Implementation of research agendas in the training of engineers: Academic training with social sense

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Abstract. The implementation of research intervention strategies is presented as the main theme of this longitudinal study, within the framework of the application of the research agenda of engineering programs. Classroom work, training practices, business practices, classroom projects, and research group projects are proposed as training scenarios. The strategies are actions that are applied in three productive processes of interest for the engineering, such as: (i) productive process of object systems (ii) primary biomass productive process and (iii) primary artisanal cosmetics production process. The objective is to show the results of the research agendas application as an academic process planning tool for form research competencies. Three cases have presented that show the knowledge construction and the research intervention traceability in different the engineer fields in his training process. The three production processes become application centers of an area of the engineer research interest, as is the supply chain optimization. In the results, the planning methods of the agenda highlight, with the collective construction of knowledge of the training process, the targeting of the area of research interest, the linking of actors, the articulation of research lines of the program, and the scope of the strategies of intervention and didactics by scenarios. The study shows training relevant processes in the economic, social and environmental fields, promoting collective learning opportunities and fostering innovation through inclusive industrialization.

1. Introduction
Understanding the polysemy of research agendas, this study presents them as strategic tools for collective planning. Based on contextual demands, institutional offers, dialogue of knowledge between the experiential and academic knowledge of teachers, researchers, students, all of them in close contact with social actors. These tools are used to establish a knowledge management roadmap in the training of professionals in any area [1]. Likewise, research agendas are interpreted as instruments to improve the processes of teaching, formative research and knowledge transfer [2]; these agendas raise the perception of researchers and students about the immediate environment and, the global trends of science and technology to produce sustainable and ethical actions at the frontier of knowledge [3].

The implementation of this instrument in the industrial engineering program was carried out over four years. Training scenarios were established: the classroom, the training and business practice sites and the research groups, as well as the projects, the activities of the class, and other investigative intervention strategies [1]. The training scenarios (TS) are proposed as spaces for the improvement of
skills, profiles and languages, through specially planned instructional activities, with content and structures that respond to curricular proposals [4].

As previously mentioned, this implementation was applied on three productive processes of interest to the engineer: (i) productive process of object systems (POS), (ii) primary productive process of biomass and (PPB) (iii) primary productive process of handmade cosmetics (PPC).

The POS (i) [5] is the development of a complex system of interaction [6] that applies systemic design thinking [7] and tends to group a set of materials in the design of an object, which considers the user in relation to the conditions of correct use, fulfilling a purpose. In other words, the object must fit the user and not the user adjust to the object.

The PPB (ii) is the set of thermochemical, biochemical, and physicochemical processes for the transformation of biomass, as a heterogeneous raw material from plant or animal species [8]. The case applied in the training process of the industrial engineer was oriented to the analysis of the technical potential to produce renewable energy from industrial waste of the African oil palm, *Elaeis guineensis*, called “Cuesco” in Norte de Santander, Colombia [9,10].

Finally, the PPC (iii) is the set of activities related to the transformation of native natural resources into unprocessed primary products, which are used as a basic product, functional material and / or additive in the production of personalized cosmetics [11]. Thus, it includes the processes of collection, extraction, production and distribution. In the study case, the PPC was oriented towards the extraction and evaluation of the microbiological quality of the essential oils of orange, moringa, eucalyptus, rosemary, arrayan and their secondary products, all obtained for use in the artisanal cosmetics industry [12].

Thus, the study presents the university role importance as a social technological development pillar, through the research agendas implementation as planning tools, knowledge dialogue, and training actions focused on the production processes development, that makes use of society interest renewable organic materials, considering the potentialities, needs, and opportunities of the region.

2. Materials and methods

Using correlational matrices, national and international references were reviewed, giving priority to the functional articulation between the governmental and institutional economic sectors. The evaluative criteria were the productive sectors of interest of the local governments, the topics of interest and the performance of each economic sector, the spearhead or the prospective topics, the articulation between topics of interest and the targeting of research at the institutional level. In the subsequent analysis, preference was given to the thematic areas of research interest (TARI) in the academic program according to institutional offer and proposed capacity.

