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PAPER

Innovative Proposed Model between Formative Research and Accreditation of Engineering Programs

Laberiano Andrade-Arenas(✉), David Llulluy-Nuñez, Jesus Vilchez-Sandoval, Hipólito Reyes-Del Carmen, Luis Romero-Untiveros, Juan Lara-Herrera, Josellyn Alata-Palacios

Facultad de Ciencias e Ingeniería, Universidad de Ciencias y Humanidades, Lima, Perú

landrade@uch.edu.pe

ABSTRACT

Peruvian universities, as mandated by the University Law 30220, are required to establish research centers in order to obtain their licensing and optionally obtain accreditation for educational quality. In line with this requirement, the research study aims to propose an innovative model that establishes a connection between informative research conducted by students in the Systems Engineering and Computer and Electronics Engineering program and the accreditation process. For the development of the study, the soft systems methodology and the Maltese cross, both based on a systemic approach, were used. The study follows a qualitative approach; utilizing interviews with 15 stakeholders, and the data was analyzed using Atlas Ti22. The evaluation of the proposed model, which examines the relationship between formative research and accreditation, was conducted by experts. Criteria such as clarity, coherence, relevance and consistency were considered, resulting in an average value of 92.5%. This signifies approval since the threshold is set at a minimum of 75%. The study concluded that the proposed model is coherent as it effectively integrates research components from the first semester to the last semester and establishes a meaningful connection with the elements of accreditation. The research's contribution lies in its potential to benefit the university educational sector by allowing institutions to adapt the proposed innovative model according to their specific educational framework.

KEYWORDS

accreditation, formative research, university, soft systems, Maltese cross, innovative model

1 INTRODUCTION

Globally, formative research in university students depends on external and internal factors, such as the university's curricular program, educational model, university laws, national and international accreditation policies, and other factors. Thus, the university management, based on its guidelines and educational policies,

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proposes the way to articulate the research part with accreditation. This will depend on the curricular plans of the study programs, with a specific focus on courses related to research.

One of the countries in South America that initiated formative research efforts was Colombia in the 1990's. In contrast, in Peru, a strong promotion of formative research began more recently in 2015 with the licensing of universities. In Peru, the development of research is considered one of the primary functions of universities, as explicitly stated in the law. Likewise, research, technological development [1], and innovation are essential factors for ensuring the accreditation of various programs, including engineering programs. Therefore, it is necessary to incorporate the cultivation of research skills in the training process of the future professional. For this reason, some universities include formative research programs in their curricula as early as the first semesters [2]; others adopts research management systems models that allow the implementation of a formative research program for students. In addition, formative research is understood to mean the training in research-related courses integrated within the curriculum.

Research forms a fundamental pillar of education, especially in university education. In this sense, it is very important that this component is integrated in the educational model of universities to guarantee its application in the curricular design of educational programs. Accreditation models for study programs include criteria or standards related to formative research, enabling the evaluation of how well this dimension is internalized and systematized within the students' educational process. All university accreditation models include the training of researchers, and in particular, the two national accreditation models implemented in Peru incorporated the research criterion within their respective evaluation models [3] [4]. Research has emerged as a pivotal pillar in the practice of the engineering profession, emphasizing the need to nurture research capabilities of professionals starting from the first semester. Formative research develops capacities for lifelong learning and contributes as a basis for the elaboration of scientific articles and degree theses. Currently there are 250,000 engineering students in Peru, with the most sought after program being Civil Engineering, Systems Engineering and Industrial Engineering. The duration of engineering studies in Peru is 5 years. Accreditation in Peru can be obtained through various institutions, such as the National System of Evaluation, Accreditation and Certification of Educational Quality (SINEACE), the Institute for Quality and Accreditation of Computer Science, Engineering and Technology Programs (ICACIT), or the Accreditation Board of Engineering and Technology (ABET). Accreditation is not indefinite, but rather has a specific duration, and to be accredited you must meet all the requested requirements. Currently, there are 29 programs accredited by ICACIT.

In the Faculty of Science and Engineering of the Universidad de Ciencias y Humanidades (UCH), the Formative Research program is implemented as an integral part of the curricular program. This program aims to develop research competencies in students throughout their academic journey. These competencies and abilities are obtained through the subjects of the first semesters, such as Interpretation and Production of texts, Writing and Argumentation and Academic Research, which is the initial part of the program. By laying a strong foundation in research methodologies and academic writing, the program prepares students for advanced research work as they progress in their studies. The intermediate part of the program focuses on essential subjects such as statistics and scientific knowledge. The advanced part consists of courses on Methodology of Scientific Research and Thesis for obtaining the degree. The university's research model encourages students to contribute to society through interdisciplinary and multidisciplinary projects [3]. However, at the UCH under study, the intermediate program was not integrated with the initial and advanced program, as the study plan was not designed for it. In addition, the emphasis in the context was primarily on the university's licensing rather than the accreditation of the individual programs. In addition, there are areas to improvement concerning the research skills of engineering students, particularly in writing and the effective utilization of technological tools [5] [6]. As a result, there has been a low production of theses and a limited number of graduates in the engineering programs.

Moreover, the application of the soft systems methodology, which is based on the systemic approach, will be applied. This methodology enables an integrative and holistic analysis of accreditation and formative research by examining the whole and its constituent parts. Therefore, the objective of this research is to develop a proposal for formative research that contributes to accreditation of engineering programs at UCH. Subsequently, we will design a formative research model that is aligned with the accreditation process. The integration of formative research and accreditation can complement each other with greater preponderance. Finally, the proposed model will be submitted to an expert evaluation.

Having stated the above, it is specified that this research work is made up of the following structure. Section 2 presents the literature review. This is followed by Section 3, which details the methodology to be used in the research. Section 4 presents the results and discussions obtained, and finally, Section 5 presents the conclusions drawn from the research.

2 LITERATURE REVIEW

This section focuses on the integration of formative research and accreditation in engineering programs. It encompasses the examination of various data, including results, conclusions, methodology, and other relevant aspects. By considering the limitations identified in the reviewed articles and opportunities for improvement made by other researchers, this section enables the development of a research work that aligns with the existing literature.

Formative research plays a crucial role in universities as it facilitates the development of students' research skills. Moreover, it should be complemented by accreditation, which serves as an evaluator of this dimension. There is a clear necessity to significantly improve programs by incorporating formative research. When research becomes an integral part of professional training, it becomes a powerful tool for intellectual and motivational transformation, contributing to the quality of professional education. This integration should be explicitly reflected in the curriculum, study plans and the overall structure of the academic program [7]. Research should serve as the foundation and cohesive element across all subjects. To this end, it must be guided by a research tutor who motivates and guides the students in all the components of research. Besides, the author [8] states that formative research can be related to project-based courses by examining students' perceptions. Establishing such a connection is contingent upon the effective implementation of a well-structured study plan.

Universities are now expected to fulfill not only their teaching responsibilities, but also to make significant contributions through social responsibility and research.

Consequently, all accreditation models incorporate criteria or standards assess the quality of research [9]. It is also necessary to clarify the need to articulate teaching and learning with research, technological development, innovation, and social responsibility. In this article, the researchers conduct a documentary review methodology to analyze how formative research is approached within the quality models of the Peruvian university system. The aim is to enhance the quality of professionals graduating from universities.

Accreditation processes play a vital role in ensuring continuous improvement, which ultimately leads to a better service for students and enhance the reputation of academic programs. Therefore, it is important for engineering programs to obtain international accreditations such as ABET. Both ABET and ICACIT are accreditation models for engineering programs, with the difference being that the first one has a greater scope than the second; In addition, ICACIT has its roots in ABET and, as a result, many of their criteria align with each other. Likewise, the national and international accreditation of these programs, conducted by the accrediting institutions such as ICACIT and later ABET, helps to establish trust by continuously improving both academic and administrative processes, as exemplified by the transition from the ICACIT accreditation model to ABET at the Professional School of Systems Engineering of the Universidad Nacional San Agustín (UNSA) [10].

Research in any field of study should embrace an interdisciplinary, multidisciplinary, and transdisciplinary. By doing so, problems can be examined from different approaches, which allows for development of a systemic solution. Engineering schools often face complex challenges that extend beyond their disciplinary boundaries and require a deep understanding of diverse realities. To address these challenges, conceptualization spaces are implemented, aiming to foster coherent processes aligned with the institutional work and high-quality accreditation policies [7]. Hence, we seek to analyze relevant aspects of research training within the School of Engineering of the American University Corporation considering the challenges imposed by the disciplinary, multidisciplinary, interdisciplinary and/or transdisciplinary tensions of the sciences. The importance of establishing specific and transparent objectives within the self-evaluation process is emphasized as an essential tool for the continuous improvement of academic processes, research endeavors, and educational quality management. This good practice not only fosters educational innovation but also ensures the sustainability of the ongoing accreditation process, thereby increasing the liklihood of university self-regulation through a systematized process [11]. To conduct a qualitative study, the project was initiated by presenting it to an internal committee comprising research teams, leading to the preparation of a final report that encompasses the results and an improvement plan. In addition, a comparison was drawn between the primary objective of accreditation, which involves monitoring educational programs including curriculum, teaching and learning, equipment, student performance, and more, as opposed to outcome-based evaluations and research applications present in those educational plans [12]. This makes it possible to identify and reach achievements and objectives within the field of engineering, aligning student-learning outcomes with institutional and professional criteria. These criteria are reflected in specific contexts that can be interpreted as research focal points. A comparative study was conducted to highlight the non-homogeneous behavior observed between the primary objectives of the accreditation systems and their implication in the research axes associated with to engineering education.

