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Formative research. Experiences in the Environmental Engineering career at the Universidad Nacional de Loja

La investigación formativa. Experiencias de la carrera Ingeniería Ambiental de la Universidad Nacional de Loja

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ABSTRACT

Formative research is a university activity where the role of the teacher is essential, mainly as a counselor who cultivates motivation and knowledge in his students in response to social and personal demands. The purpose of the article is to socialize the teaching experiences of the application of formative research as part of the Knowledge Integration Project (PIS). The formative research methodology was assumed to have four moments within the framework of the Knowledge Integration Project, being assumed as an alternative for the curricular development of the Environmental Engineering career in accordance with the needs posed to education. The four examples of research carried out by students applying the designed strategy showed the relevance of the topics, concern for the environment, and interest in the purpose of the profession. Furthermore, these experiences favored the application of professional knowledge and skills, together with the professional and human growth of the participating subjects. The experiences developed point to favorable trends in the quality of teaching, in the training of students, and in the solution to social problems when formative research is promoted as a pedagogical strategy.

Keywords: educational projects, experiential learning, learning, training.

RESUMEN

La investigación formativa es una actividad universitaria donde es importante el rol del docente, principalmente como orientador que cultiva la motivación y los saberes de sus estudiantes en respuesta a las demandas sociales y personales. La finalidad del artículo es socializar las experiencias docentes de la aplicación de la investigación formativa, como parte del Proyecto Integrador de Saberes (PIS). Se asumió la metodología de la investigación formativa con sus cuatro momentos dentro del marco del Proyecto Integrador de Saberes, en pro del desarrollo curricular de la carrera Ingeniería Ambiental a partir de las necesidades planteadas a la educación. Los cuatro ejemplos de investigaciones realizadas por estudiantes aplicando la estrategia diseñada evidenciaron la pertinencia de los temas, la preocupación por el medio ambiente y el interés por el objeto de la profesión. Además, estas experiencias favorecieron la aplicación de conocimientos y habilidades profesionales, unido a un crecimiento profesional y humano de los sujetos participantes. Las experiencias desarrolladas apuntan a tendencias favorables en la calidad de la docencia, en la formación de los estudiantes y la solución a problemas sociales, cuando se fomenta la investigación formativa como estrategia pedagógica.

Palabras clave: aprendizaje, aprendizaje activo, formación, proyecto de educación.

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INTRODUCTION

Universities prepare the professionals necessary to transform society and contribute to its development (Chankseliani et al., 2021; Chankseliani & McCowan, 2021; Compagnucci & Spigarelli, 2020). Therefore, the guiding role in the training they offer must always consider the social demands and the diversity of contexts that impose constant challenges on education and the teachers who make it possible (Bayuo et al., 2020; Moscardini et al., 2022; Santos et al., 2020).

Currently, this training and its relationship with the surrounding environment occurs in complex scenarios, mainly due to changing contexts, hence the causes and possible solutions must be constantly analyzed (Beasley et al., 2020; Carpenter et al., 2022). To do so, professionals must develop skills and competencies that allow them to face the constant changes that society faces in the present and in the future (Dvir & Schatz-Oppenheimer, 2020; Fajaryati et al., 2020; Fitzgerald, 2020).

In this sense, higher education has the challenge of training and preparing professionals suitable for this performance, and formative research is a way for teachers who are in charge of this challenge (Ahmad, 2020; Goulart et al., 2021). Nowadays, one of the most important statutes in higher education is its mission, which offers a unique platform in opportunities to carry out formative research since it combines the three fundamental substantive processes as a strategy that generates synergies and is dedicated to development as a journey (Abad-Segura and González-Zamar, 2021; Chankseliani and McCowan, 2021; Olo et al., 2022; Ruiz-Mallén and Heras, 2020).

