PERIÓDICO TCHÊ QUÍMICA
ARTIGO ORIGINAL

PLANO ESTRATÉGICO PARA FORTALECER A PESQUISA COMO MECANISMO PARA AUMENTAR A FORMAÇÃO SIGNIFICATIVA BASEADA NA PESQUISA FORMATIVA

STRATEGIC PLAN TO STRENGTHEN RESEARCH AS A MECHANISM TO INCREASE MEANINGFUL TRAINING BASED ON FORMATIVE RESEARCH

PLAN ESTRATÉGICO PARA FORTALECER LA INVESTIGACIÓN COMO MECANISMO PARA INCREMENTAR LA FORMACIÓN SIGNIFICATIVA A PARTIR DE LA INVESTIGACIÓN FORMATIVA

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RESUMO

Introdução: A atividade acadêmica de alunos e professores constitui a base da formação profissional em engenharia. O treinamento em engenharia elétrica sempre teve menos interesse para os estudantes universitários em comparação com outros programas de treinamento profissional. No entanto, nos últimos anos, esse interesse tem diminuído para além das tendências anteriores, efeito detectado em todos os cursos de engenharia, que tem sido acelerado pelos mecanismos de ensino a distância adotados em face da disseminação do COVID-19. Por isso, entre os mecanismos de incentivo aos jovens, está incluída a promoção de atividades de pesquisa. Este estudo descreve o modelo proposto nos programas de Tecnologia e Engenharia Elétrica da Universidade Distrital Francisco José de Caldas como um elemento distintivo de sua estratégia de formação em pesquisa. **Objetivos**: Oferecer alternativas com tendência ao fomento das atividades de pesquisa atuais dos grupos de pesquisa da área de engenharia elétrica da *Universidad Distrital* (Colômbia) para aumentar o desempenho dos processos de pesquisa formativa, em particular com aspectos motivacionais, desenvolvimento da consciência crítica e fortalecimento de resiliência. **Métodos**: Um plano estratégico foi desenvolvido para aumentar a atividade relacionada aos processos de pesquisa dentro do programa acadêmico. A partir da dinâmica apresentada nos últimos sete anos, foi projetado para os próximos sete anos um conjunto de estratégias que visam fortalecer e estimular essa tendência. **Resultados e Discussão**: Prevê-se que este plano estratégico venha a aumentar a atividade acadêmica, nomeadamente no que se refere aos indicadores de produção científica. As projeções para os próximos sete anos apontam para um aumento da participação dos alunos relacionados às publicações científicas, da população em grupos de pesquisa e do desenvolvimento de projetos. **Conclusões**: O esquema proposto corresponde a um modelo ajustado a instituições de ensino superior com população estudantil de baixo estrato acadêmico e sob padrões nacionais que priorizam a qualidade na educação sob a óptica dos recursos físicos tanto quanto dos recursos humanos, particularmente aqueles que promovem a consciência crítica de nível local e da realidade nacional. Nesse sentido, o plano proposto é altamente relevante e promove um dos pontos fortes identificados no programa acadêmico.

Palavras-chave: *incentivo à educação, ensino de engenharia, pesquisa formativa, atividade de pesquisa, plano estratégico.*

ABSTRACT

Background: The academic activity of students and professors constitutes the basis of professional training in engineering. Training in electrical engineering has always been of less interest to university students compared to other professional training programs. However, in recent years, this interest has decreased beyond previous trends, an effect detected in all engineering programs, which has been accelerated by the distance learning mechanisms adopted in the face of the spread of COVID-19. Therefore, among the incentive mechanisms for young people, the promotion of research activity has been included. This study describes the model proposed within the Electrical Technology and Engineering programs of the Universidad Distrital Francisco José de Caldas as a distinctive element of its research training strategy. **Aims**: To offer alternatives tending to promote the current research activities of the research groups of the electrical engineering area of the Universidad Distrital (Colombia) to increase the performance of the formative research processes, in particular with motivational aspects,

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development of critical awareness, and strengthening of resilience. **Methods**: A strategic plan was developed to increase the activity related to research processes within the academic program. It was based on the dynamics shown in the last seven years, and a set of strategies aimed at strengthening and encouraging this trend was projected for the next seven years. **Results and Discussion**: This strategic plan is expected to increase academic activity, particularly related to scientific production indicators. Projections for the next seven years indicate an increase in student participation related to scientific publications, the population in research groups, and project development. **Conclusions**: The proposed scheme corresponds to a model adjusted to higher education institutions with student populations of low academic strata and under national standards that prioritize quality in education from the point of view of both physical and human resources, particularly those that promote critical awareness of local and national reality. In this sense, the proposed plan is highly relevant and promotes one of the strengths identified in the academic program.