The accreditation process conducted by ICACIT involves the evaluation of 12 criteria for self-evaluation, with a specific focus on the Engineering program [13]. Within these criteria, three key aspects are are particularly relevant to research: the quality of the faculty' research, research conducted to obtain the bachelor's degree, and the publication of research findings. The methodology employed by ICACIT emphasizes problem-based and project-based learning approaches. As a part of this process, a final evaluation of the thesis project course and Thesis Seminar, was conducted at the end of the semester (X). The results indicated that 69% of the students obtained an evaluation level between "satisfactory" and "outstanding." This outcome serves as an indicator that the implementation of problem-based and project-based learning methodologies is effective and efficient.

The program's educational objectives (PEO) constitute one of the elements that needs to be evaluated to ensure its continuity in line with the university's mission and vision [14]. A comparative PEO study was conducted in accredited universities in the department of electrical and electronics engineering in Malaysia. The study was quantitative, where the methodology used in this comparative PEO study was based on the data from the statement of educational objectives of the electrical and electronics engineering program. The results of the PEO comparative study suggested that the attributes of competence, ethics, professionalism, and leadership have high priority. However, it was also emphasized that the growing demand for entrepreneurial, multidisciplinary, and soft skills should also be considered when reviewing the institution's engineering curriculum.

The impact of globalization 3.0 and the increasing emphasis for quality assurance and competitiveness of engineering education has been further amplified [11]. With the education being influenced by globalization, educational institutions and systems now face competition on a global scale, rather than just local or national contexts. This paper specifically examines the outcomes of accreditation process aimed at enhancing excellence in engineering education. The study was a qualitative study focusing on the outcomes of accreditation to enhance excellence in engineering education.

In summary, it can be concluded that formative research is important in the training of university students from the first semesters, with different levels of complexity. Likewise, it should be included in the curricular plan for its execution in engineering programs. Accreditation serves as a complement to students' research skills, as it includes research-related criteria. However, certain gaps exist. One such gap is the limited emphasis on the research component of accreditation, which tends to focus more on the academic aspects. In addition, there is a need to explore the utilization of technologies to optimize both the accreditation and formative research processes.

3 METHODOLOGY

The soft systems methodology [13] and Wilson with the Maltese cross was performed. It is a qualitative, non-experimental approach. The stages of the methodology are detailed below:

3.1 Unstructured situation

In the initial stage of the study, the primary objective was to gather insights into the challenges and issues pertaining to the subject of the investigation. For this purpose, interviews were conducted with all identified stakeholders involved in the process, including teachers, students, researchers, authorities, governmental bodies and accrediting entities. The current situation at UCH revealed a gap between the formative research and the accreditation process. Regarding formative research, students in the initial stage of their studies face difficulties in reading and comprehension. However, as the progress towards the final stage, they are able to produce articles and theses. Nonetheless, a significant gap was identified in the intermediate stages of the program. Furthermore, the accreditation of engineering programs includes criteria related to research and social responsibility, areas in which the UCH is actively promoting improvement. On the other hand, the engineering programs are undergoing a curricular redesign, with the aim of restructuring the curriculum to facilitate the integration of formative research courses with the elements necessary to support the accreditation process.

3.2 Structured situation

In this second stage, the involved parties, objects, entities, among others, are interconnected and linked together. For this purpose, these elements are grouped as subsystems Weltanshauung (W); W1, W2, W3, W4, W5 and W6 (see Figure 1).

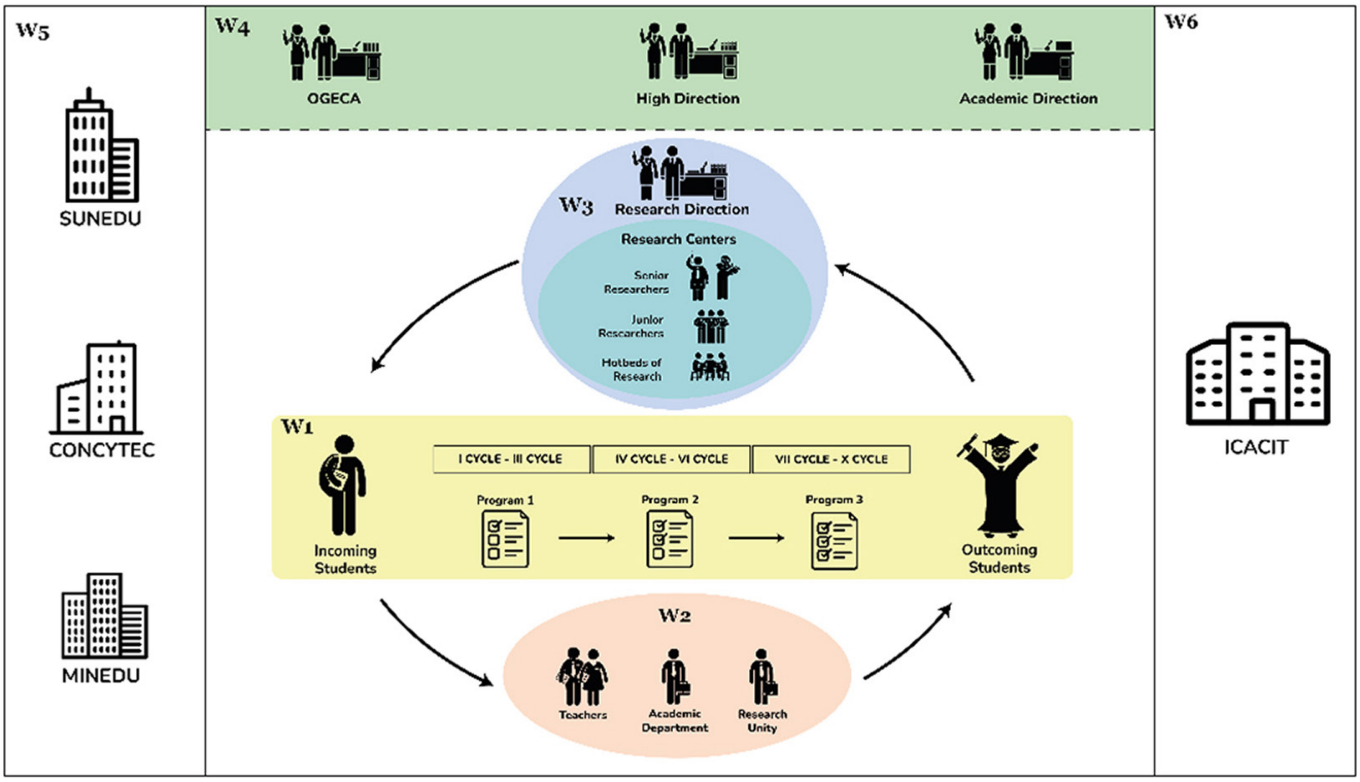


Fig. 1. Systemic pictorial chart

3.3 Basic definitions

The process of creating root definitions for the Ws, is crucial for establishing clarity and understanding of their semantic aspects and scope. These definitions provide a comprehensive view for the analysis and ensure that all the W's are clearly defined.

W: Weltanshauung – It is the perception of the identified problem is gathered by conducting interviews with each W, allowing them to express their viewpoints [15].

T: Transformation – It refers to the way in which each W transforms from the current situation to the desired situation. During the interviews, questions are posed to gather insights into the stakeholders' perceptions of both the current and future situation. This enables a deeper understanding of the transformation process and provides additional elements for the analysis.

W1: Students. A student is understood as a person who has this role within the university educational community and who fulfills the functions of a learner.

Program 1: Its purpose is to lay the foundations for the development of students' research skills and competencies. It consists of courses from the first semester to the third semester, namely Interpretation and production of texts, writing and argumentation, and Academic research. This program is also known as the initial program.

Program 2: Its purpose is to strengthen the acquired research skills by engaging in research work within specialty courses. It consists of courses from the fourth semester to the sixth semester, referred to as the intermediate program.

Program 3: Its purpose is the elaboration of scientific articles, thesis project, and the beginning of the thesis. It consists of courses from the seventh semester to the tenth semester, which include Methodology of Scientific Research (MIC), Research Seminar, Thesis 1, and Thesis 2. This program is also called advanced program.

Perception (W1): The following question was posed to three students: "What do you think about the subjects related to research in the process of your professional training?"

Transformacion 1 (T1): The following question was asked: "How do you think formative research is currently doing? In addition, how would you like to see it in the future?"

W2: Academic unit. It serves as a vital entity through which UCH fulfills its teaching, research, and service functions, encompassing a set of interconnected academic programs.

Teachers: They play a crucial role in guiding students' learning by facilitating research activities that fosters student engagement and participation.

Academic Department: It functions as an academic service unit that brings together teachers from related disciplines, facilitating the study, research, and enhancement of content while improving pedagogical strategies.

Research Unit (UDI): It operates as an organizational unit within the faculty, primarily responsible for managing and coordinating research activities conducted by the faculty.

Perception (W2): The following question is asked to 2 stakeholders: "What do you think about the importance of formative research and accreditation in vocational training?"

Transformation 2 (T2): The following question is asked: "How do you think formative research and accreditation is currently doing in the engineering faculty? And how would you like to see it in the future?"

