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PAPER

Mobile Application of Inductive Multi-Strategies for Virtual Teaching of Research to Engineering Students

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ABSTRACT

The university curriculum requires the implementation of various strategies for research training. Accordingly, the present study aims to implement a multi-strategy mobile application for the teaching of research by engineering students of a private Peruvian university. Using a mixed methodology, in the first study, action research was applied with the participation of four teachers and two academic coordinators. Management documents such as the University Law and curricular documents such as syllabi were analyzed. Thus, a multi-strategy learning session was designed and tested according to SINEACE standards. Then, in the second quantitative study, the proposed sessions suggested by the teachers were applied to a sample of 167 students of Systems Engineering, Mechanical Engineering, Civil Engineering, and Industrial Engineering, who achieved "excellent progress" in conceptual skills and "good progress" in procedural skills for research.

KEYWORDS

university curriculum, research competencies, higher education, engineering education

1 INTRODUCTION

The curriculum is a proposal that adapts to contextual changes and is part of educational reforms, for which the responsible participation of the protagonists is essential when proposing curricula [1]. Of course, the general purpose of the curriculum is related to various concepts, of which, perhaps the most common are knowledge and learning, which demand actions from the protagonists of these educational processes [2]. In other words, the curriculum is associated with educational processes as a whole. These processes involve, first, the initial diagnosis of educational problems as a starting point for developing the curriculum. Second, the planning of the curricular program or study plan. Third, the execution of the curricular program in the development of subjects and teaching processes. Fourth, the evaluation process of the graduate profiles [3]. All this process should result in achievements in the learners, such as, for example, their active participation

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during the teaching processes and learning achievements [4]. But, for the curriculum to be always improving, it needs to be evaluated. This evaluation process is a responsible and prudent action [5] because it achieves improvements in educational processes and pertinent adaptations to new contexts. This curricular evaluation contemplates processes, from its planning, the inputs for its application, the processes, and the educational products [6–7]. Thus, after this evaluation, a diagnosis of the needs for improvement is achieved. In this way, diversified curricular proposals are proposed [8], according to the social and cultural needs of the students [9].

1.1 The university curriculum and engineering research

The curriculum represents the organization of the various study programs, which arise from the implementation of educational policies and the work of teachers [10]. Undoubtedly, it represents the political reason associated with the organization and purpose of education for all [11]. Therefore, it contemplates strategic objectives that guarantee the optimal fulfillment of equity, teacher training, and quality higher education [12]. In this way, appropriate curricular proposals that respond to the demands of diversity are achieved [13]. However, in order to guarantee the training of research professionals, the curriculum must consider the role of teachers who do research, thus contributing to the training of research competencies [14]. This is feasible to achieve if constant teaching processes are planned that develop research and innovation in a transversal way; achievements that should be disseminated in academic events [15]. Thus, the university curriculum would contribute to the training of research professionals and to social development. However, there is the question of how to apply what is planned in the curricular programs. To this end, it is considered that the curriculum is associated with concepts such as syllabus, processes, praxis, or educational products; therefore, it is the essence of university higher education [2]. Depending on the curricular approach (for example), in the curriculum approach, the focus of attention of the curriculum lies in the contents or knowledge to be transmitted, in which the concept of competencies is not absent [2]. To this concept of competencies, the logic of research training can be added. For example, the curriculum for the teaching of research, not only in the theoretical field but also to educate researchers for the pursuit of practical knowledge [11]. Moreover, to verify these achievements, systems of evaluation of academic work should be implemented to demonstrate the development of their research skills [16]. Thus, university curricular programs should include evaluation systems and research teachers [15].

Of course, this is no exception in engineering careers. In these careers, the innovation of teaching models that are articulated with research and accreditation processes is required to improve the quality of education [17]. Thus, education plays a key role in engineering education because it contributes to scientific research that has made significant contributions to social progress [18]. For this reason, during the pandemic, engineering continued to provide contributions related to medical technology for the prevention and treatment of patients [19]. Therefore, engineering faced challenges during the pandemic, requiring educational adaptations to dose the academic load and apply applicative methodologies—achievements that continued after the pandemic [20]. This fact did not exclude the improvement of the quality of research teaching [17].

