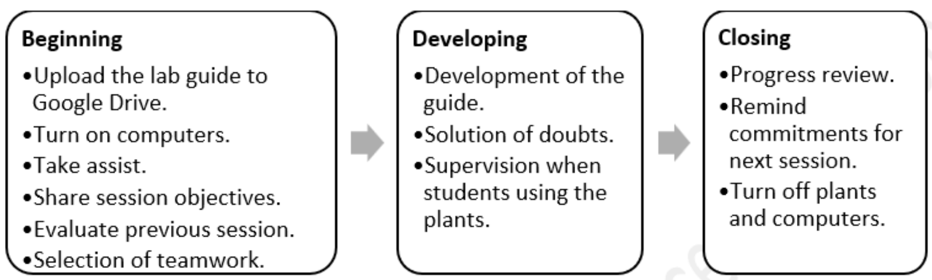


Figure 3. Phases of the didactic sequence

The professor plays two different roles in each phase of the didactic sequence: the role of a designer at the initial phase when designing the laboratory sessions and assessment rubrics and the role of an expert in the development phase when solutions to technical or theoretical questions are needed.

The didactic sequence focuses on laboratory practices. Thus, professors must generate this resource by considering the methodology proposed in Step 6. For this reason, Figure 4 displays the contents of the laboratory guides according to the learning style models of Felder and Silverman, which facilitates the easy construction of the activities for the concept.

Figure 4 illustrates a general structure for the laboratory guide in the automatic control area presented in Table 3. This structure was presented in a general manner, such that all concepts can be easily extrapolated to other fields of engineering. Using this structure, a laboratory guide was designed for linearization and operating point concept.

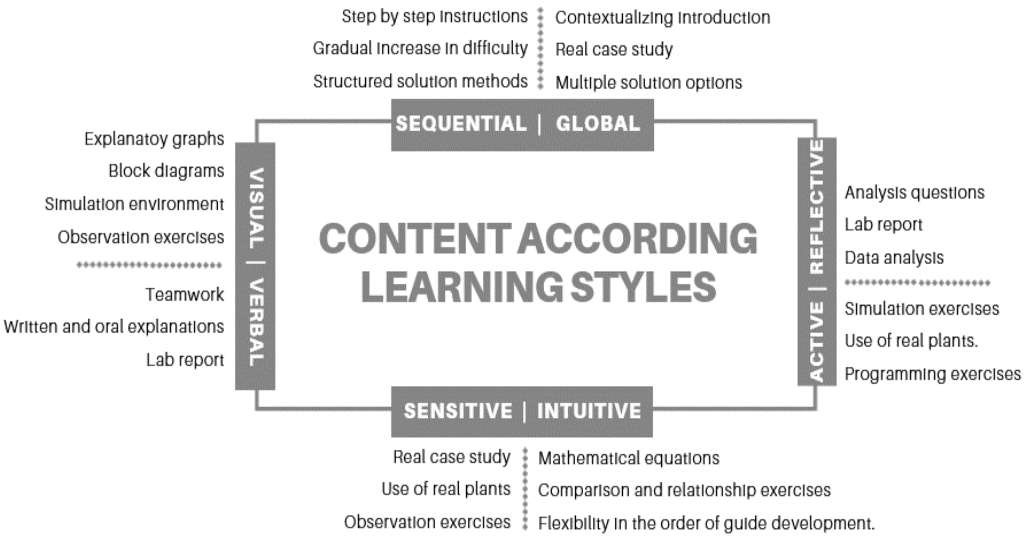


Figure 4. Laboratory contents according to the learning style models of Felder and Silverman

| Components style | Description | Learning style |
|---|---|---|
| Objectives | The objectives that the student must achieve with lab session are described. | Sequential, reflective and verbal |
| Introduction | The student is contextualized about the purpose of lab session and an overview of the concepts to be taught is provided. | Global and verbal |
| Mathematical calculations | Activities of mathematical calculations that the students must do for the correct development of lab guide. | Intuitive and reflective |
| Programming | These are programming activities of an interface that students must develop in a software. | Active and visual |
| Implementation | These are activities of simulation and using real plants. The simulation activities are performed using a specialized software. | Active, visual, and sensitive |
| Assessment description | Students are briefly described how lab guide will be evaluated as well as some tips to sending their lab report. | Sequential and verbal. |

Table 3. General structure of the laboratory guide

For the test group, a lab guide was designed according to the structure presented in Table 3. For the control group the original lab guide was used. The main difference between both guides being that the original guide did not consider the use of real plants and it was based solely on simulation. Also, the original guide did not have graphical explanations.