W3: Research management. Actions aimed at strengthening research at the university include:

Directorate of Research. This department is responsible for proposing guidelines and policies aimed at strengthening the research culture at the university. It is also responsible for planning, executing, monitoring, and evaluating the strategic and operational activities related to research.

Research Centers. These centers consists of researchers from various disciplines such as Humanities, Health, Management, Science, and Engineering. They are organized based on the university's research areas.

Senior Researchers. These professionals possess extensive experience and play a key role in managing research projects. They also mentor and support faculty members and junior researchers in strengthening their research skills.

Junior Researchers. Junior Researchers are individuals who are at the early stages of their research careers, often starting as research assistants.

Research Seminars. These are specialized groups of students who have developed research skills. They are directed by a senior researcher who guides and orients them for the development of research aligned to their study program.

Perception (W3): The following question was asked to four stakeholders: "What do you think of the formative research programs in the Faculty of Science and Engineering?"

Transformation 3 (T3): The following question was asked: "How do you think the development of programs 1, 2 and 3 is currently going in the School of Engineering? How does the articulation of the research program help the accreditation of the School of Engineering? How would you like to see it in the future?"

W4: Directive management. Directive Management is the set of strategic actions developed by the University's Senior Management.

Top Management. It is the highest governing body of the university whose function is to provide guidelines and policies aimed at improving the efficiency and effectiveness of academic and research management indicators.

Academic Management. Es la dirección que se encarga de la gestión de los docentes y del proceso formativo de los estudiantes.

Quality Management Office (OGECA). It is an area that supports the management in matters related to the continuous improvement of the university service and is in charge of following up the whole process of accreditation of the engineering programs.

Perception (W4): The following question was asked to two people involved: "What do you think about formative research in student education?"

Transformation 4 (T4): The following question was asked: "How is the accreditation process of the Faculty of Science and Engineering currently going? How could it be related to formative research? And how do you see the link between formative research and accreditation in the future?"

W5: Government entities. Ministry of Education (MINEDU). It is a government agency that regulates university higher education and research.

SUNEDU. It is in charge of licensing and supervising compliance with Peruvian University Law No. 30220. The National Superintendence of University Higher Education (SUNEDU) supervises compliance with the eight basic conditions of quality.

CONCYTEC. National Council of Science, Technology and Innovation (CONCYTEC) promotes, coordinates, supervises, and evaluates the actions of the State in the field of scientific and technological research.

Perception (W5): The following question was asked to 2 stakeholders: "What do you think about formative research in universities and its relationship with accreditation?"

Transformation 5 (T5): The following question was asked: "How do you think formative research and accreditation is currently in Peru in engineering programs? And how would you like to see it in the future?"

W6: Accreditation entities. ICACIT. is an international accrediting agency specializing in science, engineering, and technology programs.

Perception (W6): The following question was asked to two participants: "What is your opinion about formative research in universities and its relationship with accreditation?"

Transformation 6 (T6): The following question was asked to a stakeholder: "How do you think the current state of formative research and accreditation in engineering programs in Peru is? And how would you like to see it in the future?"

3.4 Conceptual models (C.M)

They are activities (A) to be carried out for each W. These activities are oriented to the realization of the transformation (T), that is, from the current situation to the desired. It is suggested that the activities to be carried out should be in the range of 5 to 9; the activities are developed by the W according to the soft systems methodology. These activities begin with action verbs.

What activities should be carried out to achieve the desired situation?

C.M1: Students

A1. Elaborate a plan for research seedbeds.
A2. Select the courses that represent the integrating courses.
A3. To carry out strategies for interdisciplinary and multidisciplinary research.
A4. Training of teachers in the research area.
A5. Articulate the courses of program 1 with program 2.

C.M2: Academic unit

A6. To have contact with leading professionals.
A7. Promote business support.
A8. Promote the dissemination of technological advances.
A9. Search for entrepreneurial jurors in thesis submissions.
A10. Encourage participation in specialty events.

C.M3: Research Management

A11. Invite specialist teachers to guide the work of the MIC course.
A12. Promote interdisciplinary and multidisciplinary research.
A13. The curriculum must be at the forefront of emerging technology.
A14. Motivate through the updated lines of research by completing the program 2.
A15. Consolidate by strengthening the research seedbeds.

C.M4: Directive Management

A16. Strengthen the subjects that are linked to the formation of critical and reflective students.
A17. Continue to promote the publication of articles by students.
A18. Implement peer mentoring by students with more developed research skills.
A19. To train guiding researchers to consolidate the training process with research skills.

A20. To dose activities and generate the conditions to optimize the accreditation processes through continuous improvement.

C.M5: Government Entities

A21. Encourage research, particularly in engineering, to contribute to the development of the economy and social welfare.
A22. Continue and improve scholarship programs in the field of engineering, but at the same time, talent repatriation policies should also be strengthened.
A23. Implement an undergraduate mobility program to promote the exchange of students with other universities for research purposes.
A24. Include formative research as part of the indicators to be evaluated within the Basic Quality Conditions for Institutional licensing.
A25. Promote the articulation between Universities and the State with the participation of students in the analysis of social problems.

C.M6: Accreditation Entities

A26. Include an explicit standard on formative research in the Accreditation models.
A27. Articulate formative research with standards related to mobility or internationalization.
A28. Promote the development of innovation and the generation of entrepreneurship.
A29. Articulate formative research with applied research and social responsibility.
A30. Articulate the Accreditation model with the certification of engineering competencies through the College of Engineers.

4 RESULTS AND DISCUSSION

The interview analysis takes into account the questions asked to the Ws. These questions are based on their perceptions and on the transformation of the current and future situation. In addition, ATLAS.ti 22 software was used as a complement to optimize the analysis (see Figures 2–5).

The questions that were asked to each W was to gather their perceptive on the research program. (1, 2, and 3) and the problem under study. The purpose was to obtain insights and perceptions from each group, which would then make the transformation process. Regarding the Figures 2–5, the first number represents the document, followed by a colon, which indicates the lines entered into the entered into the Atlas.ti software. The numbers after the paragraph mark indicates the specific line within the document. The sample consisted of 15 individuals, including 3 students, 2 from the academic unit, 3 from the research management area, 2 from the university's board of directors, 2 from government entities and 3 from accrediting entities. The sample was intentionally selected from a population of 45 individuals.

4.1 Analysis of the interview with respect to program 1

In the Faculty of Science and Engineering, research is conducted from the first semester; with a focus on the development of analytical thinking among students. Through their inquiries, students develop the ability to construct their arguments and counter-arguments (see Figure 2). They begin to understand what they read, as well as acquire skills in writing monographs, engage in argumentation and counter-argumentation [16]. The relationships that exist between the courses that comprise program 1 and students' perceptions are evident, highlighting the significance of developing strong reading and writing abilities. The aim is for students to engage in critical argumentation and counter-argumentation as part of their research endeavors.

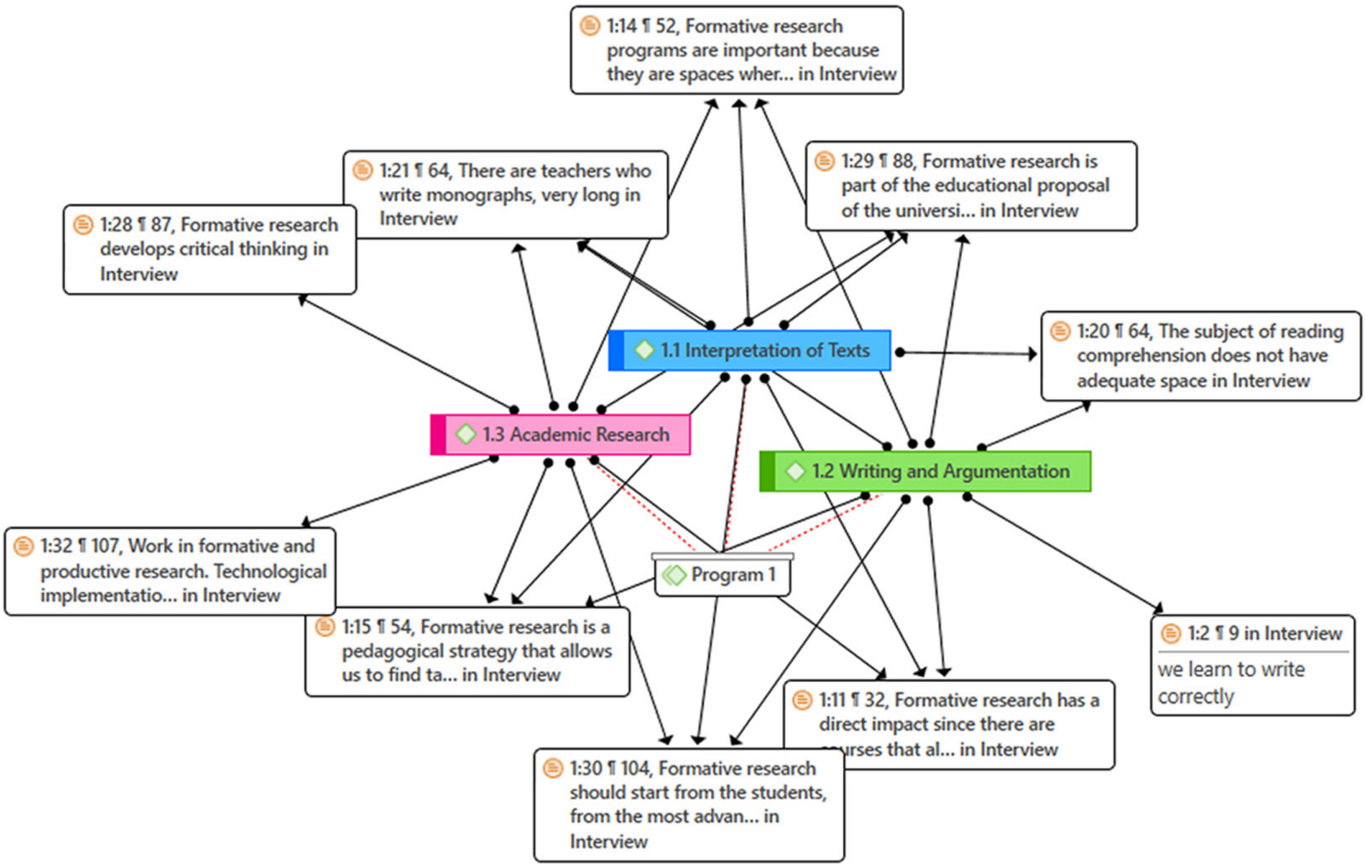


Fig. 2. Relationship of the interview of Program 1 through networks

(…) *The research we do in some subjects helps us in our professional training, since we learn how to write correctly, as well as how to research in depth on current issues* (…) W1a.