1.2 Problems of teaching research to engineering students

In Peru, although there have been advances in research, indexed production is only 2% of Latin America, below Brazil (49%) and Mexico (15%) [12]. This is due to the lack of articulation between formative and productive research [17]. According to the National System of Educational Evaluation and Accreditation (SINEACE), in university education, it is suggested that research teachers should carry out research teaching; thus, it will be feasible to educate innovative professionals [15]. This is necessary because research is essential to generate knowledge and achieve practical solutions [21]. In addition to its relationship with the principles of social responsibility [22]. Thus, in Peru, since the enactment of the current University Law in 2014, the development of curricula promotes research during professional training [17], and obtaining academic degrees (bachelor's or master's) is managed. In addition, the development of renewable curricula is supported [23]. In order for Peruvian universities to guarantee quality standards, for example, the standard of comprehensive training, teaching, and learning processes, which includes the study plans and the competency-based approach articulated with research, development, and innovation [15].

With these standards, research in Peru has shown progress but also difficulties. For example, in 2016, of the 3374 Peruvian researchers, only 2192 (65%) were research professors, who represented 2.6% of university professors in Peru [24]. This is worrying because, in engineering, it contributes to technological advances [18] [19]. Furthermore, in 2021, deficiencies were observed in terms of the quality of writing, research imbalance by careers, the quality of sources consulted, and also a weak incorporation of ethical procedures [25]. For these reasons, Peruvian universities urgently need to consolidate strategies to optimize teaching for research. These strategies were proposed by SINEACE during 2016 [15]. In addition, since their implementation until today, they have been gradually applied. For example, the incentive to research in Peru has been encouraged; in addition, that from the classrooms teachers develop as researchers [26]. In this way, contributing to the improvement of university teaching [27].

Currently, these teaching strategies demand the implementation of virtual education, which is consistent with the demands of the Ministry of Education (MINEDU) and the Peruvian University Law; in this way, the academic areas and research departments of universities are organized to provide educational services [28]. And particularly, for the teaching of research, in Peru, universities develop their educational proposals according to the Guide for the design and development of research G-DEP-002 of SINEACE, which provides standardized procedures to execute research [29]. With these guidelines and virtual education [28], during the pandemic, teaching was optimized [30]. Requiring the use of digital tools and technological platforms, with which digital competencies were developed [31]. This helped to make curricular adaptations in engineering careers, optimizing teaching, academic tasks, and the implementation of new evaluation systems [20]. As well as the teaching of research according to the different levels of research scope (descriptive, correlational, and explanatory) for quantitative, qualitative, or mixed research; whether basic or applied [29]. That, in Peruvian engineering, had an impact on the technological contributions during the pandemic [19].

1.3 Study objectives

In order to promote research, it is necessary that, from the classroom, teachers assume the role of researchers and promote the teaching practice of research, linking scientific knowledge with social practice [26]. Furthermore, they should conceive the curriculum as a means to teach research in a theoretical and practical way [11]. Through subjects and evaluation systems [15]; pertinent and in line with research competencies [16]. Thus, associating the curriculum to the concept of "learning session," which should be understood as the step-by-step of how the teacher teaches specific content. Therefore, by analyzing these educational needs, this study aims to implement a multi-strategy mobile application for the teaching of research by engineering students of a private Peruvian university.

2 MATERIALS AND METHODS

The design is a mixed sequential type [32] (see Figure 1). In which, in the first action research type study [33], the problematic was reflected on; research learning session proposals are elaborated with inductive multi-strategy methodology. This methodology allows the development of flexible active learning [34]. For this curricular adaptation, the context was analyzed in a participatory way to propose the new teaching methodology [1]. Accordingly, teachers and academic coordinators from a private university. Thus, by applying semi-structured interviews and a documentary analysis guide, the syllabus of a first-year research course was diagnosed. The responses and findings were coded [35]; applying the ATLAS ti software [36] (see Figure 2). Emerging categories were extracted with which strategies for improving the learning sessions were proposed. Then, the didactic units of the syllabus and the weekly contents were modified. This allowed the implementation of an inductive multi-strategy teaching and learning methodology [34].

