Proceedings of the ASME 2021
International Mechanical Engineering Congress and Exposition
IMECE2021
November 1-5, 2021

IMECE2021- 69400

STRATEGIES FOR THE IMPROVEMENT OF RESEARCH COMPETENCES IN THE PROFESSIONAL TRAINING OF ENGINEERS

Carlos R. Vidal[1], Yimy Gordon[1], Deibys Barreto[2], Juan Fajardo[2], Pedro Fragoso[1]

[1]Universidad Popular del Cesar (UPC), Valledupar, Cesar, Colombia
[2]Universidad Tecnológica de Bolívar (UTB), Cartagena, Bolívar, Colombia

ABSTRACT

The objective of this study is proposing strategies to strengthen research competencies needed by engineers in training. An analytical, situation research was conducted in four Engineering programs from a public university located in the municipality of Valledupar, Cesar Department, in Colombia. A Likert-scale questionnaire of 50 items was designed; while a document, review was performed applying a matrix that systematized the information about the study plan. Ten experts and five experts respectively validated the content of the questionnaire and of the matrix. The interpretation of the data evidenced that the greatest deficiencies of students were methodological competencies such as "result analyses". They lack foundations on the use and interpretation of data, which hinders data processing for disseminating results, conclusions and recommendations in research reports. It is therefore necessary to transform the curriculum, including better teaching, pedagogical and didactic methods.

Keywords: Research competencies, Professional training, Generic competencies, Engineering

NOMENCLATURE

UPC Popular University of Cesar
CAN National Accreditation Council
ICTs Information and communication technologies
CIDTEC Research and Technological Development Centre for Charcoal
CIDI Research Centre for Engineering Development

1. INTRODUCTION

Research training comprises the development of abilities for solving problems, as well as for analyzing them critically, not only the development of introductory conceptual issues in research. Some Engineering programs offer classes of theoretical nature where teachers nor students apply no practical strategies. This is aggravated by the fact that they are considered "filler" classes, which generates apathy among students towards research courses, which in turn hinders their possibilities of developing research competencies [1] [2] [3].

Competencies refer to a set of abilities integrated at different levels, acquired through education, that allow people to function as autonomous, conscious and responsible individuals in multiple scenarios and contexts of social, personal and professional life. The term "competence" encompasses the integral formation of students in different areas: cognitive (knowledge), psychomotor (knowledge, performance, aptitudes), affective (knowing how to be, attitudes and values) [4] [5]. Thus, this concept cannot be narrowed down to simple work performance, nor to the accumulation of knowledge to carry out a task; it rather contains a whole set of abilities — cultural, affective, occupational, productive— which project and evidence the ability of a person to solve any given problem, within a specific and changing context [6] [7].

On the other hand, analytical thinking is one of the most important intellectual abilities throughout an engineer's training, since it teaches them to make decisions, establish guidelines and offer solutions to the problems that can arise in their work environment [8]. Research can teach certain skills to access and manage data, as well as ethical aspects such as respecting sources and intellectual property. Disseminating the results of any investigation also demands knowing how to choose the most appropriate means to do so, as well their protocols, and other skills such as structuring ideas coherently, choosing relevant data, properly presenting data using verbal, graphic and statistical resources [9] [10]. Research competencies tend towards the application of knowledge, emphasizing the different spheres involved in this activity, among which the epistemological, methodological, technical and social dimensions stand out [11] [12]. Developing research competencies implies their relation to the professional training process, honing skills to observe, ask, register field notes, experiment, interpret data and write about professional practices.

It is evident that, for an engineer, research training bears a high level of complexity, and it includes characteristics that are implicit in research related to their line of work. As well as different practices, methodological rigor, standardization and regulation, and all kinds of evaluative, formative, administrative and management operations that go along with the same structure of the research [13] [14] [15] [16].

Professional training programs offered in the area of Engineering do not ignore the particular characteristics of each one, and proposals for teaching research are part of the curricula, therefore, strategies to improve this type of competencies are necessary.

2. MATERIALS AND METHODS

This study was carried out as a situation analysis, an applied, non-experimental, field and cross-sectional research [17] [18]. The sample was composed of 265 students and 25 teachers from the last semesters of four Engineering programs in a public university located in the municipality of Valledupar, Cesar Department, in Colombia.