There are students who have difficulty in writing an essay because they have not had a solid foundation in secondary education; in this case, they are helped by reinforcement with teacher tutors. These students must develop their research skills in order to have a foundation in higher grades [17].

(…) *Currently, the courses we have learned have partly served us for our thesis, but we have forgotten what we learned in the interpreting courses and other courses, since the other professors did not continue teaching so as not to forget us and thus arrive at the last cycles with more knowledge* W1b. (…) *There are teachers who write very long monographs; there is a lack of training in this area.* (…) *should be a little more practical* W1c.

Likewise, teachers must be trained in the teaching-learning process of text interpretation, academic writing, and academic research courses. Scientific writing is important, as it allows the development of research skills and research abilities [18].

The University under study implemented program 1 with the objective of cultivating students' reading and writing skills. However, they encountered challenges in reading comprehension of the majority of students. Program 1 was emphasized in the curriculum as a transversal course, that is to say, it was applicable to the entire study program. The final course of this program is Academic Research where students learnt to search different platforms and databases, as well as the use of a bibliographic management software, like the Mendeley [19]. Likewise, the formative research that begins in the first semester, is guided by the research and academic direction's principles and guidelines. These guidelines shape the development of curricular plans and are reflected in the course syllabi and class sessions.

4.2 Analysis of the interview regarding program 2

Figure 3 identifies the importance of the courses that make up program 2 and the networks between the different perceptions of the different interviewees. The contributions of these courses allow students to apply them in advanced courses to develop their different projects. Moreover, in the networks observed, statistics is the fundamental basis for analyzing and treating data and then processing it using different complementary tools. Likewise, the scientific knowledge course allows the student to have scientific foundations so that the student has a solid theory.

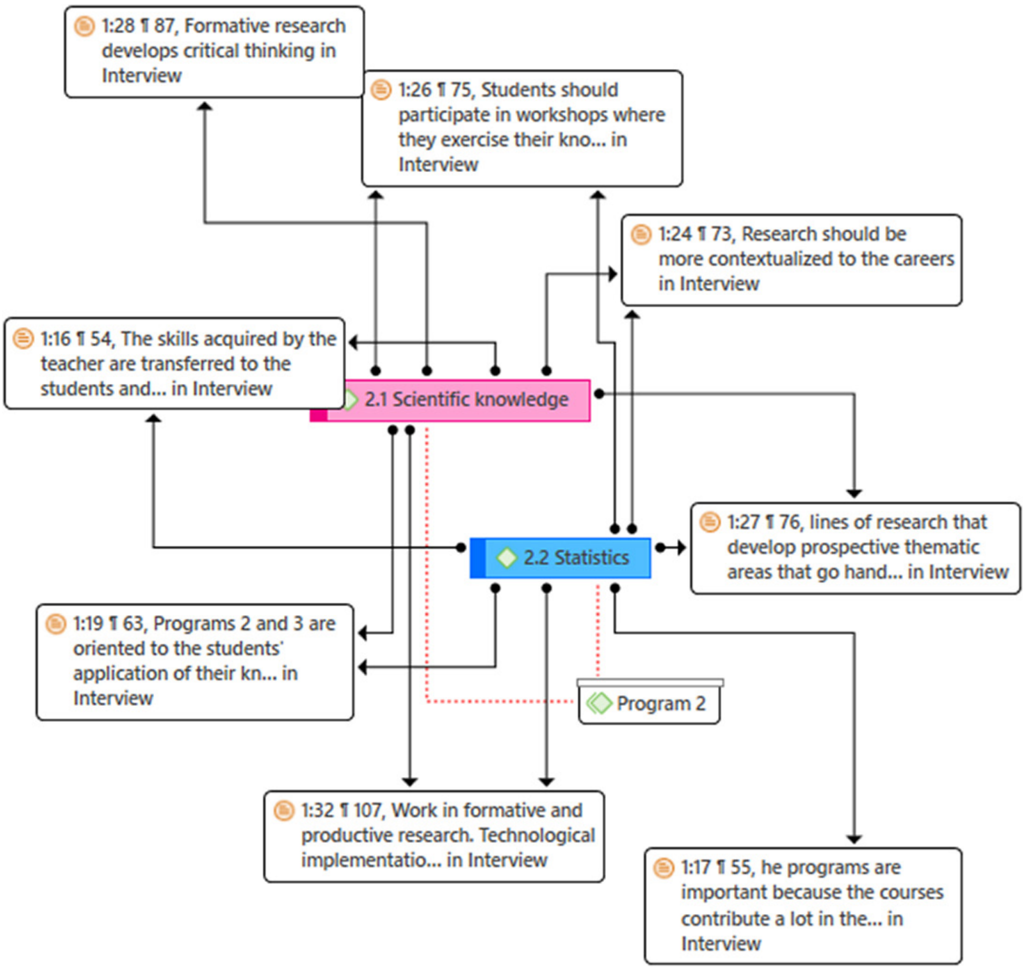


Fig. 3. Relationship of the interview of Program 2 through networks

(…) *The skills acquired by the teacher are transferred to the students and this is not only the case in research courses but also in some specialty courses* (…) W3a*.*

Teachers must be trained to be able to effectively guide students not only in utilizing technology in their research, but also in cultivating ethical behaviour, human sensitivity, and holistic development [20]. This complements the development of multidisciplinary projects.

(…) *Program 2 is important because the courses contribute significantly to the application of the specific knowledge acquired in the career courses and allow us to show the community in general the products of their training process, such as scientific articles*. (…) *Some are good at scientific writing and others at data analysis* W3b*.*

Program 2 consists of the courses in statistics and scientific knowledge.Initially, faced challenges as it was not available to all students in program 2. The statistics course is both practical and theoretical, allowing students to gather survey data related to their research topics, often employing quantitative approaches. Through this course, students develop research skills to analyze and interpret the results obtained from a descriptive or inferential statistics [20]. It serves as a basis for the research of thesis courses, projects, article writing, among others.

On the other hand, the scientific knowledge course serves as a theoretical foundation for integrating various knowledge aspects within the research environment. It enables students to differentiate between the different levels of research, research approaches, and research paradigms, among others [21]. In addition, students develop their critical thinking skills, reflective thinking skills, and translate it into their writing through courses that are adapted to it.

4.3 Analysis of the interview with respect to program 3

Figure 4 shows the articulated relationships between the different courses that make up program 3, as well as the perceptions of the different people involved. The dependence between thesis course 1 and thesis course 2 is notorious. This is due to the fact that one of them is a prerequisite of the other in the study plan. In addition, the relationship between the scientific research methodology course and the thesis seminar is related since they take 50% of the first course and in the following course, they finish 100% of the article.