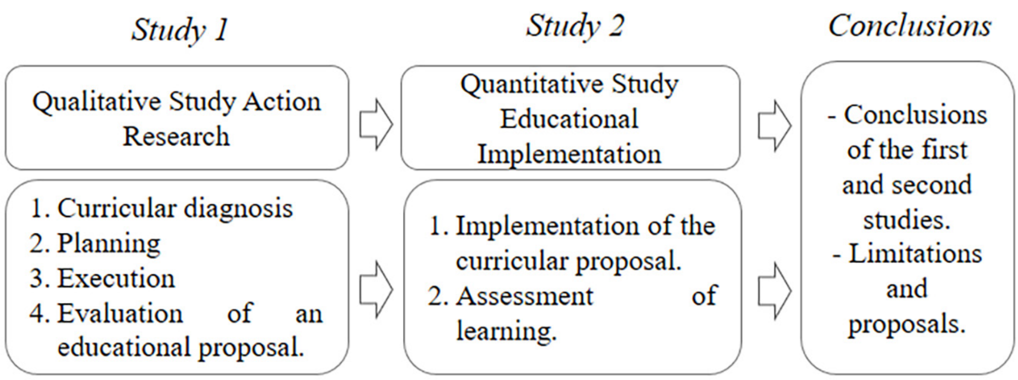

Fig. 1. Research process (mixed method of two studies)

3 STUDY 1

This study is qualitative [32] of the action research type because it was oriented to the diagnosis, planning, execution, and evaluation of an educational proposal [33]. This developed according to the SINEACE guidelines aimed at achieving teaching and learning processes for university science education [15]. For which, we proceeded according to the guide for the design and development of research G-DEP-002 of SINEACE [29].

3.1 Documental sampling

A convenience sample [37] was selected, consisting of four engineering teachers of the research course with experience publishing scientific articles and two academic coordinators. In addition, a documentary sampling was used to select the most relevant files [38] according to the two categories of analysis: pedagogical management and teaching and learning process. Thus, there were four types of documents: normative, curricular planning, teaching, and students' academic products (refer to Table 1).

Table 1. Information from the documentary sample

Analysis Categories	Sources	Selected Documents
Pedagogical management	Regulatory documents	– University Law (No. 30220) – Accreditation Model for University Higher Education Study Programs – SINEACE Guide for the design and development of research G-DEP-002
	Curriculum planning documents	– Curricular program – Syllables
Teaching and learning process	Teaching and learning planning documents Archives of teaching processes	– Lesson plans, slides – Readings (scientific articles) – IEEE Reference Guide [39] – Academic writing demonstration videos
	Student academic products	– Article writing plans – Student essays

3.2 Instruments

Semi-structured interview guide. This guide was designed to obtain information from questions with a certain level of flexibility [35]. It was planned according to the following categories: pedagogical management and teaching-learning processes. Thus, three questions were elaborated for each category. For example, for the first category of pedagogical management, the question was asked: *How are the educational policies of the University Law and the SINEACE standards applied in the learning sessions of the research courses? Could you explain?* Then, for the second category of teaching—learning processes it was asked *What are the difficulties in teaching in the research courses? How does this affect the students?* The information extracted was coded with the acronym "*SIG*" (see Figure 1).

Documentary analysis guide. This guide was prepared based on the document analysis technique of the National Autonomous University of Nicaragua [40]. Thus, according to the analysis categories established in Table 1, the selected documents (pedagogical management and teaching-learning processes) were explored. Then, in the emerging categories, information to improve the learning sessions was identified. This was coded with the acronym "*DAG*" (see Figure 1). It is important to mention that for each category, suggestions for modifying the learning sessions were requested. In addition, both instruments were subjected to validation by an expert [41]. This was done by teachers with experience in teaching research and writing scientific articles.

3.3 Analysis and discussion of results

Next, the process of analysis and discussion of results is explained in three phases; first, the diagnosis of the research teaching. Second, elaboration and testing of the learning session proposal. And third, validation of the learning session.