A theoretical and conceptual review was conducted on research competencies. Experts and normative documents were consulted, bibliographies and webpages were reviewed in order to build, describe, identify, analyze and draw conclusions about strategies to develop research training, human capital and micro-curricula in order to define indicators, relationships and contributions to research competencies training in the Engineering programs of the Popular University of Cesar.

A questionnaire adapted to the "Evaluation scale for research competencies" (EECI, or "escala de evaluación de competencias investigativas" in Spanish), used by Ortega & Jaik in 2010 [19], was applied. This instrument is divided into two parts: methodological competencies, with 38 items, and generic competencies, with 12 items. All 50 items are adapted to a Likert scale, with five numeric values: 0= N: Nothing; 1=VL: Very Low; 2= L: Low; 3=H: High and 4=VH: Very High.

Each item is oriented towards the evaluation of competencies related to the problem statement of a research, the structure of the theoretical and the methodological framework, the assessment of results, the use of a second language, the application of mathematical reasoning, the use of information and communication technologies (ICTs), and the frequent use of bibliographic sources. The content of the questionnaire was validated by ten experts, ensuring its reliability with the Cronbach Alpha method, which resulted in a validity of 0.969 [20]. The statistical analysis of the data collected with the survey was carried out with the program IBM SPSS Statistics for Window. The methods used were the analysis of variance (ANOVA) and Tukey's Post Hoc, with the objective of identifying the differences in means by dimension, in contrast with the lowest ones, such as the variable involved in the study from the interpretation of five categories of analysis according to the following scale:

Table 1. Scale for the interpretation of results

Evaluation scale	Category of analysis
1.00 < 1.80	Absent
1.81 < 2.60	Barely present
2.61 < 3.40	Moderately present
3.41 < 4.20	Present
4.21 < 5.000	Very present

Institutional documents were reviewed applying a matrix which systematized the information in the Engineering study plans about the strategies used in research training related to research groups, research "seedbeds" or groups composed by teachers and/or students dedicated to long-term researches.

Likewise, Lines of research, degree alternatives, and micro-curriculum characteristics such as contents, academic credits and teaching strategies in research-related courses from the study plans of the four Engineering programs linked to this study. Five experts validated the structure and content of the matrices [20].

3. RESULTS AND DISCUSSION

3.1 Methodological competencies:

The results for methodological competencies present in Engineering students are hereby presented. This include abilities to state the problem of a research, to structure a theoretical and methodological framework, as well as to assess results. Table 2 shows the 0.000 variance obtained with the ANOVA method for methodological competencies, lower than the referential significance level of 0.05. This demonstrates significant differences in the compared indicators.

Table 2. ANOVA for "Methodological competencies"

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	13.009	3	4.336	6.404	0.000
Within Groups	869.363	1284	0.677		
Total	882.372	1287			

Regarding Tukey's Post-Hoc test, the comparison shows the differences between the different indicators in the field of "Methodological competencies" in the variable "Research competencies".

Table 3. Tukey's Post Hoc for "Methodological competencies"

Methodological competencies	N	Subset for alpha = 0.05		
		1	**2**	**3**
Results	265	2.74		
Methodological framework	265	2.81	2.81	
Problem statement	265		2.96	2.96
Theoretical framework	265			2.98
Sig.		0.718	0.110	0.973

There are significant differences among them, illustrated in the distance between the results for each indicator, even the one which obtained the highest score in comparison to the lowest one, as shown in Table 3, shows the results of the comparison between the means of the indicators analyzed from “Methodological competencies”. Tukey’s Post Hoc test identified three subsets, placing in the first one the indicator “Results”, which resulted in the lowest score with 2.74 points, therefore catalogued as “Moderately present”. Next, the indicator “Methodological framework” was placed in the second subset, with a mean of 2.81 points. The indicator “Problem statement”, with 2.96 points, was placed in both the second and third subset. Both of these indicators were catalogued as “Moderately present”. Finally, the indicator “Theoretical framework”, with the mean of 2.98 points, was placed in the third subset. Although having the highest score, it still fell into the category of “Moderately present”.

The results allow affirming that, regarding “Methodological competencies”, the students evidence more deficiencies in the indicator of “Results”, since they lack statistical abilities. The indicator “Methodological framework” obtained a higher mean score than “Results”, demonstrating that students possess more knowledge in this area. The indicator of “Problem statement” evinced a better disposition about “Methodological framework” but a larger distance with “Results”. Lastly, the statistical analysis provided a better result in the students’ competence related to “Theoretical framework”.