Investigative intervention strategies (IIS) were proposed, differentiated by TS, project profiles were constructed, and the capacity and technological demand of the program were analyzed, as well as the institutional and context capacity and demand. The IIS were categorized grouping aspects of quality taken from national policies that regulate higher education at the undergraduate level [13]. The categories were determined: strategic training for the development of research skills, strengthening information and communication technologies (ICT) for research, development of research in the strict sense and knowledge social appropriation.

For the prioritization of areas, the criteria were qualified in interdisciplinary work groups, agreed by the team to measure institutional offer and installed capacity. These are: pertinence (P), opportunity (O), viability (Vb), impact (I), vigency (V), ability of linking actors (ALA), sustainability(S) and technological capacity (TC); and each criterion was assigned the following relative maxims weights in the 1 to 10 scales respectively (1.6), (1.2), (1.6), (1.7), (1.3), (1.3), (1.4), and (1.1). This identified greatest interest thematic areas to productive sectors, such as supply chain optimization in the logistics sector; scenarios modeling, and simulation in the logistics sector; and, competitiveness and business management in the agricultural and forestry sector: biomass and bioprocesses (see Table 1).
Table 1. Prioritized TARI.

| TARI selected                                                                 | I (1.7) | P (1.6) | Vb (1.6) | S (1.4) | V (1.3) | ALA (1.3) | CT (1.1) | TH       |
|-------------------------------------------------------------------------------|---------|---------|----------|---------|---------|-----------|----------|----------|
| The supply chain in the logistics sector optimization.                        | 1.7     | 1.6     | 1.3      | 1.1     | 1.3     | 1.1       | 9.4      |          |
| Modeling and simulation of scenarios in the logistics sector.                 | 1.7     | 1.6     | 1.6      | 0.7     | 1.3     | 1.3       | 1.1      | 9.3      |
| Competitiveness and business management in the agricultural and forestry sector: Biomass and bioprocesses. | 1.7     | 1.4     | 1.6      | 1.0     | 1.3     | 1.3       | 1.0      | 9.3      |
| Productive chains of food by regions in the agricultural and forestry sector. | 1.7     | 1.6     | 1.2      | 1.0     | 0.8     | 1.3       | 0.6      | 8.2      |
| Agro-transformation of agricultural products: biomass and bioprocesses.       | 1.3     | 1.6     | 0.8      | 0.6     | 1.3     | 1.3       | 0.8      | 7.7      |

2.1. Project profile construction

Seven aspects were defined for the project profile design of: TARI, research or development type, academic programs, research units required and actors to be involved (A), disciplines that are articulated (D), execution deadlines, and estimated amounts. The profile project is generated from the definition of three research focuses in which it is possible to delve into the thematic areas of interest. The three project profiles correspond to applied research. Table 2 shows the three focuses relevance to address the TARI from various disciplines. Table three shows the correspondence of the project profiles defined by focus, the actors involved and the disciplines articulated.

Table 2. Research focuses and TARI.

| TARI selected                                                                 | Focus 1: POS | Focus 2: PPB | Focus 3: PPC |
|-------------------------------------------------------------------------------|--------------|--------------|--------------|
| The supply chain in the logistics sector optimization                        |             |             |              |
| Modeling and simulation of scenarios in the logistics sector                 |             |             |              |
| Competitiveness and business management in the agricultural and forestry sector: Biomass and bioprocesses. |             |             |              |
| Productive chains of food by regions in the agricultural and forestry sector. |             |             |              |
| Agro-transformation of agricultural products: biomass and bioprocesses.      |             |             |              |

The profiles of specific projects for targeting are presented in Table 3.

Table 3. Project profiles.

| Projects                                                                 | Focus | A                              | D                              |
|-------------------------------------------------------------------------|-------|---------------------------------|---------------------------------|
| Design of an of object systems for the health sector.                    | POS   | Companies in the health sector and industrial engineering and physiotherapy program. Health and engineering research groups. | Health sciences, administrative and engineering. |
| Evaluation of the technical and financial feasibility for obtaining bio-products. | PPB   | Industrial process companies. Industrial engineering program and bacteriology program. Engineering research groups. External research groups in production, fluids and renewable energy. | Health sciences, administrative and engineering. |
| Development of strategies for the production and marketing of cosmetics derived from perennial and oleaginous plantations. | PPC   | Industrial process companies. Industrial engineering program and bacteriology program. Health and engineering research groups. | Health sciences, administrative and engineering. |
2.2. Technological capabilities and demands
The analysis of the technological capacities and demands to execute the proposed projects focused on the identification of aspects associated with the human component, laboratories, software, techniques and materials. Technological capacities and demands were identified for the agricultural and forestry sector, as well as for logistics. The available technological capacities were represented in: teacher of training courses for industrial engineering, bacteriology and physiotherapy, research groups of engineering and health students and, for the realization of field work, in chemistry and biology laboratories, computer laboratories, physiotherapy laboratories and industrial engineering laboratory. The unavailable technological requirements were determined from the analysis of the methods required by the project activities. They were identified among others: pilot plants, expert advice, bioreactors, analysis in specialized laboratories, extractors and specialized software.