Diagnosis of the research teaching and learning process. Theoretical knowledge is generated from research [11] and solutions to social problems [21]. Therefore, it is essential to develop research competencies in students during their university studies [14]. Based on these arguments, competency-based education receives special attention because of its practical orientation [15]. That is, it focuses on developing theoretical and practical skills in students. Thus, the curriculum has a leading role. Therefore, it is necessary to perform a diagnostic evaluation of it [3]. Mainly in engineering careers, in which it is necessary to innovate research teaching models (formative research), achieving educational quality [17] (see Figure 2).

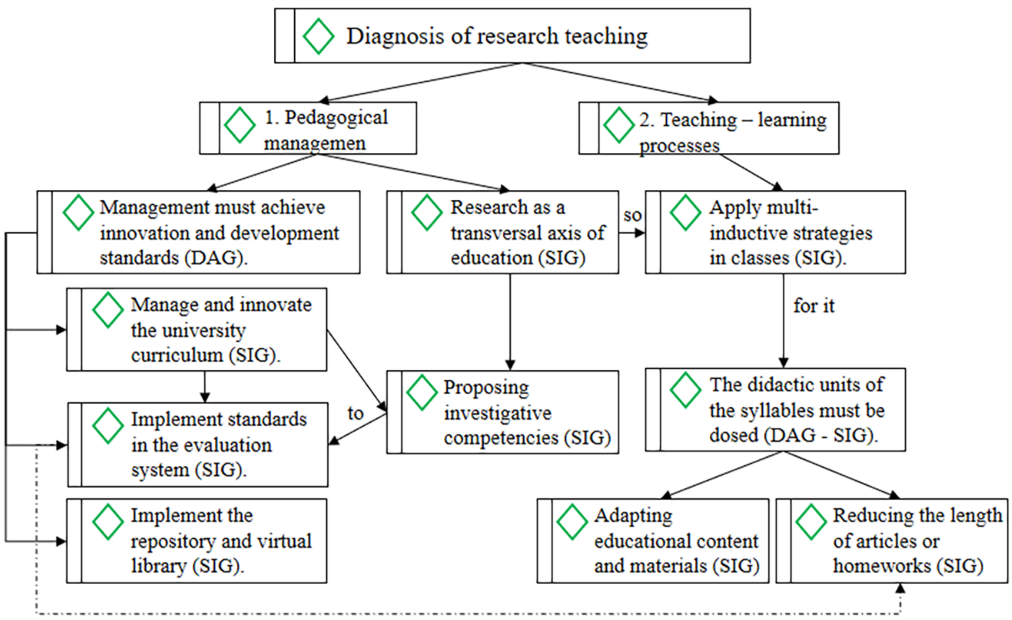

Fig. 2. Coding of the category's pedagogical management and teaching-learning processes

Thus, when the answers of the teachers and the information of the documentary analysis were analyzed, it was identified that the university curriculum should be managed according to the standards of research, innovation, and development, as well as adapting the evaluation system, coinciding with the approaches of SINEACE [15] [29]. At the level of the category of teaching and learning processes, teachers suggest revising the syllabi and developing research competencies by applying inductive multi-strategies, dosing the contents to be taught, and reducing the size of the academic papers requested at the end of the course (see Figure 1).

Development and testing of the proposed learning sessions. Any curriculum is susceptible to modification, which requires taking into account collective participation [10]. In these processes, there are different perspectives on the difficulties [1]. However, teachers organized themselves and proposed a learning session (lesson plan) applying multi-strategies inductively (see Figure 3). Understanding induction demands analyzing particular cases to reach general conclusions;

the teachers proposed that engineering students analyze previously selected readings in their virtual classroom. Then, apply questions of how to do or not to do the research.