Keywords: *Education incentive, engineering education, formative research, research activity, strategic plan.*

RESUMEN

Antecedentes: La actividad académica de los estudiantes y profesores constituye la base de la formación profesional en ingeniería. La formación en ingeniería eléctrica siempre ha contado con menor interés para los jóvenes frente a otros programas de formación profesional. Sin embargo, en los últimos años este interés ha disminuido más allá de las tendencias previas, efecto que se ha detectado en todos los programas de ingeniería, y que se ha acelerado por los mecanismos de formación a distancia adoptados frente a la propagación del COVID-19. En consecuencia, entre los mecanismos de incentivo a jóvenes, se ha incluido el fomento a la actividad investigadora. Este estudio describe el modelo propuesto al interior del programa de Tecnología e Ingeniería Eléctrica de la Universidad Distrital Francisco José de Caldas como elemento distintivo de su estrategia de formación investigativa. **Objetivos**: Ofrecer alternativas tendientes a fomentar las actuales actividades de investigación de los grupos de investigación del área de ingeniería eléctrica de la Universidad Distrital (Colombia), con el fin de incrementar el desempeño de los procesos de investigación formativa, en particular con aspectos motivacionales, desarrollo de conciencia crítica, y fortalecimiento de la resiliencia. **Métodos**: Se desarrolló un plan estratégico orientado a aumentar la actividad relacionada con procesos de investigación dentro del programa académico. Se partió de la dinámica mostrada en los últimos siete años, y se proyectó para los próximos siete años un conjunto de estrategias tendientes a fortalecer e incentivar esta tendencia. **Resultados y Discusión**: Se espera que este plan estratégico aumente la actividad académica, en particular relacionada con los indicadores de producción científica. Las proyecciones para los próximos siete años indican un incremento en la participación estudiantil relacionada con publicaciones científicas, población en semilleros de investigación, y desarrollo de proyectos. **Conclusiones**: El esquema propuesto corresponde a un modelo ajustado a instituciones de educación superior con población estudiantil de bajos estratos académicos, y bajo normas nacionales que priorizan calidad en la educación desde el punto de vista de recursos tanto físicos como humanos, en particular aquellos que promueven la conciencia crítica de la realidad local y nacional. En tal sentido, el plan propuesto es altamente pertinente, y promueve una de las fortalezas identificadas en el programa académico.

Palabras clave: *Actividad investigadora, formación en ingeniería, incentivo de la educación, investigación formativa, plan estratégico.*

1. INTRODUCTION:

Traditionally, higher education programs in electrical engineering have suffered from low interest from young students (Gero, Stav, and Yamin, 2016; Jesiek and Jamieson, 2017; Maciejewski *et al*., 2017). Compared to other higher education options, electrical engineering programs lose interest because the relevance of the curricular content is not easily identifiable, which in many cases detracts from the academic program, and even leads to abandonment of studies (Conceicao, Esquerre, Martins, and Oliveira, 2020; Martínez, Martínez, and Montiel, 2021; Roy, 2019). Furthermore, the large amount of new content introduced in the first years of training makes these programs one of the most complex and least attractive (Sultana, Khan, and Abbas, 2017). Also, those students who manage to reach the last academic periods in most cases, do not have a complete picture of what it means to be a professional in the electrical field in its local and global context (Silva *et al*., 2020). These problems are greater among women, who, due to the dynamics of the academic program, can be considered as belonging to a minority population (Beede *et al*., 2011; Lord, Layton, and Ohland, 2011). This situation has worsened in the last year as a consequence of the distance learning strategies implemented by the government and institutions to guarantee social distancing to reduce the spread of COVID-19. However, in a developing economy for young people from lower social strata, this has resulted in the abandonment

of study programs due to the need to support their families economically (Pokhrel and Chhetri, 2021; Qadir and Al-Fuqaha, 2020).