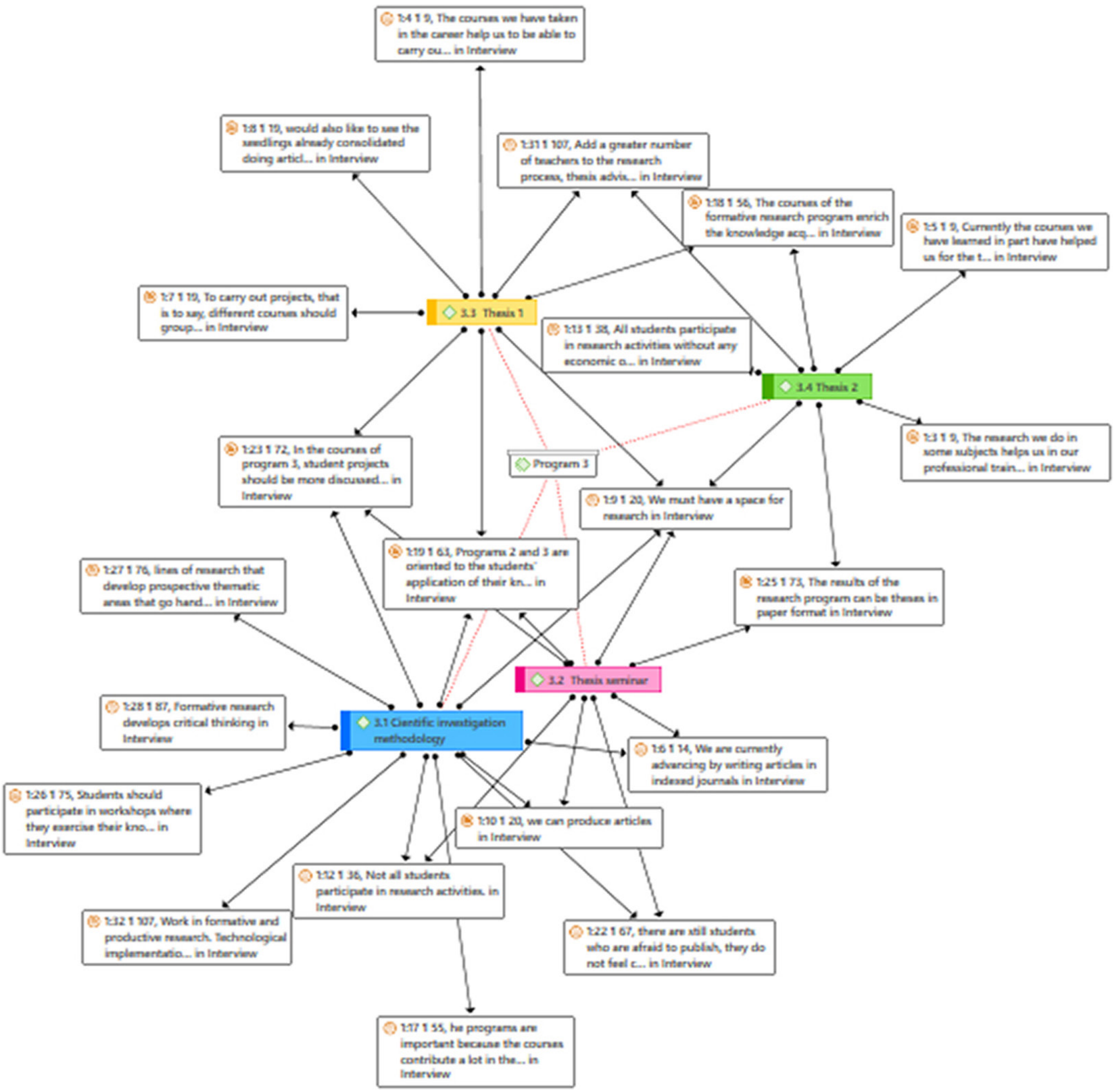


Fig. 4. Relationship of the interview of Program 3 through networks

(…) *We are currently making progress by publishing articles in indexed journals, but the thesis course lacks greater strength in its culmination* (…), *some classmates have forgotten the rules of spelling, sentences and how to make a paragraph that is what we were taught in the first cycles.* (…) W1a. *We must have a space for research, where, with the support of the University, we can produce articles, but with applications, for this we need the use of laboratories* (…) W1b. *Also, teachers should be trained in everything that has to do with research* (…) W4c.

The courses within the formative research program contribute to enriching the knowledge acquired by students and provide them with a global and holistic view that will allow them to approach the development of their thesis more effectively in the final cycles. However, it is important to note that the number of courses in the final cycles should be minimized to ensure optimal focus and dedication to the thesis project [21].

(…) *Not all students participate in research activities. The last semesters contain a heavy academic load. The existing lines of research are reiterative. In the last semesters of the curriculum there should be less academic load to give more room for research* W2a.

It is important to consider that not all students will pursue a research-oriented path, as many of them will specialize as engineers. However, those students who have a keen interest in research, they can be selected to join the university's research institute [22]. In addition, these students should be given the opportunity to develop their research skills. Therefore, it is recommended to avoid incorporating numerous additional courses in the final semesters, showing more time and focus for research-related activities.

(…) *Interdisciplinary lines can be handled, greater flexibility and openness. The results of the research program can be theses in paper format* (…) W3b.

Within the courses of program 3, students engage in research projects to demonstrate their research competences. However, there is a lack of emphasis on the development of multidisciplinary and interdisciplinary projects [23]. While students possess intriguing ideas, there is a need for greater practical application as their knowledge tends to be more theoretical in nature.

(…) *Student motivation should be worked on as a central aspect and research seedbeds that promote research in professional careers. W3c. Students should participate in workshops where they exercise their know-how in startups, the courses of the curriculum should be more flexible to adapt to foresight courses (…). I would also like to see the already consolidated seedlings making articles with other colleagues from the electronics career, and from other faculties (…)* W1a.

Formative research programs hold great significance as they provide students with opportunities to apply the knowledge they acquire, thereby fostering continuous learning skills and facilitating their seamless integration into the productive sector with a critical mindset. These programs also serve as a means to promote research seedbeds [24]. It is worth noting that these programs are useful not only for students but also for teachers. Formative research serves as a pedagogical strategy that enables the identification of talents among students through the forming of study circles, student branches for startups, and other projects.

Peruvian universities employ several approaches to formative research, which actively involve students in the development of research projects at different levels of complexity as integral part of their subjects. These approaches include training students in various aspects related to research, allowing them to meet the curriculum requirements and ultimately undertake, implement and support a research project to fulfill the thesis submission requirement.

Formative research plays a vital role in developing critical thinking, generates alternative knowledge, and encouraging the questioning of established knowledge.

In addition, the development of new technologies and accreditation should be driven by the highest quality indexes and standards.

Formative research serves as a crucial mechanism for providing students with research experiences, fostering the habit of research, which is vital in countries such as Peru, as it to contribute to the overall development of society.

4.4 Analysis of the interview with respect to accreditation

Figure 5 shows the relationship among formative research, graduate profile, and continuous improvement. The insights gathered from the interviews conducted with various stakeholders indicate that accreditation process should give greater preponderance to formative research and its associated criteria. In addition, internationalization efforts play a crucial role in providing students with a holistic view.

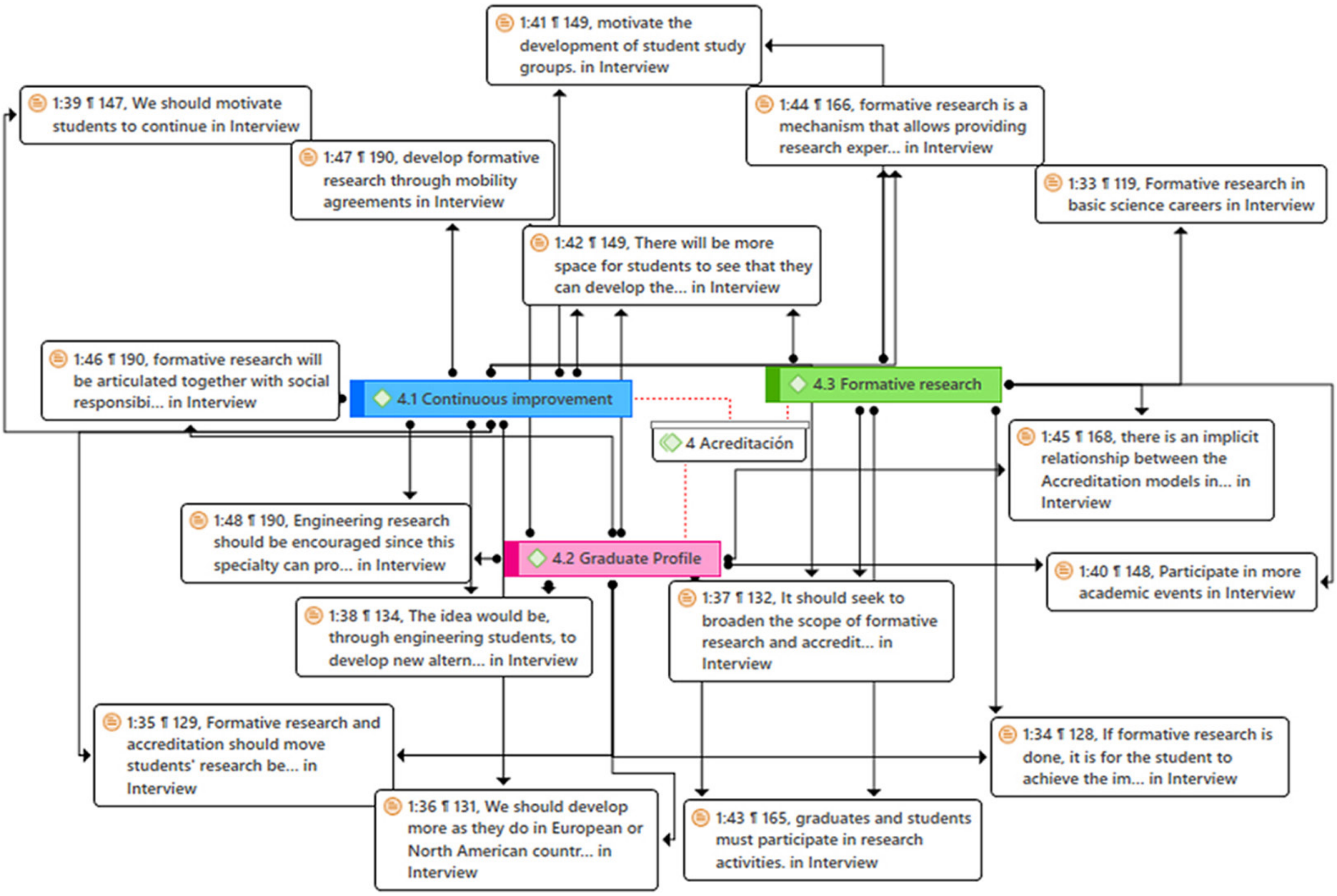


Fig. 5. Relationship of the interview on network accreditation

(...) *We should motivate students to continue (their education) not because they will find better jobs or better income (...) but rather by how qualified they are to carry out professional activities.* (...) *An academic teaching base and support is required. Then, it would be necessary first to ensure also that hard core of teachers who can advise these groups. This is what some call Capstone projects* W5b.