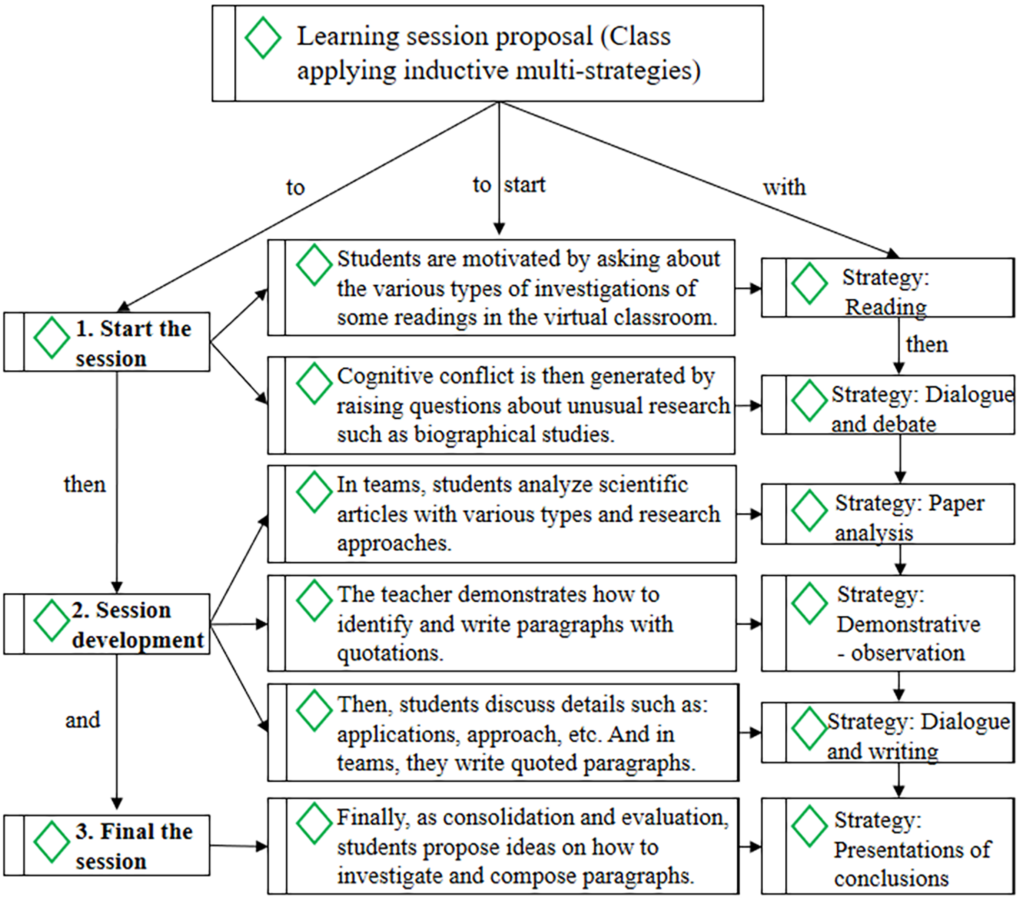

Fig. 3. Proposed learning session based on inductive multi-strategies

For the sessions, the teachers propose students analyze particular cases of research (scientific articles in engineering or related sciences). Then, they discuss the methods applied in the study. Finally, the engineering students draw general conclusions. In the example mentioned in Figure 3, the teachers proposed strategies of reading, dialogue, inductive case analysis, and active learning. However, for other sessions related to writing and citing authors, they proposed other modeling strategies (demonstrative example). In these, the teacher writes a text fragment demonstrating how to use connectors and cite according to the IEEE [39]. The exposed session was tested among teachers, who recognized that the process was simpler because it does not start by talking about research in an abstract way. On the contrary, it starts on the basis of readings and concrete cases.

Validation of the research learning session. The curriculum must achieve the equal participation of students in the classes, ensuring that they value their learning [4]. Therefore, research methodologies should be integrated according to student diversity. Thus, the application of multi-strategies favors flexible methods [26] to adapt the class to the type of content to be taught and the competencies to be developed. This constitutes a criterion to validate the learning session tested by teachers (refer to Table 2).

Table 2. Validation of the learning session

Categories of Analysis	Moments of the Session	Evaluation of Teachers and Coordinators
Pedagogical management	Start of the session Development of the session Closing of the session	– The modification of the contents and methodology according to the University Law (No. 30220). In the case of didactic materials. However, the participation of the students is necessary to plan the classes. – The research ideas proposed by the students are feasible for evaluation. But in order to comply with SINEACE, it would be necessary to have a rubric.
Teaching and learning process	Start of the session Development of the session Closing of the session	– With respect to the application of multi-strategies, it can be seen that each moment of the session presents different forms of active learning. – Demonstration of citation searching and writing is a necessary proposition. – The inductive strategy is a simple way for the student to learn how to do research; it is applied in the first two stages of the session (should be applied in the closing). – Individual activities according to the learning levels.