The results correspond to those reported by Jaik & Ortega [21], as well as by Glazunova [13], who found that the differences in relation to the indicator of “Results” are basically due to the difficulty for students to manage measures of central tendency, to correlate data, to conduct frequency analysis, as well as to interpret statistical data.

3.2 Generic competencies:

The generic competencies applied by engineering students considered were possessing English as a second language, mathematical reasoning, using ICTs, and managing information for the development of the research. Table 4 shows the 0.000 significance level obtained with the ANOVA method, a value lower than the referential significance level of 0.05. Significant differences can be thus identified between the compared indicators.

Table 4. ANOVA for “Generic competencies”

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	553.295	3	184.432	219.991	0.000
Within Groups	1076.453	1284	0.838		
Total	1629.748	1287			

Regarding Tukey’s Post-Hoc test as shown in Table 5, the comparison shows the differences between the different indicators in the field of “Generic competencies” in the variable “Research competencies”. There are significant differences among them, illustrated in the distance between the results for each indicator. Nonetheless, this distance is shorter in comparison to the indicators of “Methodological competencies”, which show greater differences.

Table 5 shows the results obtained when comparing the means of indicators that belong to “Generic competencies”. Tukey’s Post Hoc identifies four subsets. The first one includes the indicator “English as a second language” with the lowest score, 2.21, cataloguing it as “Barely present”, likewise to the indicator “Mathematical reasoning”, located in the second subset with a mean of 2.51. The indicator “Information management” presents a mean score of 3.41 points, being placed in the third subset and catalogued as “Present”. Finally, the indicator “Use of ICTs”, with 3.74 points, is found in the fourth subset conveying the highest score and being catalogued as “Present” among Engineering students linked to this study.

Table 5. Tukey’s Post Hoc for “Generic competencies”

Generic competencies	N	Subset for alpha = 0.05			
		1	2	3	4
English as a second language	265	2.12			
Mathematical reasoning	265		2.51		
Use of ICTs	265			3.41	
Information management	265				3.74
Sig.		1	1	1	1

According to these results, the field of “Generic competencies” is “barely present” due to the negative incidence of the lack of knowledge concerning the English language, which can be probably attributed to the almost null application of strategies in this language in the study plans. Similarly, “Mathematical reasoning” has little presence in statistical results: it is evident that the application of mathematical reasoning to analyze research contexts is deficient. Regarding the management of information and the use of ICTs, both are present, which improves the mean score of answers regarding generic competencies. As is known, the use of the Internet becomes more and more popular every day among university students, which allows them to access different sources of information [13] [14] [16].

3.3 Strategies for research training in the Engineering programs of the Popular University of Cesar:

Research groups and seedbeds:

This investigation includes the programs of Agroindustrial, Environmental, Electronic and Systems Engineering from the Popular University of Cesar in Valledupar, Cesar Department, in Colombia. This programs stimulate training and research as part of their curricula through the promotion of research centres and groups such as the Research and Technological Development Centre for Charcoal (CIDTEC) and the Research Centre for Engineering Development (CIDI), formally created by agreements of the superior council of the University. They carry out the three main functions of the University: research, expansion (or social impact) and academics. Researches are led by research groups; expansion, by way of the department of industrial queries; and academics, through study centres.

In the curricula previously mentioned, research, curricular and extracurricular training is implemented through particular classes from the study plan, research seedbeds and groups led by teachers and researchers linked to each program. Current research groups linked to Engineering programs are presented in Table 6.

Table 6. Research groups linked to Engineering programs by category.

Academic program	Research groups	Categories established by MINCIENCIAS	Research seedbeds
Agroindustrial Engineering	6	A – B – 2R – 2Endorsed	7
Environmental and Health Engineering	2	B – Recognized	5
Systems Engineering	2	2B	8
Electronic Engineering	2	2C	4
TOTAL	**12**		

Table 6 shows that the Agroindustrial Engineering program has six research groups, which is proportionally related to the vocation towards productive development of the region corresponding to the agroindustrial sector, as well as to the fact that it is the oldest program of the University, having been created in 1994. From this date onward, other Engineering programs were created, meaning that they are relatively young, no older than 27 years of age. It can also be recognized that only one of the groups has earned the A category on MINCIENCIAS, which allows affirming that it is necessary to improve the scientific production of engineering programs through research.