A positive feature, however, is the continuous growth of scientific publications with student participation, a fact that shows a growing interest of students in research and activities related to applied engineering (Jurgens, Kumar, Hoover, McFarland, and Jurafsky, 2018; Patience, Patience, Blais, and Bertrand, 2017). Research turns out to be a motivating factor in academic training processes, and its impact is positive for students, teachers, and the academic institution (Fatah and Mohammad, 2017). Despite this, student participation in research projects is very low in public academic institutions with a student population mainly comprised of persons from lower academic strata (Caleño and Ridríguez, 2020; Cricelli, Greco, Grimaldi, and Llanes, 2018). Many of these young people share their academic activities with economic responsibilities at the family level, which drives them to seek academic options that require less effort. Besides, given that this problem has not been given the importance it deserves in many cases, student participation in research is affected by problems of lack of interest, limited time, mentors without the management capacity, and reduced funding (Dino *et al*., 2020).

The faculty of engineering programs in Colombian public universities also have similar deficiencies in terms of research (Camelo and González, 2004; Salinas, Abreu, and Tamayo, 2020). According to the biannual reports of the Ministry of Science, less than 10% of the teaching staff report research productivity, and the teaching staff with research capacity in these institutions is less than 30% of the teaching population dedicated to training in these academic programs (Bucheli, 2019; Chalela and Rodríguez, 2020). These numbers contrast with the opinion of the teachers since most of them state that they are willing to carry out research and consider that this type of activities are highly beneficial for the training process of the students, beyond the benefits in quality that it entails for the training process itself (Gabalán, Balcero, Vasquez, Martínez, and Fonseca, 2019). The value of research for professional training processes is undeniable; this is a strategy that has been shown to increase the commitment of students to their careers, encourage the development of graduate studies, cultivate critical thinking, and make students more responsible for their training process (M. Hernández, Vallejo, Tud ”on, Hern” andez, and Morales, 2019; R. Hernández, Marino, Rivero, and Sánchez, 2020). In many institutions, the development of research work is a degree requirement. However, beyond the requirement, it is necessary to develop a culture and an environment that favors and strengthens research as a fundamental part of the training process and the dynamics of the university (Ospina and Galvis, 2017; Uskov *et al*., 2018). In addition, it has been observed that students who participate in research throughout their professional studies are much more likely to continue researching throughout their professional careers, resulting in the development of an important competitive advantage for the country.

Consequently, as a strategy to improve the performance of the professional training process and increase institutional quality metrics, many higher education institutions have begun to strengthen their research instrument through different approaches. In some cases, they have opted to include project-based learning in the curriculum to cultivate the interest of students in research (Martínez, Jacinto, and Montiel, 2016; Puente, Guerra, Oro, and Llinas, 2020). In other cases, specific research methodology subjects have been included as additional required credit (Guerra, Rodriguez, and González, 2017; Serrano, Pérez, Solarte, Torrado, and Trigueros, 2021). Although these strategies manage to increase the percentage of student participation in research activities, the truth is that a mandatory research scheme does not encourage student interest, nor does it create commitments with their learning process and strengthen their autonomy. It is necessary, therefore, to develop research approaches that encourage autonomous student activity.

2. MATERIALS AND METHODS:

The mission activities of the Universidad Distrital are mainly linked to the social development processes of the city of Bogotá and are reflected in its training, research, and social projection axes. Although some activities are prioritized over others in some cases, the truth is that these three missionary axes are equally valuable and mutually support each other, which is why it is inappropriate to analyze each of these aspects separately when detailing the academic function of the University. In the particular case of the Electrical Engineering program and its Electrical Technology cycle, there is a close relationship between training and research, which has served as the basis for continuous improvement programs and a formative research strategy consolidation. This strategy has been

able to cement and project the dynamics of research shortly under the premise that the student's understanding is an important part of the teacher's research, which is a requirement for the students' significant learning.

The formative research approach adopted by the Curricular Project revolves around a set of activities between teachers and students to strengthen the student's self-critical abilities, make him/her aware of his/her training process, and create the basis for scientific self-training. These activities are designed by the teachers within the research projects of the research groups, participation in the research groups, in the development of the subjects of the curriculum, and the work of specific end-of-course projects. However, at the same time, they are a fundamental part of the teaching process. The Curricular Project complements this strategy with others sponsored by both the Faculty and the University, including support for the development of research projects in research groups, organization of academic events, and support for disseminating results in national and international conferences.