As can be seen, according to the teachers and coordinators, the learning session complies with the requirements of the University Law and the SINEA-CE [15] [29]. Thus, the application of inductive multi-strategies turns out to be a simple way to teach research. Therefore, it was decided to apply 17 learning sessions. However, as a limitation, in this process of planning, methodological proposals, and evaluation, engineering students were not involved. Furthermore, considering that only 32 (22.4%) of the 143 Peruvian universities have scientific production [24], it is necessary that engineering students suggest how they can be taught and thus contribute to research production.

4 STUDY 2

This study is quantitative [32]; in which the educational improvement proposal [33] was applied. It was based on inductive multi-strategies during 17 learning sessions. Which was subsequently evaluated according to the quality standards according to the Guide for the elaboration and application of rubrics G-DEP-04 of SINEACE [42]. It was adapted according to the guide for the design and development of research G-DEP-002 of SINEACE [29]. The application of the proposal was developed as follows:

4.1 Implementation process for multi-strategy session proposals

Because the pandemic generated the migration to virtual education [43], the application process of this educational proposal was carried out using the Flipped Classroom methodology, because it allows interaction between teachers and students, promoting participatory and active learning [44]. In addition, technological tools allow organizing teaching content, such as videos that support the Flipped Classroom or recording presentations that students can watch from their mobile phones or tablets. This methodology, during the synchronous class, the teacher focuses on attending to the progress of the students, who have more opportunities to ask questions [45] (see Figure 4).

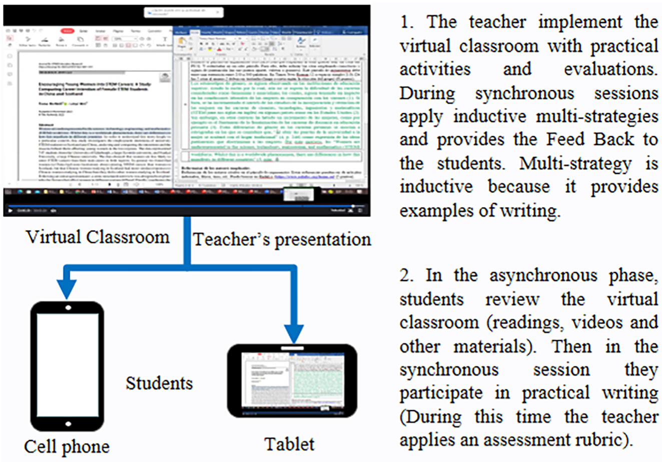

Fig. 4. Flipped Classroom for the application of inductive multi-strategies

Thus, the subject "*Introduction to Scientific Writing*" was implemented. For this purpose, the four components of FLIP (flexible environment, learning culture, intentional content, and professional professor) were applied [46]. *Flexible Environment:* A virtual classroom was implemented with the Blackboard Learn platform [47], guaranteeing the flexibility of activities for 17 weeks of classes, in which students had four tasks to produce two products (partial and final essay). *Learning Culture:* Learning was promoted by motivating writing and, as an example of this, the teacher shared his publications in indexed journals. *Intentional Content:* Includes technological educational materials that enhance learning experiences [48]. Content was selected according to the SINEACE guidelines for teaching [15], the Guide for Research Development [29], and the IEEE referencing guide [39]. *Professional Professor:* A professor, who formerly used a blackboard, now explains making use of information technologies [49]. In addition, qualified as a researcher by the National Council of Science and Technology and Technological Innovation (CONCYTEC) [50], who had experience publishing articles in journals, was selected (see Figure 4).

4.2 Participants

A convenience sample was selected [37]; of 167 students from engineering majors; 95 males (56.9%) and 72 females (43.1%) between the ages of 16 and 25 years ($M_{age} = 21.77$, $SD = 4.56$). The students were enrolled in the subject "*Introduction to Scientific Writing*" in four different schedules of Systems Engineering, Mechanical Engineering, Civil Engineering, and Industrial Engineering.