On the other hand, Table 6 shows that the Systems Engineering program has more research seedbeds, in average four per each research group, which can be due to a larger effort in educational research within the contents of the classes of the study plan.

Research lines of the Faculty of engineering:

The work of research groups and seedbeds is sustained by a normative document concocted by the Research Committee of the Faculty of engineering under the guidelines of the Research Division of the University. Their objective is to gather all subtopics addressed separately in groups or seedbeds of the Engineering programs. These are:

Innovation and development of food and non-food biotech products: Encompasses the topics: innovation and development of food products, innovation and development of non-food products, biotechnological processes of the agroindustrial program.

Business development: Encompasses the topics: business development in the agroindustrial sector (from the Agroindustrial Engineering program) and, in general, allows this topic to be common to other programs that so require.

Post-harvest physiology and technology of vegetable and perishable products: Encompasses topics of the homonymous research line from the Agroindustrial Engineering program.

Automatization and process control: Encompasses topics related to automatization, simulation, design of equipment and agro-industrial process plants, from the Agroindustrial Engineering program, as well as to automatization and process control from the Electronic Engineering program.

Telematics, networks and communications: Encompasses topics addressed in the Electronic and Systems Engineering programs, specifically the research lines "Telecommunications, networks, Networks, and telematics, respectively.

Information and communication technologies (ICTs): Encompasses topics such as software engineering, educational informatics and information systems from the Systems Engineering program.

Bioengineering, optoelectronics and laser instrumentation: Encompasses signal processing and microelectronics from the Electronic Engineering program:

Smart systems: Encompasses subtopics from the homonymous research line from the Systems Engineering program, as well as the line of robotics from the Electronic Engineering program.

Information security: Encompasses topics related to this research line by the Systems Engineering program.

Sustainability and environmental management: Encompasses topics studied by the research lines of: Integral management of biodiversity and environmental heritage, Cleaner production and environmental technologies, Integral management of hydric resources, Occupational health and risk management, Solid and liquid residue treatment, Development of new products and materials from mining and energy resources, Sustainable technologies for the exploration and exploitation of mining and energy resources, soils and air.

Degree options in engineering programs:The current student regulations enacted by way of a normative document written by the superior council of the University offers students the possibility of degree as an engineer by choosing any of the following alternatives:

1. Research projects (monograph)
2. Preparatory exams
3. Seminars
4. Exemption of students who obtain a 4.50 overall average and who have never failed one or more subjects throughout their career
5. Exemption of students from the different undergraduate programs of the Popular University of Cesar, who take the test in the same application period and obtain in each of the generic and specific tests scores equal to or higher than the average plus one standard deviation of the national reference group
6. Industrial semester
7. Compulsory social service
8. Professional practices

However, in the period from 2015 – I to 2018 – I in the academic programs of environmental and Sanitary Engineering, Agro-Industrial Engineering, Electronic Engineering and Systems Engineering, graduate students have only used as a degree modality the research papers, professional internships and degree seminars as shown in the table in Table 7.

Table 7. Graduate students from the Engineering programs according to grade alternatives from 2015 to 2018

Engineering programs	Grade options		
	Research projects	Professional practices	Seminars
Environmental and Health Engineering	477		
Agroindustrial Engineering	99	9	23
Electronic Engineering	241	59	
Systems Engineering	231	26	80

Table 7 points out that the most predominant alternative used by Engineering students to obtain their degree in this University is research projects (84%), which strengthens the research activity of the Popular University of Cesar, followed by seminars (8.27%) and professional practices (7.55%).

3.4 Research courses in Engineering programs

The strategy for training engineers in the Popular University of Cesar is based on a system of academic credits, which distributes the time spent in classrooms and in the other activities related to academics. Table 8 shows the cycles which constitute the Engineering programs and the courses oriented towards in each one.

Table 8. Formation cycles and research courses in the Engineering programs from the Popular University of Cesar.