The development of research needs to be in the public domain and supported by a commitment of all the agents in the training process. More than an institutional requirement, research training and the research processes themselves require all those involved to commit to this activity and actively promote it within their academic activities. From this perspective, the proposed research development plan focuses more on the internal activities of the research groups than on the development of courses aimed at training in research methods and strategies. The internal dynamics of the research groups generate activities of the process in which the interdisciplinary objectives of the University can be reflected, as well as the social conscience of the academic program. In scenarios such as internal group socialization meetings and others at the university level, students can discuss their ideas, contrasting them with the vision of teachers in a clear research approach. Also, these spaces satisfy at a higher level the needs of students regarding a better learning environment, which leads to a better and greater interest in research and study, both in academic life and later in their professional life.

A large proportion of the teachers of the Curricular Project are currently developing strategies to investigate their teaching processes and those developed by their colleagues. Thanks to these initiatives, teaching and its evaluation are beginning to become a commitment of their training activity, evolving far beyond the natural demands of the University. This is also shaping a strong field of research in professional training proper to the university, the Faculty, and the academic program, which produces specific disciplinary results useful both for the institution and for other entities at the national and international level with similar profiles and objectives.

2.1. Aims and targets

The curricular project is aware that establishing a research culture is an integrated process with a high demand for resources, planning, and time. Also, it is essential to have an adequate environment both at the institutional level and in terms of the curricular project, teachers, and students. The academic program has understood this dynamic since its origins, which explains its strong inclination towards research and research training processes. The internal management structure of the program, as well as the profile defined for its professors in each call for applications, has greatly helped to strengthen its research lines in a strategic manner while at the same time linking the training processes to research. The research culture that has been established has managed to date to define an academic environment for teachers and students that actively promotes self-critical and independent learning, making students much more aware of their training process, and therefore increasing their significant learning.

In terms of specific goals, the program has maintained a research policy that has allowed categorizing its groups at a national level thanks to its production and that it preserves and strengthens for the coming years. Since 2014, the academic program has maintained 19 permanent faculty members, who have joined the program according to the needs in areas of work identified throughout the previous years. Following the University's regulations, this is the teaching staff with the capacity to conduct research. As a result, the behavior of academic production in the last seven years has increased considerably, as shown in Table 1. Based on these data, and considering that the teaching staff will remain the same under the same regulatory conditions and research incentives, it is possible to build a projection model to estimate the behavior of academic production for the next seven years (Table 2). This prediction model was built using a deep LSTM (Long Short-Term Memory) network

with a hidden layer of 15 units with ReLu (Rectified Linear Unit) activation function, and using 100% of the historical data for training during 100 epochs and data from years 2015 to 1018 for validation (Figure 1). These data are estimated from the historical behavior. However, they allow establishing a goal that guarantees the recognition and categorization of the research groups and the academic program.

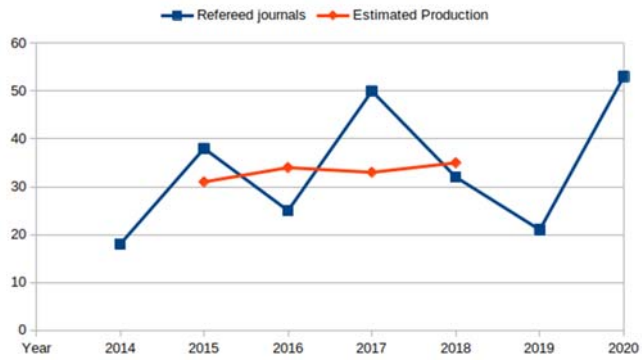

Figure 1. LSTM model of projection in the production of articles in peer-reviewed journals

3. RESULTS AND DISCUSSION:

3.1. Strategies

Throughout the previous experience of the research groups of the curricular project and the University, a set of key elements that directly affect the research environment and its level of productivity have been identified. These elements are:

- Participation in research projects
- Correct design of project objectives
- Vocation for research
- Academic and management leadership
- Positive group work environment
- Workgroup organization
- Group communication
- Resources (financial and human)
- Appropriate compensation

More than half of these elements are dependent on the people who make up the research activities. In this sense, the research groups have proposed strategies to change the culture in order to increase the results, oriented in six basic processes: (1) active linkage of new students to the research seedbeds, as well as new researchers to the groups, under the principle of diversity in areas of interest, population diversity, and working group sizes, (2) rotating the position of people within research groups and working groups, (3) fostering values and attitudes of members towards a different stance for academia and its competitive advantages, (4) encouraging the change of behaviors that may be negative for the training and research processes, while encouraging other positive ones such as the continuous presentation of progress in front of the working group, as well as in events for the dissemination of results, (5) changing the structure and organization of the different working groups by identifying each member's own capabilities, and (6) changing the image of the research processes and of the groups that carry out research activities.