4.3 Instrument

Research Competencies Evaluation Rubric: It evaluates research competencies. It consists of two dimensions: the first dimension of conceptual competencies evaluates knowledge for searching specialized databases in engineering or related sciences. Knowledge for the planning of writing and the use of logical connectors. The second dimension of procedural competencies evaluates the adequate identification of quotations, adequate paraphrasing without altering the sense of the message, and the process of writing paragraphs. As well as the referencing according to the IEEE [39]. The rubric has five criteria with options ranging from "unsatisfactory progress" (1 point), "fair progress" (2 points), "good progress" (3 points), and "excellent progress" (4 points). It was elaborated according to the Guide for the elaboration and application of rubrics G-DEP-04 of SINEACE [42] (refer to Table 3). Accordingly, the total rating of the rubric was: "unsatisfactory progress" (5–9 points), "regular progress" (10–14 points), "good progress" (15–18 points), and "excellent progress" (19–20 points). The rubric was validated according to expert criteria [41]. Then with factorial validity analysis with the Kaiser-Meyer-Olkin (KMO) sample fit test with a score of .74 and Bartlett's Test of Sphericity was significant ($\chi^2 = 744{,}911$, $df = 10$, $p < .001$) proving to be valid [51]. Then, in the reliability analyses, the Cronbach's alpha coefficient was .85. Evidencing optimal levels of reliability [52]. Furthermore, Table 3 shows that the total corrected item correlation ranges from .389 to .883. Assuming that, optimal values should be greater than or equal to .300 for each item to be considered consistent [51].

Table 3. Analysis of the corrected total correlation of the rubric criteria

Dimensions	Evaluation Criteria	Total Correlation of Items
Conceptual competencies	Specialized search skills (searches specialized databases in engineering or related sciences).	.389
	Writing skills (planning of writing and use of logical connectors).	.545
	Citation localization (identification of citations belonging to the article's author).	.863
Procedural competencies	Paraphrasing quotations (adequate paraphrasing without altering the author's message).	.883
	Writing skills (paragraph writing process from transcription, logical linking of citations, and referencing according to IEEE).	.809

4.4 Results

According to the rating ranges of the rubric with achievement levels of "unsatisfactory progress" (1 point) to "excellent progress" (4 points). Table 4 shows that in the ***conceptual competencies***, students achieved averages of 3.72 for specialized search knowledge and 3.52 for writing knowledge, evidencing "excellent progress." In the ***procedural competencies***, during the practical activity, they achieved a "good progress" with a mean of 3.37 in citation location, 2.75 for citation paraphrasing, and 2.89 for writing skills.

Table 4. Analysis of means

Rubric Evaluation Criteria	N	Minimum	Maximum	Mean	SD
Specialized search knowledge	167	2	4	3.72	.569
Writing skills	167	2	4	3.52	.751
Conceptual Competencies	167	2	4	3.62	.552
Appointment location	167	3	4	3.37	.485
Paraphrasing quotations	167	2	4	2.75	.961
Writing skills	167	2	4	2.89	.951
Procedural Competencies	167	2	4	3.00	.772
N valid (per list)	167				

Then, exploratory boxplot analyses were performed to identify atypical or extreme cases [53]. Thus, Figure 5 shows that, in ***conceptual competencies***, 75% of 167 students (approximately 125) are between "good progress" and "excellent progress." Nevertheless, 25% (approximately 43) are between "fair progress" and "good progress." With respect to ***procedural competencies***, 50% of the students (approximately 84) are between "good progress" and "excellent progress". The other 50% are between "fair progress" and "good progress."