### 3.3. Instruments

For Step 8, it was formulated an assessment strategy from two perspectives: a rubric by competencies and a perception survey to determine if students acquired the intended knowledge in the linearization and operation point concepts.

The rubric by competencies was designed by adapting the model proposed by Tobon, Pimienta and Garcia (2010) for the objectives identified in Step 3. The Tobon model consists of the following steps: 1) identify the competence to be evaluated, 2) determine the criteria or parameters with which the competence will be evaluated, 3) determine the evidence that the student must deliver to the professor to achieve the required competence, 4) select the levels of mastery of the concept acquired by the student and 5) establish the weighting and score of each of the criteria to be evaluated.

This type of rubric allows a connection between theory and practice, since acquiring a competence implies not only acquiring knowledge but also applying it in a specific context. Also, this type of rubric allows the rapid detection of the difficulties that students may encounter by having a clear outline of what activities must be carried out to acquire competency (Tobón et al., 2010).

Table 4 presents the rubric designed. A passing score of 3.0 was obtained using the scoring scale of the Universidad Nacional de Colombia, with maximum and minimum scores of 5.0 and 0.0, respectively.

For the perception survey, a close-ended questionnaire was disseminated. Items were validated using Cronbach's alpha coefficient (Oviedo & Campo-Arias, 2005). The questionnaires were structured to evaluate the methodology, content of the guide, teamwork, and self-assessment. Thus, 10 items were designed for the linearization and operation point concept as it's shown in the following:

- Q1: Rate if the methodology used for the lab session was appropriate
- Q2: Rate the clarity of the operation point concept you gained from the lab session
- Q3: Rate the clarity of the linearization concept you gained from the lab session
- Q4: Compared to theoretical class, did the understanding of the concept improve through the lab session?
- Q5: Do you consider that using real plants are important for understanding the concept?
- Q6: Do you consider that homework is necessary to better understand the concept?
- Q7: Do you think it is important that the lab guide contains illustrations?
- Q8: Do you think you can explain in detail the procedure performed in the lab session to other people?
- Q9: Did the methodology used in the lab session fit your learning style?
- Q10: Rate the performance of your team during the lab session

At this point, the didactic strategy was established. Table 5 presents the didactic strategies for the linearization and operation point concepts, which consider the content and particular resources of each concept.

The last step was implementing the didactic strategy for teaching the selected concept to the students of the course Input–Output Control at the Universidad Nacional de Colombia during the second semester of 2023.

| | | | |
|---|---|---|---|
| **Competence to be evaluated** | • Identify the difference between the operating point and the equilibrium point of a control system.<br>• Perform the linearization process manually to obtain the transfer function of a control system. | | |
| **Score per level** | • Initial level: 2 points.<br>• Basic level: 3 points.<br>• Autonomous level: 4 points.<br>• Strategic level: 5 points. | | |
| **Guide concept** | **Criterion** | **Evidence** | **Weighting** |
| Equilibrium point | Calculate the equilibrium point of the system using its mathematical model. | Calculations made in the report | 6% |
| Operating point | Perform test on the plant to find the desired operating point for the system. | Tests performed in the laboratory. Operating point presented in the report. | 6% |
| Linearization | Calculate the linearization of the system manually from the mathematical model. Obtain the transfer function of the system. | Calculations made in the report and Matlab scripts. | 30% |
| Analysis and answer to questions | Identify the difference between operating point and equilibrium point.<br>Perform a comparison between the linear model, the nonlinear model and the real systems data to validate the linearization around the operating point. | Analysis and graphs presented in the report. | 30% |
| Transfer function reduction | Simplify the order of the transfer function using the final value theorem and the non-dominant pole criterion. | Mathematical calculation and graphs presented in the report. | 6% |
| Report | Presents a clear, concise and coherent laboratory report | Laboratory report | 14% |
| Co-evaluation | Recognize and evaluate the performance of co-workers | Survey | 8% |