In the literature, research on formative research appears reflected, such as the studies of Restrepo (2003), Velandia-Mesa et al. (2017), Venegas et al. (2019), and Turpo-Gebera et al. (2020), with no contradictions in their definitions. In general, formative research presents similar characteristics to these proposals, such as its pedagogical nature and its objective of solving problems through active participation, both from students and teachers (Campos-Ugaz et al., 2022).

With the background literature observed in the foundation of this study, it can be stated that formative research involves a marked orientation towards knowledge, its joint construction in the different teaching and learning environments, as well as participation as a driving factor (Bohren et al., 2021). Therefore, with research as a governing process, students and teachers can deconstruct prejudices, analyze and synthesize information to produce new knowledge, prepare and accompany the development of personal and professional skills that are curricular identified as key in future performance, as well as present the main findings resulting from individual and collective competition in the activities (Sands & Aunger, 2020).

As can be seen, these conceptual elements do not contradict what is expected in terms of planning, performance, and objectives of common research, given that its approach is constructivist and oriented towards interventions, the two main qualities that stand out in comparison with other epistemic roots close to positivism. However, as can be seen in the study by Bohren et al. (2021), formative research is a rich diversity in gnoseological matters since its multidimensionality makes it easier to explore the process from the curricular perspective, from the investigative and professional practice, from the methodologies used, from the knowledge produced, but also based on categories such as costs and efficiency. This shows that formative research has the potential to go beyond its instructive and investigative scope.

In this regard, another similar approach is provided by Cortés et al. (2019), who assume it as a practical methodology that facilitates the construction of knowledge based on discovery. Consequently, they consider that dialogue should be emphasized as an essential characteristic in the search for solutions; this allows students to develop in social contexts of professional action in interaction with other students and their teachers.

Precisely, this interaction in and with the contexts of action where they will practice their profession once they graduate offers a space to reevaluate goals and consciously configure the life project. In addition, for teachers, the institutions linked to research and the specific places where it is carried out, it is an enriching, innovative process that generates helical experiences that are crucial today (Bellandi et al., 2021; Cai et al., 2020; Morawska-Jancelewicz, 2022).

All this allows us to consider that the methodology for the development of formative research is a guide for learning and articulates the needs of all educational and social agents. It should be noted that the choice of content is a complex activity because there are no established rules or guidelines that constitute a guarantee for successful learning. However, in the literature, there are elements to consider when trying to apply formative research (Pérez Gamboa et al., 2023; Sánchez Carlessi, 2017):

- At the career level, an analysis of the curriculum, the professional profile, the objectives and the expected learning results must be carried out, considering ways to apply them in subjects.
- At the group level, the objects of study, the psychopedagogical needs of the students who make up the group, the real state of the capacities and skills, based on their evolutionary development, must be identified.
- At the subject level, it is necessary to carry out an analysis of the sequence of content in the subject, its logic, updating and coherence with the discipline, in order to promote the process in correspondence with the socio-economic, political and cultural reality of the country.

In short, formative research is essential in the preparation of prosocial and critical thinking professionals, oriented towards lifelong and lifelong learning, who identify and solve emerging problems (Alt and Raichel, 2022; Hart et al., 2021; Tobón and Luna-Nemecio, 2021). Additionally, it stands out by allowing the dissemination of information and the incorporation of knowledge, promoting positive attitudes and skills so that students learn to research through reflection and practice.

At the National University of Loja, formative research is applied from a project supported by the Integrative Chair. In this work, the project and its purpose are presented, as well as the results obtained by the students of the Environmental Engineering degree in the implementation. Therefore, this manuscript seeks to socialize the teaching experiences of the application of formative research within the framework of the Knowledge Integration Project (PIS) in order to contribute to the field of higher education and the development of future research of a similar nature.

METHODOLOGY

In the study whose main results are offered, the methodology for formative research was applied. According to Ramírez et al. (2018), this procedure comprises four phases that allow students and teachers to appropriate this methodological strategy:

Phase 1. Group awareness

It constitutes a necessary space for guidance, or exchange to generate interpersonal knowledge, establish links and promote motivation for the development of project activities. In this phase, autobiographies, mental and conceptual maps, essays, conceptual, critical and creative analysis, reports, blogs were used.