Engineering programs from the UPC	Formation cycles	Research courses
Agroindustrial Engineering	1. Basic training: basic sciences and engineering basics 2. Professional training 3. Research training 4. Complementary trainings: human, economic and administrative sciences 5. Institutional courses	1. Epistemology and research methodology 2. Research seminar I 3. Research seminar II 4. Project formulation and evaluation 5. Experimental design
Environmental And Health Engineering	1. Basic training: basic sciences and engineering basics 2. Professional cycle 3. Professional expansion cycle 4. Institutional courses	1. Research seedbed 2. Epistemology 3. Research methodology I 4. Research methodology II 5. Research project 6. Project I 7. Project II 8. Experimental design
Systems Engineering	1. Basic training: basic sciences and engineering basics 2. Applied engineering 3. Complementary training: Institutional courses 4. Research training	1. Research methodology 3. Research seminar 4. Research project I 5. Research project II 6. Engineering project formulation and evaluation 7. Project management TI
Electronic Engineering	1. Basic training: basic sciences and engineering basics 2. Professional cycle 3. Professional expansion cycle 4. Human sciences 5. Integral component 6. Research training	1. Research seminar 2. Project I 3. Project II 4. Experimental design 5. Research seedbed 6. Research methodology 7. Engineering project formulation and evaluation

According to Table 8, Engineering programs from the Popular University of Cesar are comprised by three cycles: basic, professional and expansion cycles. Besides, they include a set of additional courses. It is worth noting that the basic cycles share a set of classes or courses according to each discipline. Each program has a credit-oriented structure, which can differ in times depending or not on the student in each class.

Table 9 gathers the amount of courses in each program and the specific amount of courses oriented towards research. Shows that the Environmental and Health Engineering program orients 13.6% of its courses in the study plan towards developing research competencies, followed by Systems Engineering and Electronic Engineering with 13% and 12.5% respectively, while Agroindustrial Engineering only includes 8.9%.

Table 9. Total number of courses in each program and total number of research courses in Engineering programs.

Engineering programs in UPC	Total courses	Research courses	%
Agroindustrial engineering	56	5	8.9
Environmental and health engineering	59	8	13.6
Systems engineering	54	7	13
Electronic engineering	56	7	12.5

3.5 Teaching strategies

Engineering programs included in this study have developed a study plan based on the contextual cognitive pedagogical model of constructivist nature. In the context of this study, teaching strategies used by teachers responsible for research training in the Engineering programs of the Popular University of Cesar were classified according to Pimienta (2012), with the objective of determining which methodologies actually contribute to the development of research competencies and which are just strategies to ascertain previous knowledge or organize information [22]. Thus using the following teaching strategies:

Strategies to ascertain previous knowledge:

1. Brainstorming
2. Concept review
3. Direct question
4. Exploratory question
5. Literal question

Strategies that promote understanding through information organization:

1. Graphic organizers such as mental and concept maps
2. Essays
3. Round tables
4. Class activities that integrate the international dimension using a second language (workshops, case studies, among others)
5. Master classes in the classroom
6. Student presentations
7. Rubrics
8. Evidence portfolio
9. Introductory presentations to each thematic nucleus
10. Theoretical application workshop
11. Conversations
12. Correlating scientific articles from other national and international universities
13. Posters
14. Timelines
15. K-W-L charts
16. Summaries
17. Forums
18. Conferences
19. Phillips 66
20. Buzz groups.
21. Auto-regulated reading (IPLER method)
22. Mindfacts

Active methodologies to contribute to the development of competencies:

1. Studying topics of scientific research related to problems identified for project design
2. Reviewing and analyzing methodological components of disciplinary and interdisciplinary scientific articles
3. Developing research proposals
4. Problem-based learning
5. Inquiry-based learning
6. Simulations
7. Proposing exercises in which research projects from the University are inquired and analyzed, and the methodology identified
8. Designing research projects which propose a problem along with a possible answer, without developing it
9. Student presentations
10. Integrated panel for exchanging drafts and proposals
11. Case studies
12. Case discussion
13. Identifying conceptual and practical aspects of research projects
14. Field research
15. Teamwork in order to learn collaboratively
16. Field observation as significant learning
17. Scientific writing exercises (brief articles for revision)
18. Text analysis
19. Class projects
20. Research seminars
21. Virtual mediations
22. Roleplaying
23. Business visits

The above evinces those teachers from the Engineering programs of the Popular University of Cesar use strategies and methodologies with which they seek to develop research competencies in their students. Nonetheless, bearing this categorization in mind, it can be deduced that 54% of the strategies used are meant to ascertain students' previous knowledge (10%) and to promote understanding by way of organizing information (44%), none of which are adequate for developing actual research competencies.