Students in their senior courses must carry out integrative projects that are called Capstone. This allows students to be interdisciplinary by integrating projects from different careers such as systems and electronics [25]. This depends directly on the curricular plan; and this is updated approximately every 3 years. Students should be motivated to develop projects that solve societal problems [26]. To this end, the university must budget for student research; in addition, faculty researchers and research tutors must be trained in the specific areas [7].

(…) *In the model for the accreditation of university higher education programs (Sineace 2016) which applies to all programs including engineering programs, does not specifically address formative research as a standard. In the self-evaluation reports, the quality committees elaborate the self-evaluation report according to the approach or experiences that it develops* W6b.

Formative research and accreditation should go beyond the sole objective of obtaining academic degrees and producing immediate outcomes [11]. Similar to European and North American countries, where students, including those in engineering or other fields, aspire for continuous personal growth and knowledge expansion. The scope of formative research and accreditation should be broadened to encompass goals beyond mere professionalization and economic achievements [27].

(…) *It is well known that the development of a country depends to a great extent on its education. For quite some time now, we have been talking about the quality of education and the General Law of Education contemplates it, so much so that the National System of Evaluation, Accreditation and Certification of the Quality of Education was created.* (…) *which would allow access to accreditation or simply to self-regulation. Sineace proposed a model for the Accreditation of University Higher Education Study Programs through which it recognizes the diversity* W5b.

The National accreditation model established by SINEACE incorporates standards for obtaining degree and title. The fulfillment of these standards can be directly related to the integration of formative research within the teaching and learning process [10]. Therefore, it can be concluded that, there is an implicit relationship between Accreditation models in Peru and the application of formative research in the training of undergraduate students.

4.5 Confirmed and validated conceptual model

For the purpose of grouping activities, the MoSCoW technique (M: Must; S: should; C: Could; W: won't) was utilized. This technique helps prioritize the most crucial activities, eliminate those that do not add value, and consider potential modifications to certain activities without significant impact. Based on this criterion, the selected activities were chosen to ensure their relevance and alignment with the desired outcome.

In order to carry out the confirmed and validated activities (VA), a process of grouping activities (A) based on their affinity was conducted. Activites that did not add value were eliminated (E), and any newly identified activities were inserted (I) as necessary (see Figure 6). Table 1 shows the selected VAs with the addition of activity A 31 resulting in the obtaining of VA 9.

Actividade	AV1	AV2	AV3	AV4	AV5	AV6	AV7	AV8	AV9
A1	A								
A2		A							
A3			A						
A4			A	A					
A5				A					
A6					A				
A7					A				
A8				E					
A9					A				
A10						A			
A11					A				
A12			A						
A13		A							
A14				E					
A15	A								
A16		A							
A17				A					
A18				E					
A19			A				A		
A20						A			
A21							A		
A22				E					
A23								A	
A24				A					
A25								E	
A26				A					
A27								A	
A28					A				
A29					A				
A30				A					
A31									I

Fig. 6. Grouping, elimination and aggregation of activities

Table 1. Confirmed and validated activities

VA1	To carry out the policy and process of the research seedbeds
VA2	Develop a curriculum in line with emerging techno-logical trends
VA3	Establish interdisciplinary and multidisciplinary project strategies
VA4	Articulating formative research with accreditation
VA5	Develop a plan to recruit teachers with professional and business experience.
VA6	Promote national and international events
VA7	Develop students' research skills with critical thinking and contributions to society.
VA8	Articulate formative research with standards related to mobility or internationalization.
VA9	Design a prototype for the implementation of a research management and accreditation system

4.6 Maltese cross analysis

The Maltese cross approach involves analyzing the selected activities by considering the input and output information with each activity. This information is organized in a matrix shaped like a cross, with the east and west cardinal points guiding its structure, and in the activities placed in the upper north section. Additionally, the southern part of the matrix accommodates the procedures of processing the information, which can be either manual or automated.

Figure 7 shows the Maltese Cross, which consists of the cardinal points East, West, North, and South. Where in the North part is placed in the AVs that were 9 in ascending form. In addition, in the left and right wings that are the West and East respectively, are placed the inputs and outputs of information of the AVs; and in the South part is placed the Procedures of the Information Processes (PPI).

X	X	X								X				**AV9:** Design a prototype for the implementation of a research and accreditation management system.				X				X			X			X
		X			X				X	X	X		X	**AV8:** Articulate formative research with the standards related to mobility or internationalization.				X	X	X			X					
					X						X	X	X	**AV7:** Develop the investigative skills of students with critical thinking with contributions to society.		X	X						X					X
		X					X	X		X	X		X	**AV6:** Foment national and international events.				X		X	X	X						X
		X								X		X		**AV5:** Develop a plan to recruit teachers with professional and business experience.		X		X					X	X	X			X
	X		X	X	X				X	X	X	X	X	**AV4:** Articulate formative research with the accreditation.			X	X				X	X	X	X		X	X
						X	X	X			X	X	X	**AV3:** Establish strategies of interdisciplinary and multidisciplinary projects.		X	X	X		X		X	X					
					X			X			X		X	**AV2:** Carry out a study plan according to emerging technological trends.		X		X		X		X	X					
							X				X		X	**AV1:** Carry out the policy and process of the research seedbeds.	X			X				X				X		
I14.Results through survey	I13.Quality management plan	I12.Internal process plan	I11.Internal audit report	I10.Accreditation self-study	I9.Curricular update	I8.Adjustments and modifications	I7.Communications plan	I6.Internationalization plan	I5.Accreditation guidelines	I4.Budget	I3.Strategic plan	I2.Curricular plans	I1.Guidelines and policies	NORTH Activities / WEST Input / EAST Output / SOUTH PPI	I1.Guidelines and policies	I2.Curricular plans	I3.Strategic plan	I4.Budget	I5.Accreditation guidelines	I6.Internationalization plan	I7.Communications plan	I8.Adjustments and modifications	I9.Curricular update	I10.Accreditation self-study	I11.Internal audit report	I12.Internal process plan	I13.Quality management plan	I14.Results through survey
	X	X	X	X					X	X		X		Information management system								X			X	X	X	X
		X					X		X	X	X		X	Quality control system				X			X	X		X	X			
	X						X						X	Educational quality management				X			X							X
	X	X				X					X	X		Planning system			X	X			X	X						X
	X	X				X				X			X	Cost management system		X	X	X				X						
X			X							X	X	X		Control system		X	X		X		X		X	X	X		X	X

Fig. 7. Maltese cross through the cardinal points

It is analyzed by quadrants using the cardinal points East, West, North, South, and their combination.

Analysis of northwest vs. northeast quadrants. VA4, which involves articulating formative research with accreditation, stands out as having the highest input and output of information. The input information includes the universities' guidelines and policies, emphasizing the incorporation of formative research into the educational model, as well as accreditation for the recognition of educational quality. These inputs should be aligned with the strategic plan and the curricular plan, which require budget allocation for its execution for the internal audit. On the output side, the self-study for accreditation is highlighted, which facilitates continuous improvement through feedback. This output should be taken into account in the strategic plan and budgeted accordingly.

Southwest vs. southeast quadrant analysis. One of the information processing procedures that has a significant number of entries is the information management system specifically the enterprise resource planning (ERP) software. The implementation and maintenance of the ERP system requires a budget allocation for adjustments and training. To assess user satisfaction with the ERP, surveys are conducted twice a year. Based on the survey results, it is evident that there is dissatisfaction with the ERP system.

Northwest vs. southwest quadrant analysis. In the analysis of the lower part of the left wing of the Maltese Cross, the budget category stands out as a significant aspect. It is crucial to allocate resources and make an investment to automate processes and optimize activities such as the articulation of formative research with accreditation, teacher training, fostering national and international events, and student mobility. By creating multiplatform websites, these activities can be enhanced and made more efficient.