A fundamental aspect of this phase was the teaching experience and creativity, as well as the progressive consolidation of the bases for participation oriented to the diagnosis and evaluation of group strengths, the orientation of common professional and cognitive interests, as well as the initial position regarding the project. To this end, a variety of features of the action-research and project-based learning methodologies were adapted, such as the orientation towards the construction of results, the assessment of the initial state of the problem and the participants, the establishment of measures for the final evaluation and the creation of a consensual participation contract (informed consent) (Chang et al., 2022; Menon & Suresh, 2020; Parrado-Martínez & Sánchez-Andújar, 2020).

Phase 2. Project concretion

The group was required to have the bases to begin the development of the project itself, based on the experiences and knowledge gathered and generated in Phase 1. Once the progress achieved was confirmed, the students proceeded to link needs, expectations and interests based on the development of the specific actions of the project. In this phase, it was necessary for the teachers and other educational leaders involved to maintain a systematic orientation towards their students as an expression of the non-professional support relationship that they aspired to build.

In this phase, focus groups were used to discuss the established plan and triangulate the results of Phase 1, in-depth interviews to learn about the perspectives of students and teachers, as well as a record through memos in the field notebook. These data were treated based on informed consent, with special attention to ethical aspects such as confidentiality and the right to non-participation. The verbal and observational data obtained were processed through the free coding process to form a general framework for analysis. In this way, it was possible to accompany the students in their own research process while developing the study on the experience and including their constructions in the analysis framework (Dos Santos et al., 2021; Sanko et al., 2020).

Phase 3. Project systematization

Este espacio fue dedicado a empoderar a los estudiantes para lograr la organización coherente del proyecto ejecutado. Este proceso implicó no solo la preparación de los recursos necesarios para la presentación de los principales hallazgos en materia investigativa, sino en función del crecimiento personal-profesional, las transformaciones identitarias y el logro de las metas formativas trazadas (Pérez Gamboa *et al.*, 2023). Además, en esta fase se construyó de manera participativa un levantamiento de las fortalezas, debilidades, satisfacciones e insatisfacciones, así como los cambios a ingresar por parte de los docentes de cara a futuras experiencias en la carrera.

Socialization of the project

This was the final phase of the research and was set up as a space for the presentation of the projects, where the results were shared to encourage feedback among the participants, both among the students in the group and the teachers. Additionally, the initial and final states were compared, the results of the previous phase were discussed, participatory techniques were carried out to reinforce the learning results, and the evidence was passed on to the program to strengthen its methodological work and as an example for future generations of the lessons learned during the experience (Pérez Gamboa et al., 2023)

RESULTS AND DISCUSSION

The project carried out corresponded to the functions and activities of the Integrative Chair. This structure was in charge of studying the shortcomings, limitations, and professional problems of the reality that are the object of the career from the perspective of the work of the profession. Consequently, each academic period had to address an axis of study that would favor the construction of knowledge, according to the gaps identified, and strengthen the performance of future professionals in possible work scenarios.

The project constituted a methodological and evaluative strategy, where different subjects were articulated and favored the solution of professional problems while contributing to the quality of life and well-being of the participants; this is based on what is established in the previous literature (Toapanta-Pinta et al., 2021). Therefore, from its first phase, it was designed as an integrative experience of the substantive processes, especially teaching and research. By prevailing learning from the practice of collaborative dynamics, contributing to formative research.

During the period established for the execution of the experience, researcher 1 served as Coordinator of the Knowledge Integration Project (PIS). In this instance, she applied formative research in the Environmental Engineering course at the National University of Loja. In an integrated manner, teachers and students went through the four phases that the formative research methodology proposes in order to unify experiences, identify problems, and seek solutions through research.

During the implementation period, various formative research experiences were developed, going through the four stages that the methodology proposes. Below is a summary of the most representative findings of the experience.