The remaining 46% of strategies represent active methodologies used by teachers to contribute to the development of research competencies in students. These methodologies can be generalized as generative topic, simulations, projects, case studies, problem-based learning, in situ learning, ICT-based learning, service-based learning, tutored researches, cooperative learning, among others. These are the type of methodologies that teachers must implement in research learning in the academic programs of the Popular University of Cesar, although, as is evidenced in the previous classification, the amount of active methodologies is not very significant.

It can be thus inferred that one of the causes for the lack of research competencies in students from the Popular University of Cesar is the scarce implementation of strategies on behalf of teachers, their pedagogical practices, strategies oriented towards the development of research competencies in which student use their skills, abilities, knowledge and attitudes to solve problems. Therefore, a curricular transformation with better teaching, pedagogical and didactic methods must be promoted, oriented towards developing research competencies.

This evidences that Engineering programs of this University share a similar structure, differentiated by its disciplinary and specific areas, but with incipient use of ICTs as a strategy for the development of research training in students and teachers. Also considered are Delgado's statements regarding how the process of building knowledge must happen in a specific, organized context, and how its development is conditioned by significant aspects such as avoiding the overcrowding of classrooms; the improvement of the structure of the tutoring system; the planning and implementation of schedules and times of teaching-learning according to pedagogical criteria; and the abundance and diversification of teaching resources: technological and computational resources, laboratories, libraries, practice centres, among others [22].

In general, it can be asserted that Engineering programs from the Popular University of Cesar posses a basic structure, organized with the objetive of encouraging research training in students and teachers, which corresponds to what Rodríguez Acasio proposed when stating that research dynamics require an organizational and managerial process that can be adapted by researchers and co-researchers to their own needs, interests and environment. This is why the process of planning and performing researches is so important in order to obtain structured results [23].

3.6 Strategies to improve research competencies in Engineering programs of the Popular University of Cesar

Previous results allow defining the following strategies, attuned to the guidelines for the accreditation of undergraduate programs established by the National Accreditation Council (CNA) in 2013:

Strategy for research groups:

1. Increasing high-level scientific production demanded by the Science and Technology Ministry of Colombia

2. Participating in anual internal calls for financing research projects, tackling issues with high local, regional, national and international impact

3. Organizing and participating in national events for research groups, as well as disseminating results

4. Participating in events and building research networks, both national and international, that could bolster the interaction of the Popular University of Cesar with other education institutions

5. Supporting, administratively and financially, research groups for the development of projects

6. Offering a virtual space in the University's website, or even in an independent platform, to bring to light all research strategies and activities.

Strategy for research seedbeds:

1. Familiarizing first-semester students with seedbeds and other young researchers

2. Active and annual participation of students and seedbed tutors in national and international events on research seedbeds and young entrepreneurs

3. Organizing academic activities —internships, workshops, collaborative activities— related to the entrepreneurial world since the first semesters

4. Participation of students in projects involving the University, companies and the State, which can push the Popular University of Cesar forward

3. The Popular University of Cesar should assign physical spaces for the development of projects of research groups and seedbeds.

Strategy for degree options:

1. It is necessary that all alternatives for obtaining a degree include a final research product or a research report, which could allow identifying the research abilities and competencies of students.

2. Final degree projects to obtain a degree must meet the following criteria:

a. Relevance: Studies must be structured within the research lines of each program.

b. Rigour: The study must be developed within a specific field of knowledge. Research must be presented to and defended in front of a scientific committee.

c. Consistency: All the study must be coherent with the title, the problem statement, the research question, the objectives, the methodology, the expected and the final results.

Strategy for micro-curricula:

1. Updating curricula, including necessary classroom projects to successfully guarantee research training.

2. Micro-curricular contents must advance pedagogical strategies that allow to link the research process of the course's assignments to the needs of the socio-productive environment.

3. Programs must have a curricular structure with components that can offer professional and pragmatic generic and methodological competencies. Curricula must be oriented towards teaching research competencies.

4. Establishing criteria, designing strategies and organizing activities in the Faculty, in a cross-sectional manner, in order to promote abilities of enquiring, searching, as well as to inspire a curious, creative and innovative spirit in students.

5. Implementing active methodologies which can contribute to the development of research competencies in students. These methodologies can be generalized as generative topic, simulations, projects, case studies, problem-based learning, in situ learning, ICT-based learning, service-based learning, tutored researches, and cooperative learning, among others.

6. Increasing the number of research courses in study plans, in order to expand on different issues related to researching from a theoretical-practical perspective.