2.3. Context demands
The development of project profiles requires the participation of the university and the external context to make its execution viable. The following table outlines the internal and external demands of the projects outlined.

| Project                                          | Institutional demands                                      | Contextual demands                     |
|--------------------------------------------------|-----------------------------------------------------------|----------------------------------------|
| Development of strategies for the production and commercialization of cosmetics derived from perennial and oleaginous plantations. | Lab tests. Pilot plant. Expert advice. Bioreactor. Laboratory equipment and analysis. Specialized software computer lab. | Company of the cosmetic industry. Regional Growers associations. Palm growers of the region. Research groups Specialized habilitation centers. Integral rehabilitation. |
| Evaluation of the technical and financial feasibility for obtaining bio-products. | | |
| Design of an of object systems for the health sector. | | |

3. Results

3.1. Case 1: Of object systems
It is established from three scenarios: classroom work, classroom projects, training and business practices. The studied case is in the training cycle where students participate in the subjects of materials sciences, methods and times, and industrial processes in the 2nd, 5th, 6th and 7th semesters. In addition, field visits are planned, in the 5th and 6th semesters, making use of prototyping as a didactic strategy. In the 6th semester the training practices are developed with actors estimated in the demands of the context: professional center in habilitation / integral rehabilitation, teacher of training courses, research groups of engineering students, research groups of health students, tutors of research groups.

An object of support of daily and consistent use was obtained to facilitate the sensorial motor development of children with cerebral palsy, considering the individual, the family and their environment. The object of system was developed as an assistant in the process of comprehensive care by the therapist, from a collaborative and interdisciplinary work, considering the conceptual bases of techniques and approaches of neurodevelopment, concurrent engineering, materials, methods, production processes and complex systems.

3.2. Case 2: Evaluation of the financial technical viability for obtaining bio-products
An analysis of the technical potential was developed to produce renewable energy from the "cuesco" palm in Norte de Santander, Colombia [9]. It is established from three scenarios: classroom projects, training and business practices. In the training cycle, the case is included the subjects of clean production, industrial processes and simulation, in the 6th, 7th and 8th semesters, which allow the foundation of the analysis to be carried out. Field visits are planned for the achievement of the palm
"cuesco" after the extraction of the oil in 9th and 10th semesters and use of process simulators as a didactic strategy.

In the 9th and 10th semester, the training practices are developed with the actors estimated in the context demands: palm growers, teachers, students of the engineering research group, students of the health research group, tutors of the research groups. Given the results, the process of gasification of the palm "cuesco" was simulated, which allowed the training practice to be carried out with the use of the Aspen PLUS® simulator. Next, the production of hydrogen with the obtained data was estimated. The analysis was made from experimentation processes in samples of the "cuesco" palm, looking at temperature variables and biomass-vapor ratio, to determine the kinetic modeling of gasification processes [10], which allowed to theoretically estimate the production of hydrogen as primary energy.

3.3. Case 3

In the project related to the development of strategies of production and commercialization of cosmetics derived from perennial and oleaginous plantations, the extraction and evaluation of the microbiological quality of the essential oils of orange, moringa, eucalyptus, rosemary, arrayan was achieved and secondary products were obtained for use in the artisanal cosmetics industry. The project was established from the formative practice, classroom projects, training and business practices, in the training cycle the case is in the subjects of clean production, industrial processes and simulation in the 6th, 7th and 8th semesters. Field visits are planned, in 9th and 10th semester, making use of process simulators as a didactic strategy.