Synthesis of procedural aspects

In the first phase, group awareness allowed teachers to combine their creativity and implement presentation techniques, which led to the creation of safe and open spaces for exchange, which, according to the interviews, contributed significantly to group cohesion. Group bonds, for their part, began to develop at this time, but the teaching team had to lead the group at all times, which, according to the evaluation of the experience, was due to its innovative nature and the deviation from the instructional processes to which the participants were accustomed.

This first phase fostered group unity, collaboration, teamwork, the exchange of knowledge, and solidarity, which are key to the success of formative research. In addition, the activities developed showed that the exchange with nature in the tours of the study areas was a space that contributed significantly to group cohesion, a result confirmed by the teaching team. Figures 1 and 2 show the environment and the guidance of a project leader for carrying out the activities.

The completion of the project and its systematization allowed the selection of research topics in correspondence with the needs and problems identified in the area of study. Based on dialogue and collaboration, tours, collection and analysis of samples, taking of images, review of documents, and exchanges between students and between students and teachers were included. In this phase, the application of research techniques and methods in correspondence with the topics addressed was guaranteed, as well as the integration of the design to address the progress and process of the study.

The teachers appreciated the evolution of the students and the growth achieved in the subjects linked to the project and the research. The teachers recognized that the application of formative research prevents the students from reaching their degree completion process without previous research experiences. In the transcribed narratives already analyzed, the opposite could be confirmed since the data indicated that it favors professional training from research as a learning practice.

Figure 1.
Practice by areas of study

Source: own elaboration

Figure 2.
Tour of study areas by team of students and teachers

Source: own elaboration

Formative research in four themes

The students' project results provided evidence of personal and professional growth. It is noteworthy that these were presented articulately and competently to all students and teachers during the last phase, accompanying the technical data with speeches on experiential learning and the role of formative research. This progress was evaluated as satisfactory and above the expected result at the beginning of the general project.

Below, four of the themes developed by the students participating in the project are summarized. It is hoped that these examples will contribute to future studies, both in the design and in the curricular transformation of similar courses in Latin America.

Project 1: Lichens as bioindicators of air quality in the city of Loja

In the first project, two students investigated lichens as bioindicators of air quality in the city of Loja. The objective was to carry out research focused on environmental problems to understand the capacity of lichens as bioindicators of environmental quality in the city of Loja.

To carry out the project, they selected the most widely used method for analyzing air pollution, the analysis of the atmospheric purity index (IPA), which took into account the frequency of lichens present in a given area, as well as

the number of lichen species in the tree inventory. As lessons learned, these students highlighted the collaboration in the development of the study, the implementation of knowledge and skills in the presentation of the project to the competent authorities, as well as the experiences obtained in the evaluation of the social impact of the study.

Determination of water quality in a section of the Malacatos River, using macroinvertebrates as bioindicators

Another experience was the research aimed at determining the water quality of a section of the Malacatos River, using macroinvertebrates as bioindicators. This was carried out by a team of ten students and the accompaniment of three teachers. This is a highly sensitive and important topic because water pollution was one of the main causes of health problems of living beings diagnosed in the study area.

When carrying out the project, the water quality of a section of the Malacatos River (UNL campus) was analyzed through the use of aquatic macroinvertebrates. Macroinvertebrates are excellent bioindicators of water quality, since some of them require specific conditions to survive. On the other hand, others are resistant to contamination, providing the opportunity to differentiate when a river is clean or contaminated.

The results showed critical and very critical conditions of water quality in that section of the river. These indices suggested the need for the canton's citizens and authorities to improve the river's management. The research process, the practice, and the application of research methods in the verification and estimation of a real environmental problem that affects everyone was a very positive experience for the participants and their professional growth, as confirmed in the evaluation. It also allowed them to address issues related to sustainable development, examine public policies, dialogue with social agents linked to the solution of the problem, and develop infographics and other instruments to promote the care of the river.