Table 4. Rubric by competencies for linearization and operation point

| Concept | Linearization and operating point |
|---|---|
| Problem | The linearization and operating point concept are unclear for students. |
| Content | Equilibrium point, operating point, linearization, and transfer function. |
| Objectives | • Identify the difference between operating point and equilibrium point.<br>• Correctly perform the linearization process to obtain the transfer function of a system. |
| Resources | • Linearization and operating point lab guide<br>• Computers with Internet connection<br>• LabVIEW software<br>• TeamViewer software for remote sessions<br>• Matlab software<br>• VTOL plant<br>• Google Forms |
| Total duration | Sessions: one (1). Session duration: two (2) hours. Extra class work per session: two (2) hours. Total time: four (4) hours. |
| Assessment | Rubric and survey |

Table 5. Didactic strategy for linearization and operating point

## 4. Results and Discussion

For the control group, the traditional laboratory guide was used while for the test group, the guide proposed according to the didactic strategy proposed in this work was used.

The learning styles results were organized into the four dimensions according to the Felder and Silverman Model: Input, perception, processing and understanding (Felder & Silverman, 1998). For each dimension there are two possible learning styles. The results obtained are presented in Table 6.

| Dimension | Learning style | Control Group Students | Test Group Students |
|---|---|---|---|
| Input | Visual | 10 | 14 |
| | Verbal | 1 | 2 |
| Perception | Sensitive | 7 | 13 |
| | Intuitive | 4 | 3 |
| Processing | Active | 6 | 7 |
| | Reflective | 5 | 9 |
| Understanding | Sequential | 8 | 12 |
| | Global | 3 | 4 |

Table 6. Learning styles results

For the test group, the most predominant styles were the sensitive style (81,25%), visual style (87,5%), reflective style (56,25%) and sequential style (75%), while for the control group, the most predominant style were the sensitive style (63,64%), visual style (90,91%), active style (54,55%) and sequential style (72,73%). Therefore, it can be said that both groups have the same tendency in terms of learning styles, where the most predominant styles for both groups are visual, sensitive and sequential styles. Although in the processing dimension there is a difference between both groups, this difference is close to 50% so it is not a significant difference. The results agree with the study conducted in Rojas-Palacio and Arango-Zuluaga (2021) where the most predominant style was the visual style with 84% and the sensitive style with 72%. It is important to mention that the didactic strategy was designed for all learning styles, not only for the most predominant styles.

After identifying the learning styles of the students, the didactic strategy was applied (Table 5), whose effectiveness was measured using two indicators: the score obtained from the rubric and the perception surveys. These indicators include both quantitative and qualitative evaluations.

Table 7 presents the scores obtained through the rubric for each automatic control concept with a passing score of 3.0. The approval percentage for both groups was 100%. The average obtained by the test group was higher by 0.29 points, as well as the minimum score which was higher by 1.5 points.

| **Concept** | **Linearization and operating point** | |
|---|---|---|
| ***Group*** | ***Control Group*** | ***Test Group*** |
| Average | 4.47 | 4.76 |
| Mode | 4.50 | 4.8 |
| Standard deviation | 0.59 | 0.17 |
| Variance | 0.32 | 0.03 |
| Minimum | 3 | 4.5 |
| Maximum | 5 | 5 |

Table 7. Scores according to rubric by competences

Since the data are not normally distributed, and the sample size was small, it was not possible to perform an analysis of means. However, a Two variance test by Levene's method (Levene, 1960) was used to determine if there was an improvement between using the didactic strategy or not. Conducting a variance test was essential to conclude from the results. The variance test assesses the consistency in students' scores, helping to identify whether one group's performance level is superior to the other.

Table 8 presents the results for two variance test by Levene's method. $\sigma_1$ was the standard deviation of the control group and $\sigma_2$ was the standard deviation of the test group. So, the null hypothesis was $H_0\colon \frac{\sigma_1}{\sigma_2} = 1$, the alternative hypothesis was $H_1\colon \frac{\sigma_1}{\sigma_2} > 1$ with a significance level of $\alpha = 0.05$.

| Test statistic | Degree of freedom 1 | Degree of freedom 2 | P value |
|---|---|---|---|
| 4.88 | 1 | 25 | 0.018 |

Table 8. Two variance test

According to the results, $H_0$ was rejected and it was possible to state that the variance of the test group was smaller than the variance of the control group indicating that the students' scores in the test group were more similar and closer to the average than the control group scores. Hence, in terms of the scores, it is feasible to conclude that the students in the test group achieved better performance during the laboratory session.