In the course of occupational health and safety, factors that affect the productivity of the oil extraction process were identified, from safe work in the plant. In the same way, the students of the research group were linked to make them all part of the training practice of the extraction process. The results obtained lead to the improvement of oil extraction processes, safe work and decision making on the quality of the product. In the 9th and 10th semester, the training practices were developed with actors estimated in the context demands, regional growers, cosmetics industry entrepreneurs, teacher of training courses, students of the engineering research group and tutors of the research group.

As a result of what was expected, the applicability of the research interest area of the supply chain, in each of its stages, was achieved for each of the training processes / productive processes / targeting.

4. Discussion

The research agendas guide the training processes, but these are adapted according to the actors needs in the real process. The process results are obtained according to the client or interested in the context, the students adapt to the technological needs, the times and resources available in the sector companies, which leads to determining that the research agenda needs to be organized with a high level of flexibility and in a general way, adapted to current engineering trends, which translate into scenarios closer to technology. The projects finally become not only, in training programs that are transformed with the context demands and the student's participation in the process, but in something that allows the renewal and feedback of the different subject in the syllabus, in which the research teachers and teachers with related disciplinary specialties have greater influence.

The actors' participation is not achieved massively for their interests. Students participate gradually according to their preferences or interest areas. Teachers get involved depending on their disciplinary area, but the context knowledge degree and the relationship they have with environmental actors is essential. This results in the need to identify research priorities so that they are articulated with capacities, available resources, and engineering learning possibilities through different training scenarios.

Regarding the estimated time in the project profiles, there are lags, since factors are added to the process of implementing the agendas, such as the time for managing the environment technological requirements, sometimes not available in the institution, as well as, monitoring, which requires an additional demand for human talent in both programs and institutions. Also fundamental is the program director permanent promotion, the research group leader, and the teachers' disposition, who, with their
cognitive and psychosocial skills oriented towards achievement, team management, personal management, influence and thought, orient the students’ group, so they, in their training process, can assume the leadership and self-management of their knowledge.

The agendas revision was proposed every 5 years for the themes, strategies and projects updating, however what happens in practice is the new cycles opening in the same focus, that allow projects to be scaled to another level, with greater confidence context actors in the institutional capacities, adherence and belonging to the training processes, strengthening of pedagogical practices based on lessons learned, articulations between training programs which affects the interdisciplinary and transdisciplinary careers promotion, as well institutional leadership in the processes of technological development and innovation for the region.

The engineers training is a trending matter. In this regard, the Organization of American States (OAS), establishes from a prospective study in 2025 [14], that engineers must focus on what they are going to do, rather than what is going to happen. That is why 5 engineering areas are determined, such as new technologies, optimization, production, administration, finance and quality criteria, which respond to the context needs, especially in the construction of new concepts and capabilities in engineers, from the products development until the supply chains optimization through the intervention and didactic strategies by scenario application. Similarly, and based on the sustainable development objectives in the 4 and 9 paragraphs [15], it is talking about how learning at all levels promotes opportunities for process sustainability, as well as, increasingly resilient and innovative industries.

5. Conclusions

The implementation of a research agenda requires a permanent pedagogical process of monitoring by the director of the program, the leader of the research group, and the curricular committees, to periodically evaluate the progress, establish the necessary corrections and define the actions to be taken to achieve the evolution of the agendas. It is not about building new agendas, but adopting a knowledge management model, supported by information and communication technologies, strategies, methods and tools for technology transfer, to keep it constantly updated. This allows it to become dynamic and flexible to adjust to the versatility of all the actors and involved around it. In the same way, it becomes part of the teaching-learning methods transferrable to the industrial engineer's work environment, and the strengthening of science, technology, engineering, art and mathematics (STEAM) skills.

A relevant route for the monitoring of the research agenda is the socialization of foci and profiles of projects in curricular committees and with research groups, for their proper appropriation and incorporation in the pedagogical, investigative and knowledge transfer processes. Likewise, it is necessary to define a global action plan for the development of the agenda and the breakdown of the annual plans, in order to operationalize the areas of research interest, the research intervention strategies in the context and the profiles of updated and new projects. The systematization and evaluation of the development of the agenda is fundamental, through a system of impact, efficiency and effectiveness indicators. These indicators can be evaluated every six months, and those of impact can be carried out annually, involving the social and economic actors of the environment.

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