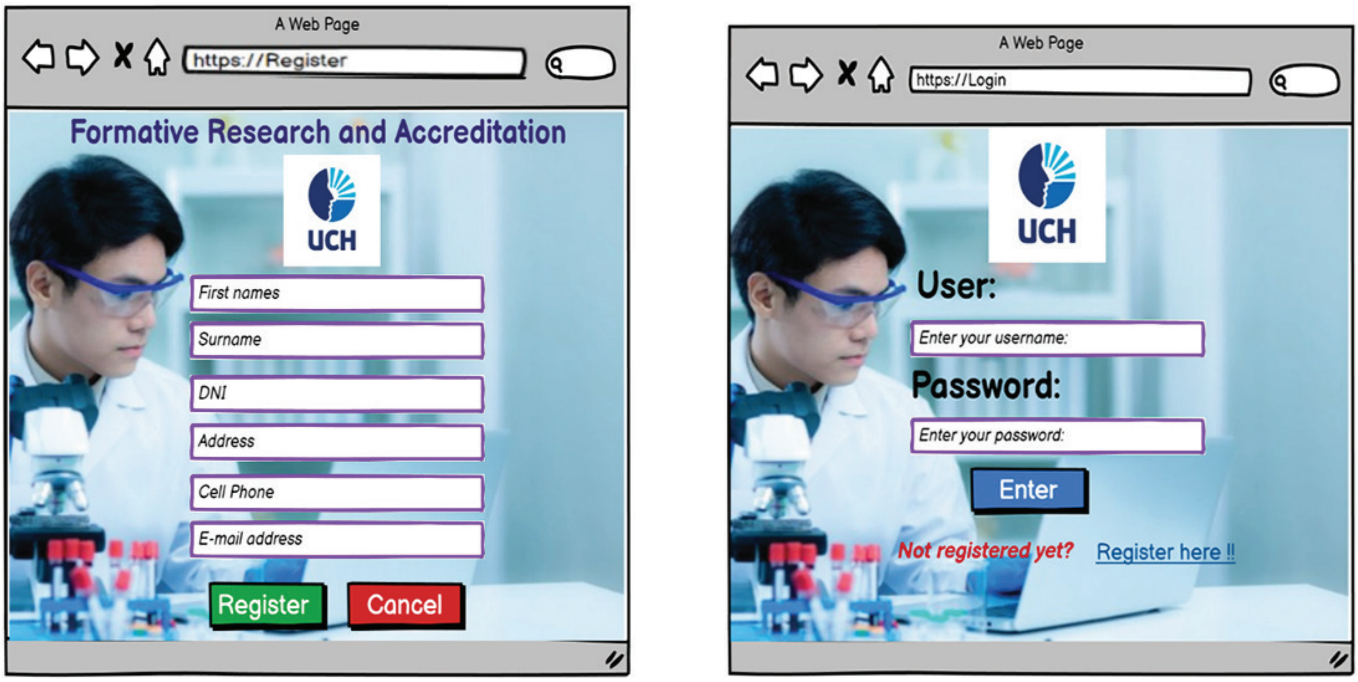
Analysis of northeast vs. southeast quadrants. Within the category of adjustments and modifications, there are six activities related to information management system, quality control system, planning system, and cost management system. One of these activities is the establishment of interdisciplinary and multidisciplinary project strategies. By implementing these strategies, research can be carried out in a holistic manner, allowing for a better contribution to society.

Analysis of northwest vs. southeast quadrants. The cross analysis of these quadrants, for a category of information such as the strategic plan, is mediated by the control system for execution through budgeting in national and international events, the implementation of a research management system, and accreditation.

Southwest vs. northeast quadrant analysis. Considering the PPI Information Management System allows for the organization of all the information of the Quality Management Plan and its implementation, including formative research and accreditation. it can optimize all the processes required by the accreditation bodies.

4.7 Prototype design proposal for formative research and accreditation

Figures 8 and 9 show the prototype made with the design software called Balsamiq. Figure 8(a) shows the prototype for registration, while Figure 8(b) displays the login. This allows end users to log in by entering all the requested data.



(a) (b)

Fig. 8. Prototype: (a) Register and (b) Login

Figure 9(a) illustrates the three formative research programs, with each program comprising the courses depicted in Figure 10. Additionally, Figure 9(b) presents the accreditation components, where each component is comprised of 11 criteria (see Figure 10).

(a) (b)

Fig. 9. Prototype: (a) Formative research and (b) Accreditation

Table 2 displays the results established by the accrediting agency ICACIT, for the students. These twelve results must be taken into account to ensure that students of the Engineering program can practice their profession correctly.

Table 2. Student results

Student Results	Concept
SR 1	Engineering knowledge
SR 2	Experimentation
SR 3	Design and development of solutions
SR 4	Individual and teamwork
SR 5	Problem analysis
SR 6	Ethics
SR 7	Communication
SR 8	Environment and sustainability
SR 9	Lifelong learning
SR 10	The engineer and society
SR 11	Use of modern tools
SR 12	Project management

4.8 Model research program courses and accreditation criteria

Figure 10 illustrates the direct relationship between formative research and accreditation. The orange-colored criteria represent the ones that will be considered for the analysis, while the others do not directly influence the research under study.

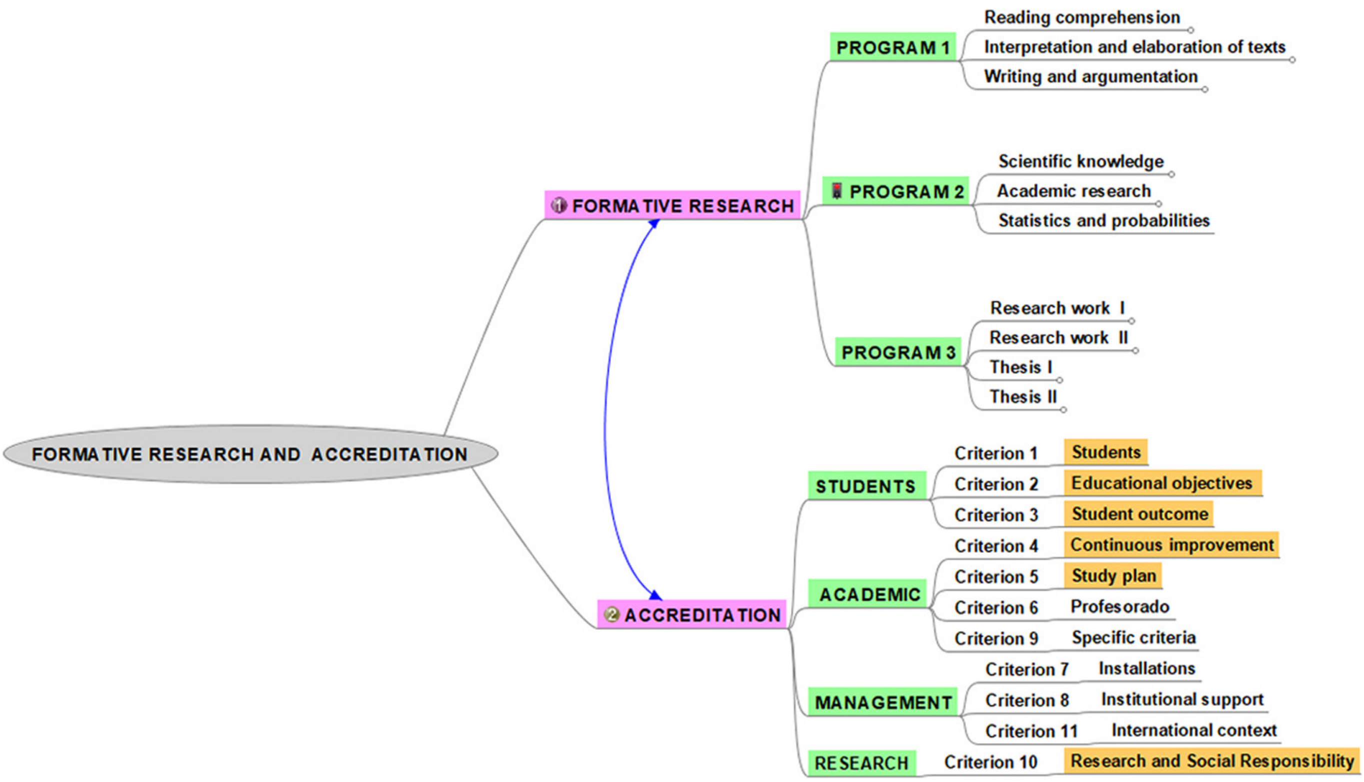


Fig. 10. Articulation of research and accreditation

Figure 11 showcases the proposed innovative model called the Holistic Incremental Model of Formative Research and Accreditation, which comprises of 4 increments. In the first increment, there is Program 1, consisting of three courses. In the second increment features Program 2, which acts as a pivotal point, also consisting of three courses. Moving on to the third increment, we have the third program, consisting of 4 courses dedicated to writing articles and theses. Lastly, in the fourth increment, we find the graduate profile, which determines whether students have achieved expected student results (SR) in their development. There are a total of 12 SRs, as indicated in Table 2. The model is holistic, since it analyzes the synergistic integration of the parts and the whole. It encompasses criteria that are represented by the orange color, which denotes educational objectives. These objectives must be demonstrated by the graduate after completingthree years of study program. Likewise, the criteria include the students themselves and the SRs. Students are expected to achieve the SRs through their subjects, making the study plan an important aspect composed of subjects with theory and practice. In addition, the criteria of research and social responsibility play a significant role. They determine the research part with social and business relevance, enabling the development of projects aligned with sustainable development objectives.

On the other hand, in the external part of the model, four processes have been included for each increment; adapted from the agile methodologies. The planning process allows to analyze the tasks and activities to be performed according to the users' requirements. Then, in the development process, a detailed description of each activity to be carried out is made through the development of the subjects in the classrooms, guided by a class session plan that is oriented to the syllabus according to the nature of the course. These must be oriented to the achievement of the SRs. In the evaluation process rubrics and indicators is utilized to evaluate the percentage of achievement in line with the self-study's declaration. Finally, the process of continuous improvement, which is also part of the criteria, allows for feedback by answering what was done well, what was done poorly, and what can be improved.