Regarding the surveys, all perception surveys were validated using Cronbach's alpha coefficient equal to or greater than 0.7. In this case, the students completed the surveys at the end of lab session. For the control group the Cronbach's alpha coefficient was 0.84 and for the test group was 0.86.

Table 9 present the surveys and a summary of the answers, respectively, where a negative score takes a value of 1, whereas a perfect score takes a value of 5. To analyze the results of the surveys, scores of 4 and 5 were considered equal, because they indicate a positive qualification. Notably, no survey was conducted for the concept of time response

For the questions in Table 9, Q1 to Q4 evaluated the methodology; Q5 to Q7 pertain to the lab guide content; Q8 evaluates the general understanding of the lab guide; Q9 if the lab guide fits their learning style and Q10 teamwork.

Overall, both groups gave a positive rating since most of the questions reached more than 50%, however, the following differences were observed between the groups: First, regarding Q2, it is observed that in the control group fewer students obtained clarity about the operating point concept (54.55%), which is practically half of the group, while in the test group the majority of students claim they gained clarity about this concept (81.25%). Second, in Q8 the percentage of students in the control group who can explain in detail what was done in the lab session is only 45.45% while in the test group the percentage is higher (75%), therefore the general understanding of the session was better in the test group.

| | Scores per students in control group | | | | | | Scores per students in test group | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Questions** | **1** | **2** | **3** | **4** | **5** | **Percentage of students who scored 4 and 5** | **1** | **2** | **3** | **4** | **5** | **Percentage of students who scored 4 and 5** |
| Q1 | 0 | 0 | 2 | 5 | 4 | 81.82% | 0 | 0 | 2 | 4 | 10 | 87.50% |
| Q2 | 0 | 0 | 5 | 0 | 6 | 54.55% | 0 | 0 | 3 | 4 | 9 | 81.25% |
| Q3 | 0 | 1 | 1 | 4 | 5 | 81.82% | 0 | 0 | 2 | 6 | 8 | 87.50% |
| Q4 | 0 | 1 | 1 | 3 | 6 | 81.82% | 0 | 0 | 2 | 3 | 11 | 87.50% |
| Q5 | 0 | 0 | 0 | 1 | 10 | 100% | 0 | 0 | 0 | 5 | 11 | 100% |
| Q6 | 0 | 0 | 3 | 5 | 3 | 72.73% | 0 | 0 | 2 | 7 | 7 | 87.50% |
| Q7 | 0 | 0 | 1 | 4 | 6 | 90.91% | 0 | 0 | 1 | 6 | 9 | 93.75% |
| Q8 | 0 | 0 | 6 | 5 | 0 | 45.45% | 0 | 1 | 3 | 9 | 3 | 75% |
| Q9 | 0 | 0 | 7 | 4 | 0 | 36.36% | 0 | 0 | 5 | 8 | 3 | 68.75% |
| Q10 | 1 | 0 | 0 | 3 | 7 | 90.91% | 0 | 0 | 0 | 3 | 13 | 100% |

Table 9. Summary of linearization and operating point surveys

Third, the students in the control group think that the lab guide did not adjust very well to their learning styles. This agrees with the particularities of the original lab guide which according to its characteristics was more inclined to verbal and reflective style and the guide did not include the exercise of putting theory into practice in a real plant. Also, the control group was mainly sensitive, visual and active styles. According to this, it is possible to assume that the students felt that the simulation was not enough to understand the concept which agrees with the answer obtained in Q5. Finally, the percentage is higher in the test group in all questions except for Q5 where the percentage is equal.

According to the above, the methodology was more appropriate for the test group because it facilitated the improvement in the students' understanding of this concept. This indicates that according to the students' perception, the implementation of the didactic strategy obtained better results.

For the lab guide content, both groups agree that it is important using real plants and illustrations for understanding the concept, in this case the control group did not have the opportunity to use real plants, which indicates that their incorporation is necessary to improve the concept understanding.

For teamwork, students produced a positive score for their teammates. Thus, the study infers that teamwork was adequate for the lab session in both groups.

Additionally, it is important to highlight that both groups we used active methodologies. Rojas-Palacio et al. (2022) demonstrated that a control laboratory with active methodology involves only four of the eight Felder and Silverman learning styles. Therefore, the main contribution of this work was to establish whether the inclusion of a complete learning styles model would enhance the students' understanding of the linearization and operation point concept.