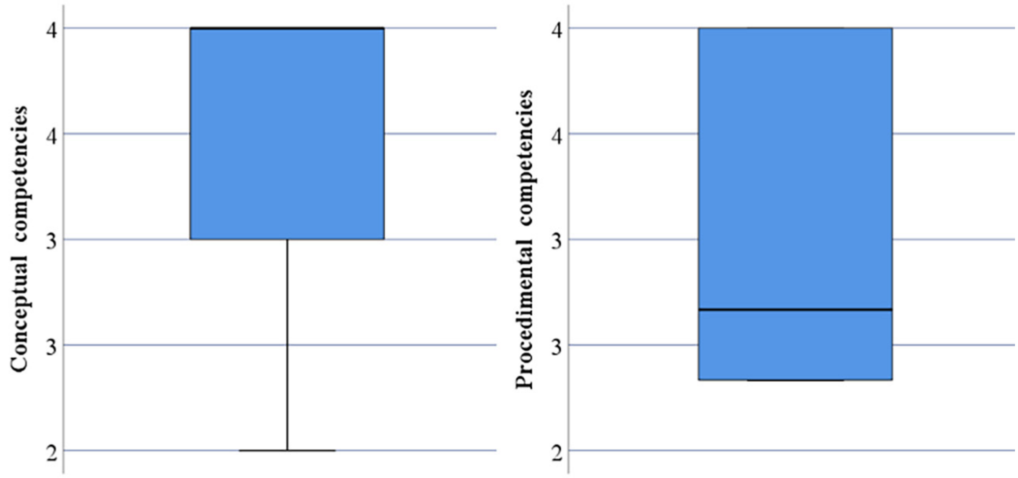

Fig. 5. Boxplot to compare the levels between conceptual and procedural competencies

4.5 Summary of results

The synthesis of the procedures for analyzing the results shows that the rubric achieved optimal values of validity and reliability to evaluate conceptual and procedural competencies. Then, the average of the evaluations corresponds to "excellent progress." Finally, the comparative analyses confirm that when evaluating procedural competencies, the levels achieved were better than conceptual competencies (see Table 5).

Table 5. Instrument validity and reliability

	Process	Results	Optimal Values
1	Rubric validation	KMO = 0.74; $p \leq 0.05$	KMO ≥ 0.70
		$\alpha = 0.85$	$\alpha \geq 0.70$
		Values: 1–6	Values ≥ 4.00
2	Mean analysis	Mean = 2.75–3.72	Mean = 4.00
3	Comparative analysis of competencies	Boxplot = 2.00–4.00	$p \leq 0.05$

4.6 Discussion

Aware of the contributions of engineering in society, it is essential to understand the role of education in the training of future engineers [18] as well as the need to innovate the curriculum and teaching processes oriented to engineering research learning [17]. For which, these teaching processes should be led by research teachers [15] and thus design research processes according to quality standards [29]. Therefore, the present study was oriented according to the objective of implementing a curricular proposal of multi-strategy learning sessions to apply an inductive methodology in the teaching of ınvestigation in general training courses aimed at students of first-year engineering careers of a private Peruvian university. Thus, ensuring that engineering continues to contribute to social progress [18]. Particularly, in the second study, an educational improvement proposal [33], based on multi-strategies [34] of the inductive type was applied. After 17 learning sessions in which students developed conceptual and procedural competencies at the investigative level, it was observed that the design of the rubric for the evaluation of investigative competencies met the requirements of SINEACE [42]. Because it achieved approval in the validation by judges [41], factorial validity [51], and an optimal reliability coefficient [52]. Moreover, each rubric criterion achieved adequate levels of consistency [51]. However, it is necessary to apply other assessment processes that complement the rubric. Next, with respect to conceptual competencies, students evidenced excellent progress. This is adequate, but it is necessary to consider that theoretical knowledge is not enough in research; practical solutions are also required [11]. Then, in the procedural competencies, that is, in the practical writing activities, they achieved good progress, lower level with respect to theoretical knowledge. This result should be taken with some caution. Because teaching processes should develop competencies for research, development, and innovation [11]. This should be in accordance with the SINEACE research development guide [29]. Thus, to carry out adequate teaching innovation processes for engineering research [17], to continue with technological contributions [18], and thus, the concern in guaranteeing efficient educational systems [15].

5 CONCLUSIONS AND FUTURE WORKS

After the analysis of both studies, it is concluded that from the teachers' point of view, it is important to execute learning sessions that apply the methodology of inductive multi-strategies to teach research. Thus, induction allows engineering students to analyze particular examples of research and writing. These helped them to develop their conceptual and procedural writing skills. Given these findings, for future work, it is expected to extend the study with the participation of students for teaching planning and also to apply the methodology in various subjects.

6 ACKNOWLEDGMENT

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