As additional internal strategies also related to the elements that are not under the control of the curricular project and its research groups, the organization of an international conference every two years has been proposed, an event that in 2019 held its third version, and in which internal research activities are awarded, the achievements of the research groups are visualized, an international panorama of the areas worked by the curricular project is presented, and the University's strategies for financing different research activities, including research projects, are promoted.

The University has also observed a growing policy for the rational management of resources allocated to research through which strategies have been implemented to allocate resources more transparent and equitable (including funding for research projects, national and international papers, and research by young researchers and graduate students) using public calls for proposals with an assessment of the academic production capacity of groups and researchers, the consolidation of autonomous research units by faculty, which promotes decentralized management, and the incentive to teachers and students in the development of research activities through recognitions.

3.2. Actions and activities

Since its inception, the curricular project has strongly promoted research activities among teachers and students. Actions and plans have been adjusted over the years based on experience. To date, there is a strategic plan that is appropriate to the conditions of the course, its faculty, the needs of the region, and the specialized equipment acquired in recent years. The primary objectives of this plan are:

- Improve the curricula of its technological and engineering cycles concerning adopting advanced knowledge, training in design strategies, research methodologies, and creating a spirit of research in future graduates.
- Take advantage of the success of research in the program to consolidate masters and doctoral programs.
- Promote and support all opportunities for students to develop their skills as researchers.

Measures proposed to promote activities in support of these objectives include: (1) the organization of an international conference with active participation of the entire academic community of the program in order to increase student interaction with knowledge, experiences and people related to research, (2) presentation of scientific posters by students during the development of the Technological Weeks (one week in October each year) in order to allow showing the skills acquired in the development of a structured research project, (3) public presentations to professors and students of the proposals for graduate work presented as research projects, (4) management meetings of the research groups supported by minutes in which, in addition to projecting the future of the group, research opportunities for students are identified, (5) elective courses for students to deepen their own interests, and (6) dissemination of funding opportunities for research projects and graduate work, both internal and external to the University.

Given the favorable results of the previous strategy, the actions and activities of the current research plan take up these ideas in the update of the 2021-2027 research plan with an updated vision following the new trends in the electrical area. Consequently, new initiatives and collaborative research scenarios between teachers and students are proposed to support the objectives of each one, particularly about continuous improvement of the curriculum supported by research processes, strengthening the critical thinking of students, their scientific knowledge and understanding of research methods, advancing the research activities of each research group with continued support in funding and workspaces, and alignment of research activities with the research lines of the Faculty. Table 3 details the specific actions and activities to be developed in coherence with the proposed objectives, the available resources, and the capacities of the research group and its students.

4. CONCLUSIONS:

Electrical engineering is a necessary professional training career in any context, given the high energy dependence of industrial, economic, and social development. However, different factors have affected its popularity as an educational program for professional development compared to other training options. This is of particular importance in developing countries such as Colombia, and in populations of low economic strata, a situation that has worsened due to distance learning strategies mandated by COVID-19, and the economic needs of the population due to the same phenomenon. To reduce this impact, it has been proposed that one of the most important strategies in the medium and long term to reduce student desertion is the active involvement of students in research processes and the establishment of formative research culture. This type of process requires time, detailed planning, an adequate environment, and, of course, resources. In this sense, a strategic plan is proposed for the Electrical Engineering program, and its cycle of Technology in Electricity, of the Universidad Distrital Francisco José de Caldas in the capital of Colombia. This is a public institution with a student population mostly from low economic strata, and in recent years has made a commitment to the development of research as a growth strategy. The proposed strategic plan aims to increase the level of significant training by strengthening research within the curricular program, promoting the research schemes of the institution, and organizing research activities following institutional policies. To develop these objectives, a set of actions is proposed, characterized by indicators, responsible unit, execution time, and required resources. It is expected that according to the previous dynamics of the program in terms of academic production, the indicators of the academic program will increase in the next seven years, the period established for the evaluation of the plan.