The variance test indicate that the implementation of the didactic strategy had a positive impact on the students' understanding in the test group because the variance of the grades obtained from the rubric was significantly reduced (Table 8). This result aligns with the results obtained in the perception survey. Therefore, according to the rubric and the survey results the didactic strategy improved the understanding of the linearization and operation point concept.

The work presented on this paper is a step forward as it presents both a statistical analysis of the grades and an analysis of perception survey which are not simultaneously present on the analyzed literature. In Samacá and Ramirez (2011), and Staehle and Ogunnaike (2014) authors received feedback from students through perception surveys but have no analysis of grades. Additionally, in Franzoni et al. (2013), Mastascusa and Hoyt (1999), Moor and Piergiovanni (2003), and Rusk et al. (2008) authors do not perform any of these analyzes, neither the grades nor the perception analysis. Hence, this study is a step forward as it provides two indicators to quantify the impact of the didactic strategy on the student´s performance: The statistical analysis of the grades and the perception survey.

Another contribution of this work is the proposal for a didactic strategy with a complete learning styles model which is also not presented in the analyzed literature. In Budiyanto et al. (2020), Franzoni et al. (2013), Mahmoud and Nagy (2009), Mastascusa and Hoyt (1999), Moor and Piergiovanni (2003), Muñoz-Ochoa (2018), Rusk et al. (2008), Samacá and Ramirez (2011), and Staehle and Ogunnaike (2014) authors do not cover a complete learning styles model.

## 5. Conclusions

This paper proposed a novel didactic strategy that integrates learning styles and active methodologies with a complete model of learning styles. The main contribution of this work was that the inclusion of a complete learning styles model improved the students' understanding of the linearization and operation point concept. Although the specific concept for this study was the linearization and operating point, the proposed didactic strategy can be extended for teaching any automatic control concept.

Also, this study established the steps in designing the didactic strategy in a general manner that is accessible to any field of engineering. The didactic strategy does not require specialized equipment and is focused on using existing resources that allow professors to easily adapt it to any learning environment.

Moreover, this paper included a grade analysis and a perception survey analysis which were used as quantitative and qualitative indicators to determine that there was an improvement in the student's understanding of the concept. These indicators allow us to do complete feedback on the didactic strategy and enable us to adapt the didactic strategy in a more efficient way for future versions.

Finally, satisfactory results were also obtained for the control group, this can be credited to the fact that it is important to have a laboratory session with active methodologies to consolidate the knowledge of a concept. However, using a learning styles model provides additional tools to design didactic material that complement the methodology, provides teachers with a better understanding of their students and impacts in a positive way the students in the appropriation of knowledge.

As a future work, we intend to improve the lab guides by considering the feedback of students and apply it to other control concepts.

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## References

Agarwal, A., Mishra, D.S., & Kolekar, S.V. (2022). Knowledge-based recommendation system using semantic web rules based on Learning styles for MOOCs. *Cogent Engineering*, 9(1), 2022568. https://doi.org/10.1080/23311916.2021.2022568

Almasri, F. (2022). Simulations to teach science subjects: Connections among students' engagement, self-confidence, satisfaction, and learning styles. *Education and Information Technologies*, *27*(5), 7161-7181. https://doi.org/10.1007/s10639-022-10940-w

Avanzini, G. (2004). *Capacitación en estrategias y técnicas didácticas.* Instituto Tecnológico y de Estudios Superiores de Monterrey. Available at: https://sitios.itesm.mx/va/dide/documentos/inf-doc/Est_y_tec.PDF (Accessed: November 2023).

Balgan, A., Renchin, T., & Ojgoosh, K. (2022). An experiment in applying differentiated instruction in STEAM disciplines. *Eurasian Journal of Educational Research*, 98(98), 21-37.

Budiyanto, C., Fitriyaningsih, R.N., Kamal, F., Ariyuana, R., & Efendi, A. (2020). Hands-on Learning in STEM: Revisiting Educational Robotics as a Learning Style Precursor. *Open Engineering*, 10(1), 649-657. https://doi.org/10.1515/eng-2020-0071

Campusano-Cataldo, K., & Díaz-Olivos, C. (2017). *Manual de Estrátegias didácticas: Orientaciones*. Ediciones INACAP. Available at: http://www.inacap.cl/web/documentos/manuales-estrategias-actualizacion-2019/manual-de-actividades-version-digital.pdf (Accessed: November 2023).