Anurans (frogs) as bioindicators of water contamination in La Quebrada del Parque Universitario (PUEAR), Loja, Ecuador

Two other students accompanied by a teacher took on the research responsibility of studying Anurans (frogs) as bioindicators of water pollution in La Quebrada del Parque Universitario (PUEAR). It is significant to mention that Ecuador is a privileged country in this sense, since it houses the fourth largest amphibian fauna in the world.

Water quality has traditionally been measured through physical and chemical processes, providing immediate characteristics of ecosystems without taking into account what may occur over time. However, at that time, the students established the current status of other alternatives known as bioindicators. Amphibians are considered good bioindicators; this is how frogs of the genus Pristimantis are considered due to the sensitivity of their skin, which is very perceptible to changes in climate or other factors. This research aimed to determine what type of species of the genus Pristimantis can act as a good bioindicator of water quality.

This research's experience and results confirmed the effect of excessive population growth, industrialization, and urbanization on rivers and lakes. These places, when contaminated by human waste, also affect the Pristimantis frog genus, which reflects terrible consequences, such as mutations, death, and disappearance of the frogs. In this study, the environmentalist inclination of the students could be observed, which, although it is typical of what is expected by the professional profile, had been diagnosed in various spaces as a weakness, so this example confirmed the value of formative research in identity transformation.

Quantification of carbon capture and storage in the University Park of Environmental Education and Recreation and Reinaldo Espinoza Botanical Garden

Another team of five students, advised by a teacher, investigated the quantification of carbon capture and storage in the University Park of Environmental Education and Recreation and the Reinaldo Espinoza Botanical Garden in the city of Loja. Climate change and the alterations it causes at a global level are the subject of analysis, but this study favored the learning of technical language in English, the transposition of international data, as well as valuable exercises of comparative analysis of policies, resources and experiences.

With the frequency of droughts, the increase in temperature, the increase in greenhouse gases, the excessive consumption of fossil fuels, and deforestation were noted; all of these are problems that affect the environment. All these problems were diagnosed by the team, and led them to design, as a complementary product, a monograph to raise awareness among future students of the degree.

Integrative analysis

All the topics addressed were connected to environmental problems, in accordance with the object of the environmental engineering profession, a fact that allowed the integration of lines and disciplines from the social sciences, such as anthropology, environmental sociology, and social psychology. The socialization of the research in its entirety will be published in a book, which is already in the editorial process, about the experiences of the project and the potential of formative research in the career.

Another important element as a result of this process was the consolidation that allowed teamwork, an important aspect of the research process that prepares students for a labor market that increasingly demands this capacity. In addition, oral competence was strengthened to present partial and final results, as did, in this case, the students who are members of the PIS with the projects executed; an aspect that was not limited to the teaching group but informed critical social and educational agents in the environmental scenario of the city of Loja.

Finally, it is necessary to highlight an important element to consider according to the teachers who implement formative research. This is given by the relationship between the objectives set and the time for their execution since, as Espinoza (2020) states, the time to apply research from the curricular point of view may affect the scientific results and the quality of the process, because they are usually short. Given this fact, it is the responsibility of the teacher who guides and trains the students to monitor and control the conception, as well as the statement of objectives according to the time available for execution.

CONCLUSIONS

Formative research is an alternative to traditional university education that, although it imposes challenges to teachers because success is built based on the role played as a counselor, it also represents a network of opportunities to empower and accompany students in an innovative and flattened way. The research conducted pointed out that these projects enhance students' knowledge and motivation, their involvement in social contexts, and their contribution to the resolution of problems observed in them.

The results of applying formative research support that students can take ownership of their own learning process. Likewise, it was observed that it is an indispensable requirement for teachers to have research training and pedagogical skills in order to successfully implement this experience.

Similarly, the experience affirms that formative research allows the execution of research exercises that promote strategic and critical thinking. The results achieved contribute to the balance of the PIS as a project that has supported the implementation by teachers and students of formative research, something that has evidenced the challenges faced by teachers in the face of the diversity of contexts and the demands of society.

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