5. DECLARATIONS

5.1. Study Limitations

No limitations were known at the time of the study.

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5.3. Funding source

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5.4. Competing Interests

The authors declare that there are no competing interests related to the study.

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Table 1. Behavior in academic production during the 2014-2020 period

	2014		2015		2016	
	Total	Per capita	Total	Per capita	Total	Per capita
Articles in peer-reviewed journals	18	0.95	38	2.00	25	1.31
Research books	2	0.10	1	0.05	1	0.05
Academic books					1	0.05

2017		2018		2019		2020	
Total	Per capita	Total	Per capita	Total	Per capita	Total	Per capita
50	2.63	32	1.68	21	1.10	53	2.79
3	0.16	3	0.16	3	0.16	1	0.05

Table 2. Projected academic production behavior for the period 2021-2027

	2021		2022		2023	
	Total	Per capita	Total	Per capita	Total	Per capita
Articles in peer-reviewed journals	36	1.89	36	1.89	37	1.95
Research books	3	0.16	3	0.16	3	0.16
Academic books	1	0.05			1	0.05

2024		2025		2026		2027	
Total	Per capita	Total	Per capita	Total	Per capita	Total	Per capita
38	2.00	38	2.00	38	2.00	39	2.05
2	0.10	2	0.10	3	0.16	3	0.16
		1	0.05	1	0.05		

Table 3. Research Plan 2021-2027

Aim	Actions and Strategies	Indicator of Achievement	Deadline for Execution	Responsible	Resources
1. Strengthen research within the curriculum, specifically to increase the student's self-critical thinking, levels of scientific knowledge, and research methodologies.	1.1 Generate a tracking of resources currently under development within the curriculum related to research.	Report on research areas within the curriculum.	12 months	Curricular Project Coordination	No additional resources are required.
	1.2 Adjust the contents related to research within the curriculum to optimize the processes aimed at encouraging the students' comprehension, development, and evaluation capabilities.	Report on the restructuring of research content in the curriculum.	24 months	Curricular Project Coordination	No additional resources are required.
	1.3 Stimulate the linkage of students to research seedbeds.	Increase in the number of students in the report of active members in research groups to the Center for Research and Scientific Development of the University.	12 months	Directors of research groups	No additional resources are required.
	1.4 Stimulate the production of publications in indexed journals with the participation of professors and students.	Increase in the number of faculty/student publications as a function of faculty workload.	24 months	Directors of research groups	No additional resources are required.
2. Promote the research schemes defined by the University, the Faculty, and the Curricular Project.	2.1 Support access to research spaces and resources according to the needs of each research group.	Allocation of spaces and resources to research groups according to the production of the group. Access to specialized spaces for students and teachers of research groups and seed groups.	24 months	Coordination of the Curricular Project and Director of the Research Unit of the Faculty	No additional resources are required.
	2.2 Encourage the use of financial support offered by the University for students to present research results at national and international conferences.	Increase in the number of students participating on behalf of the University in national and international conferences.	12 months	Coordination of the Curricular Project and Director of the Research Unit of the Faculty	No additional resources are required.
	2.3 Identify and disseminate external funding sources to support research activities.	Database with information on sources of external funding for research. Increase in the number of requests for expert financial support for research.	12 months	Director of the Research Unit of the Faculty	No additional resources are required.
3. Align the research activities of the academic program with the lines of research assumed by the Faculty.	3.1 Explore research opportunities in the face of new trends in the electricity sector.	Develop a study on the current trends in the electricity sector and the real opportunities for the University and the Curricular Project to research them.	12 months	Teachers of the Curricular Project	No additional resources are required.
	3.2 Explore opportunities to increase research in education pedagogy.	Improve support for the activities of faculty and students interested in the research area of pedagogy in education.	24 months	Director of the Research Unit of the Faculty	No additional resources are required.
	3.3 Encourage joint work between the different research groups of the Curricular Project and the Technological Faculty of the University.	Review of the current research interests of the research groups of the Faculty, and identification of opportunities for joint activities. Increase in the number of faculty and students participating in joint research projects.	24 months	Director of the Research Unit of the Faculty	No additional resources are required.