Chevalier, A., Dekemele, K., Juchem, J., & Loccufier, M. (2021). Student Feedback on Educational Innovation in Control Engineering: Active Learning in Practice. *IEEE Transactions on Education*, 64(4), 432-437. https://doi.org/10.1109/TE.2021.3077278

Coelho, U.M., & Vega, Í.S. (2019). The Pedagogical Formation and the Knowledge of Teachers in Computering in Teaching Strategies: Integration of Content, Didactic Material and Interdisciplinary or Integrator Project. *2019 XIV Latin American Conference on Learning Technologies (LACLO)* (24-30). https://doi.org/10.1109/LACLO49268.2019.00015

Dinsmore, D.L., Fryer, L.K., & Parkinson, M.M. (2022). The learning styles hypothesis is false, but there are patterns of student characteristics that are useful. *Theory into Practice*, 61(4), 418-428. https://doi.org/10.1080/00405841.2022.2107333

Felder, R.M., & Silverman, L.K. (1998). Learning and Teaching Styles. *Engineering Education*, 78, 674-681. https://doi.org/10.1109/FIE.2008.4720326

Feo, R. (2010). Orientaciones básicas para el diseño de estrategias didácticas. *Tendencias pedagógicas*, 16, 220-236.

Ferreiro-Gravié, R. (2003). *Estrategias didácticas del aprendizaje cooperativo* (1st ed.). Editorial Trillas.

Forcael, E., Garcés, G., & Orozco, F. (2021). Relationship Between Professional Competencies Required by Engineering Students According to ABET and CDIO and Teaching-Learning Techniques. *IEEE Transactions on Education*, 1-10. https://doi.org/10.1109/TE.2021.3086766

Franzoni, A.L., Cervantes-Pérez, F., & Robles, G. (2013). Teacher's Guide for Selecting Proper Digital Technology to Support Didactic Strategies Compatible with Students' Learning Styles. *2013 IEEE 13th International Conference on Advanced Learning Technologies* (366-368). https://doi.org/10.1109/ICALT.2013.112

Hassan, O.A.B. (2011). Learning theories and assessment methodologies - an engineering educational perspective. *European Journal of Engineering Education*, 36(4), 327-339. https://doi.org/10.1080/03043797.2011.591486

Heywood, J. (2005). *Engineering Education: Research and Development in Curriculum and Instruction* (Chapter 14). IEEE Press. Wiley Interscience.

Khan, S., Jaffery, M.H., Hanif, A., & Asif, M.R. (2017). Teaching Tool for a Control Systems Laboratory Using a Quadrotor as a Plant in MATLAB. *IEEE Transactions on Education*, 60(4), 249-256. https://doi.org/10.1109/TE.2017.2653762

Kheir, N.A., Åström, K.J., Auslander, D., Cheok, K.C., Franklin, G.F., Masten, M. et al. (1996). Control systems engineering education. *Automatica*, 32(2), 147-166. https://doi.org/https://doi.org/10.1016/0005-1098(96)85546-4

Kirschner, P.A. (2017). Stop propagating the learning styles myth. *Computers & Education*, 106, 166-171. https://doi.org/10.1016/j.compedu.2016.12.006

Kozulin, A., & Barberán, G.S. (2000). *Instrumentos psicológicos: la educación desde una perspectiva sociocultural*. Paidós.

Levene, H. (1960). Robust tests for equality of variances. In *Contributions to Probability and Statistics: Essays in Honor of Harold Hotelling* (278-292). Stanford University Press.

Mahmoud, A., & Nagy, Z.K. (2009). Applying Kolb's Experiential Learning Cycle for Laboratory Education. *Journal of Engineering Education*, 98(3), 283-294. https://doi.org/10.1002/j.2168-9830.2009.tb01025.x

Marosan, Z., Savic, N., Klasnja-Milicevic, A., Ivanovic, M., & Vesin, B. (2022). Students' perceptions of ils as a learning-style-identification tool in e-learning environments. *Sustainability*, 14(8), 4426. https://doi.org/10.3390/su14084426

Mastascusa, E.J., & Hoyt, B. (1999). Pedagogical and structural considerations in the design of a set of control system lessons. *ASEE Annual Conference Proceedings*.