The application of the previous strategies demands a set of resources to be offered by the University in order to successfully implement and develop them. Likewise, it is necessary for its implantation to be done in accordance to the principles of discussion, collaborative participation, respect and critical thinking by the various disciplines of the institution. For its application, an initial diagnostic phase is proposed, then a design and planning phase, an execution phase and, finally, an evaluation and feedback phase.

4. CONCLUSION

It is evident that “Generic competencies” present better results in comparison to “Methodological competencies”, which are moderately present in students. There were greater competencies of “Methodological framework” and “Problem statement”, compared to “Results”. The competence of “Theoretical framework” obtained a greater score in relation to all others, nonetheless, students demonstrated in their answers that they moderately master said competence.

“English as a second language” obtained the lowest result, which can be attributed to the fact that students consider it as a curriculum filler, therefore, it is not given its due importance in the scholarly field. “Mathematical reasoning” has a discreet presence in statistical results, which means that there are deficiencies in its application in research. “Use of ICTs” was present as a competence, since society today has enjoyed cross-sectional learning, essential for all, and is even building a sort of digital culture. Therefore, students master ICTs more than previously mentioned competencies, since the former is part of their daily life.

Also, micro-curricula of research courses do not contemplate a permanent process which articulates theory and practice in order to strengthen research training. Likewise, there are no didactic, pedagogical processes that allow students to explore inquiry strategies, to identify problems, to analyze contexts and to offer possible solutions.

ACKNOWLEDGEMENTS

To the Popular University of Cesar and to all the teachers and students of the engineering programs who provided the support and information necessary to carry out this work.

REFERENCES

[1] A. Felicetti. A. Volpentesta, "Competence Mapping through Analysing Research Papers of a Scientific Community," *IFIP International Federation for Information Processing*, vol. 349, pp. 33 - 44, 2011. [Online]. https://hal.inria.fr/hal-01566580

[2] N. A. Bushmeleva and I. I. Tsyrkun I. F. Yarullin, "The Research Competence Development of Students Trained In Mathematical Direction," *International Electronic Journal of Mathematics Education*, vol. 10, no. 3, pp. 137 - 146, 2015. [Online]. https://www.iejme.com/article/the-research-competence-development-of-students-trained-in-mathematical-direction

[3] J. M. Carot Sierra, and E. Vázquez Barrachina A. Conchado Peiró, "Competences of Flexible Professionals: Validation of an Invariant Instrument across México, Chile, Uruguay, and Spain," *Sustainability*, vol. 12, no. 12, p. 5224, June 2020. [Online]. https://www.mdpi.com/2071-1050/12/12/5224

[4] Ximena Paoa Buendía Arias , Lilian Cecilia Zambrano Castillo , and Edgar Alirio Insuasty , "Development of Research Skills ¡n Pre-Service Teachers in the Context of the Teaching Practice," *FOLIOS*, pp. 179 - 195, 2018.

[5] Jahir Gutierrez Ossa, "Modelo De Competencias Investigativas Para Empresas Desde La Relación Universidad, Empresa Y Estado (UEE) En El Caso Colombiano," *Sotavento MBA*, pp. 42-64, 2014. [Online]. https://revistas.uexternado.edu.co/index.php/sotavento/article/view/3986

[6] Andrew Sirkka and Juraj Čáp, "Enhancing Research Competences in Healthcare Higher Education," *Profese online*, pp. 30 - 38, 2015. [Online]. https://profeseonline.upol.cz/en/artkey/pol-201501-0005_ENHANCING_RESEARCH_COMPETENCES_IN_HEALTHCARE_HIGHER_EDUCATION.php

[7] E. Nurith, Huber J., and M. Berberat P. O. Reimer M. M. R. Fischer Gartmeier, "Investigation on the acquisition of scientific competences during medical studies and the medical doctoral thesis," *GMS Journal for Medical Education*, vol. 35, no. 2, 2018. [Online]. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6022582/

[8] N. N. Sanjuan and R. A. Márquez Delgado, "The “Incubators” as Research Spaces for the Novice Researcher," *Propósitos y Representaciones*, vol. 7, no. 1, pp. 230 - 248, 2019. [Online]. http://revistas.usil.edu.pe/index.php/pyr/article/view/289/659

[9] P. Colás Bravo and M. A. Hernández de la Rosa, "Las competencias investigadoras en la formación universitaria," *“Universidad y Sociedad” (RUS)*, vol. 13, no. 1, pp. 17 - 25, 2021. [Online]. https://rus.ucf.edu.cu/index.php/rus/article/view/1891