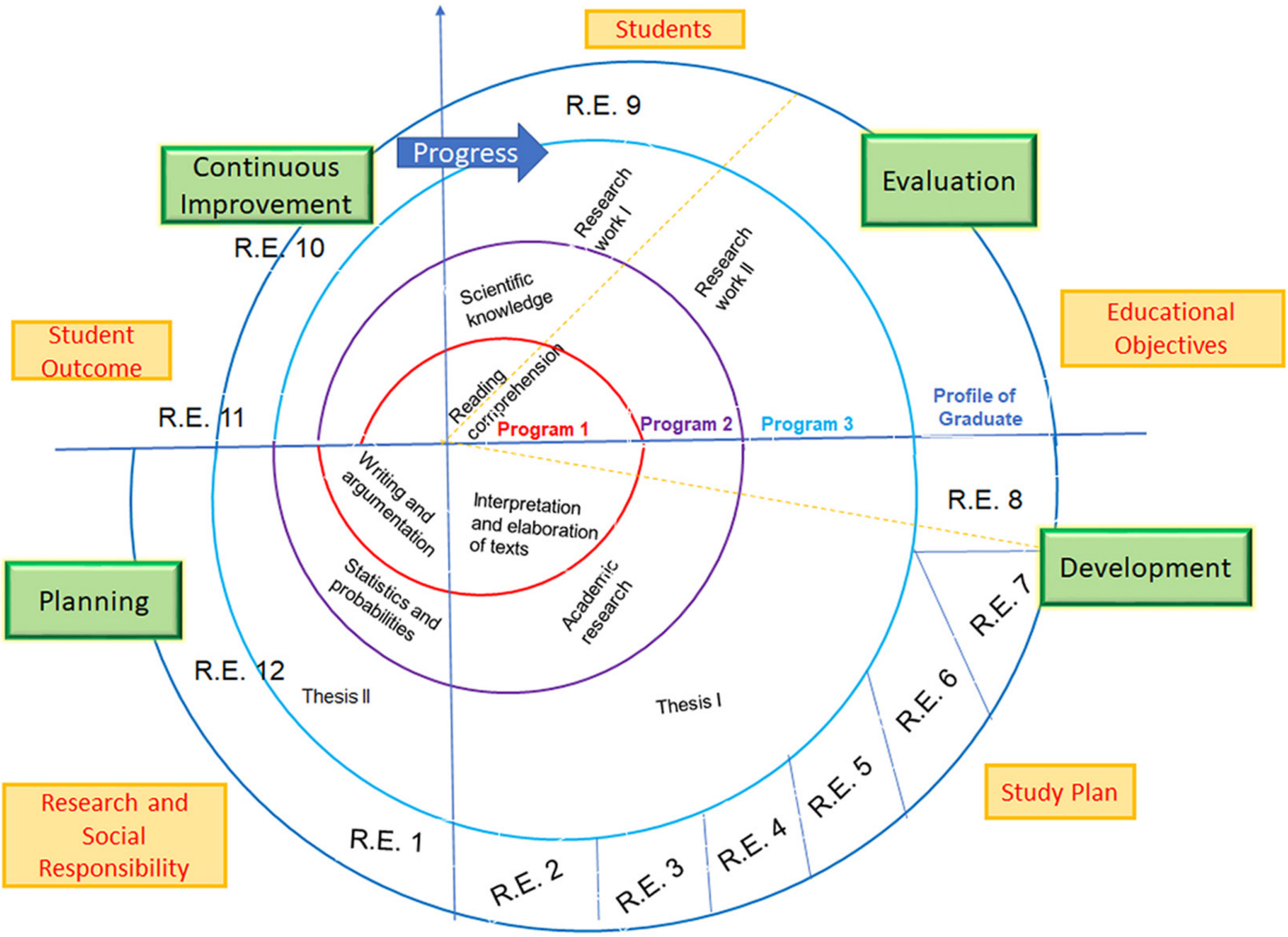


Fig. 11. Holistic incremental model of formative research and accreditation

4.9 Expert evaluation

Table 3 presents the evaluation conducted by 10 experts in university teaching, who are psychologists specialized in education. the evaluation considered several aspects: the clearly of the model is described; the coherence between incremental formative research and accreditation, the relevance of model's applicability in the university educational environment, and finally the consistency between its external and internal.

The evaluation was conducted using the semantic differential scale rating from 1 to 10, where 1 represents very low and 10 represents a very high rating. Then, a percentage equivalence was added to the evaluation, where 1 is equivalent to 10%. Then the average of all criteria such as clarity, coherence, relevance, and consistency were calculated. For approval by experts, each criterion must have a value greater than or equal to 75%. Figure 12 shows the average of each criterion, all of which exceeded 70%, with a total average of 92.5%. Thus, we consider the proposed model as approved.

Table 3. Evaluation of the proposed model

Criteria	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10
Clarity	80%	90%	90%	90%	90%	90%	80%	90%	90%	80%
Coherence	90%	90%	90%	90%	80%	100%	100%	90%	100%	90%
Relevance	90%	80%	80%	90%	80%	80%	100%	100%	90%	100%
Consistency	80%	90%	80%	80%	80%	80%	70%	80%	90%	100%

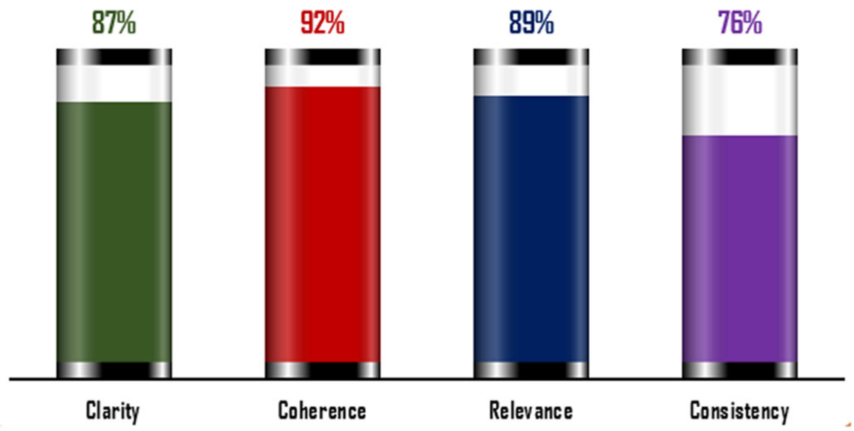


Fig. 12. Results by criteria of the proposed model

5 CONCLUSIONS

The proposed educational model aims to establish linking formative research and accreditation. This connection will facilitate part of the accreditation process of the engineering programs of the university under study. In addition, the model will be put into practice, allowing for an evaluation to be conducted after a suitable period of time. This evaluation will facilitate continuous improvement efforts.

The lessons learned during its execution will serve as a foundation for ongoing development of new versions of the model. This is because every model is dynamic, constantly evolving and changing.

On the other hand, the soft systems methodology provided an organized and coherent structure throughout the entire process. It was further complemented by employing the Maltese cross, which facilitated a quadrant analysis of the validated activities. One limitation encountered was the scarcity of innovative models of informative research and accreditation. Existing studies primarily focused on either the structure or the quality of the validated activities, without a comprehensive approach. Nonetheless, the research makes a valuable contribution to the university community, which comprises of students, teachers, and administrators.

As future work, it is suggested to adopt a multidisciplinary and interdisciplinary approach, involving various specialists in the research process. This would allow for a more integrated perspective and a deeper understanding of the subject matter.

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8 AUTHORS

Laberiano Andrade-Arenas has a Ph.D. in Systems Engineering, with studies in university teaching; extensive experience in research, with publications in Scopus. In addition, working with students with research skills and in the management of university teaching. His strength is working in groups with students, teachers and in a multidisciplinary and interdisciplinary way.

David Llulluy-Nuñez is an Electronic Engineer with a Master's degree in Control and Automation and with doctorate studies in Industrial Engineering. Research Professor recognized by the Peruvian State and associate professor at the Universidad de Ciencias y Humanidades.

Jesus Vilchez-Sandoval is an electronic engineer. He has a Master of telecommunications, and has 16 years of professional experience. Associate Professor, Head of the Quality Management Office at the University of Science and Humanities, renowned researcher, member of the Technical Committee for Standardization of Quality Management in Educational Organizations of INACAL, consultant to the Vice Minister of Communications.

Hipólito Reyes-Del Carmen is a Bachelor's degree in Education-Mathematics from the Universidad Nacional Mayor de San Marcos, Peru, in 2006. He obtained a Master's degree in University Teaching from the National University of Education, Peru, in 2016 and a doctor of science degree from Education by the National University of Education, Peru in 2108. Since 2009 he has been working as a teacher at the University of Sciences and Humanities in Peru. Areas of interest: Information Systems, Databases, Research Projects, Pedagogy and University Management.

Luis Romero-Untiveros is a System Engineer and has a bachelor's degree in Education. He got a master's degree in Social Management with major in Project Management and a master's degree in Informatics with major in Software Engineering at Pontificia Universidad Católica del Peru. He has led different projects and companies in several business lines. He has been a professor since 2016. Currently he is working on his thesis to get a PhD Degree in Strategic Management. He is interested in Politics, Management, LMS platforms, web applications and soft skills applied to technology. and is a research advisor.

Juan Lara-Herrera is a Bachelor of Science degree with a major in Electronic Engineering in 2006 from the Pontifical Catholic University of Peru. He is a candidate for a Master's Degree in University Teaching from the National University of Education. Since 2012 he has been working as a professor at the University of Sciences and Humanities in Peru. His areas of interest are Telecommunications, University Pedagogy and Research.

Josellyn Alata-Palacios is a Graduate and Bachelor in Philosophy from the National University of San Marcos. Founder and active member of the Numen Study Circle, as well as being a member of the Satori Cultural Association. She has been an organizer and speaker at various academic and research events. He is part of the administrative staff of the University of Sciences and Humanities. She independently works as an editor and layout designer for written publications.