Moor, S.S., & Piergiovanni, P. (2003). Experiments in the classroom: Examples of inductive learning with classroom-friendly laboratory kits. *ASEE Annual Conference Proceedings*. https://doi.org/10.18260/1-2--11569

Muñoz-Ochoa, P.L. (2018). Estrategias de enseñanza y aprendizaje en el área de control de procesos. *Encuentro Internacional de Educacion en Ingenieria*. Available at: https://acofipapers.org/index.php/eiei/article/view/531 (Accessed: November 2023).

Oviedo, H.C., & Campo-Arias, A. (2005). Aproximación al uso del coeficiente alfa de Cronbach. *Revista Colombiana de Psiquiatría*, XXXIV(4), 572-580.

Pardamean, B., Suparyanto, T., Cenggoro, T.W., Sudigyo, D., & Anugrahana, A. (2022). AI-based learning style prediction in online learning for primary education. *IEEE Access*, 10, 35725-35735. https://doi.org/10.1109/ACCESS.2022.3160177

Prince, M. (2004). Does_Active_Learning_Work_A_review_of_the_research. *Journal of Engineering Education*, July, 1-10. https://doi.org/10.1038/nature02568

Rasouli, M., Weissbach, R., & Yeung, D. (2017). Introducing advanced control methods to undergraduates using a state space model of a synchronous generator. *Journal of Engineering Technology,* 34(2), 16-29.

Riener, C., & Willingham, D. (2010). The myth of learning styles. *Change: The Magazine of Higher Learning*, 42(5), 32-35. https://doi.org/10.1080/00091383.2010.503139

Rojas-Palacio, C.V., & Arango-Zuluaga, E.I. (2021). Adaptación remota de prácticas de control utilizando LabVIEW y TeamViewer. *Encuentro Internacional de Educación en Ingeniería.* https://doi.org/10.26507/ponencia.1913

Rojas-Palacio, C. V., Arango-Zuluaga, E.I., & Botero-Castro, H.A. (2022). Teaching Control Theory: A Selection of Methodology Based on Learning Styles. *Dyna*, 89(222), 9-17. https://doi.org/10.15446/dyna.v89n222.100547

Roubal, J., Husek, P., & Stecha, J. (2010). Linearization: Students Forget the Operating Point. *IEEE Transactions on Education*, 53(3), 413-418. https://doi.org/10.1109/TE.2009.2026427

Rusk, N., Resnick, M., Berg, R., & Pezalla-Granlund, M. (2008). New pathways into robotics: Strategies for broadening participation. *Journal of Science Education and Technology*, 17(1), 59-69. https://doi.org/10.1007/s10956-007-9082-2

Samacá, L.F., & Ramirez, J.M. (2011). Learning Control Concepts in a Fun Way. *International Journal of Engineering Education*, 27(1), 1-13.

Sánchez-Azqueta, C., Celma, S., Aldea, C., Gimeno, C., & Cascarosa, E. (2019). ICT-Based Didactic Strategies to Build Knowledge Models in Electronics in Higher Education. *2019 IEEE International Symposium on Circuits and Systems (ISCAS)* (1-5). https://doi.org/10.1109/ISCAS.2019.8702527

Soares, S.N., & Wagner, F.R. (2011). T&D-Bench–Innovative Combined Support for Education and Research in Computer Architecture and Embedded Systems. *IEEE Transactions on Education*, 54(4), 675-682. https://doi.org/10.1109/TE.2011.2107911

Staehle, M.M., & Ogunnaike, B.A. (2014). Simulation-based guided explorations in process dynamics and control. *ASEE Annual Conference and Exposition, Conference Proceedings*. https://doi.org/10.18260/1-2--23017

Tobón, S., Pimienta, J.H., & Garcia, J.A. (2010). *Secuencias didácticas aprendizaje y evaluación de competencias* (1st ed.). Pearson Educación.

Troussas, C., Giannakas, F., Sgouropoulou, C., & Voyiatzis, I. (2023). Collaborative activities recommendation based on students' collaborative learning styles using ANN and WSM. *Interactive Learning Environments*, 31(1), 54-67. https://doi.org/10.1080/10494820.2020.1761835

Yan, V.X., & Fralick, C.M. (2022). Consequences of Endorsing the Individual Learning Styles Myth: Helpful, Harmful, or Harmless? In *Learning Styles, Classroom Instruction, and Student Achievement* (59-74). Springer.

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