[10] A. A. Torres Rodríguez, M. Campos Nava and L. Morales Maure E. F. Castro, "La construcción científica del conocimiento de los estudiantes a partir de las gráficas con Tracker," *“Universidad y Sociedad” (RUS)* , vol. 13, no. 1, pp. 83 - 88, 2021. [Online]. https://rus.ucf.edu.cu/index.php/rus/article/view/1900/1892

[11] Y. Shynar, K. Lyailya, I. Salamat, T. Nurgul. T. Uldai, K. Gulash, and B. Assel K. Kassiyet, "COMPETENCE IN THE STRUCTURE OF RESEARCH ACTIVITIES," *AD ALTA: JOURNAL OF INTERDISCIPLINARY RESEARCH*, vol. 10, no.

1 - special X, pp. 56 -58, March 2021. [Online]. http://www.magnanimitas.cz/archive

[12] O. O. GORSHKOVA, "The development of research competence among the students of technical education," *Espacios*, vol. 38, no. 56, p. 19, 2017. [Online]. https://www.revistaespacios.com/a17v38n56/17385619.html#uno

[13] O. Kuzminska and T. Voloshyna O. Glazunova, "Scientific E-conference as a Tool of Development Students Research Competence: Local Study," *CEUR Workshop Proceedings*, vol. 2105, no. 379 - 393, pp. 379-393, 2018. [Online]. http://ceur-ws.org/Vol-2105/10000379.pdf

[14] M. E. Aguilar Ferrándiz, J. C. Martín, O. García Martínez, M. Serrano Guzmán, and G. A. Cañadas de la Fuente C. Hueso Montoro, "Efecto de un programa de capacitación en competencias de investigación en estudiantes de ciencias de la salud," *Revista electrónica trimestral de Enfermería*, vol. 15, no. 4, pp. 141-151, 2016. [Online]. https://dialnet.unirioja.es/servlet/articulo?codigo=5725918

[15] F. X. Valverde Alulema and F. Llorens Largo, "Strategic portfolio of IT projects at universities," *Ingeniería e Investigación*, vol. 39, no. 2, pp. 46-57, 2019. [Online]. https://dialnet.unirioja.es/servlet/articulo?codigo=7345818

[16] C.Vidal, "Intellectual capital model for research in public universities in the colombian Caribbean Coast," *Revista Electrónica "Actualidades Investigativas en Educación"*, vol. 17, no. 1, p. 28, Enero 2017. [Online]. https://revistas.ucr.ac.cr/index.php/aie/article/view/27332

[17] J. Hurtado de Barrera, *Metodología de la investigación Guía para una comprensión holística de la ciencia*, 4th ed. Bogotá - Caracas: SYPAL - QUIRON EDICIONES, 2012.

[18] C. Fernández-Collado, P. Baptista-lucio R. Hernández-Sampieri, *Metodología de la Investigación*, 6th ed. México: McGraw-Hill., 2014.

[19] A. Jaik Dipp E. Ortega Rocha, "ESCALA DE EVALUACIÓN DE COMPETENCIAS INVESTIGATIVAS," *REVISTA ELECTRÓNICA PRAXIS INVESTIGATIVA ReDIE*, vol. 2, no. 3, pp. 72 - 75, 2010. [Online]. https://dialnet.unirioja.es/descarga/articulo/6534523.pdf

[20] T. Ramirez, *COMO HACER UN PROYECTO DE INVESTIGACIÓN*. Caracas, Venezuela: PANAPO, 2010.

[21] E Ortega Rocha A. Jaik Dipp, "Competencias y Educación. Miradas múltiples de una relación," in *El nivel de dominio de las competencias que, en metodología de la Investigación, poseen los alumnos de posgrado*. México, México: Instituto Universitario Anglo Español A. C. Red Durango de Investigadores Educativos A.C., 2011, pp. 50 - 67.

[22] V. DELGADO BENITO, La formación del profesorado universitario: análisis de los programas formativos de la Universidad de Burgos (2000-2011), 2013, Universidad de Burgos.

[23] F. J. Rodríguez Acasio, *Gestión de la investigación: Un nuevo paradigma gerencial, desde las Universidades Experimentales*. Santa Ana de Coro, Venezuela, 2018. [Online]. https://cienciamatriarevista.org.ve/index.php/cm/article/view/71