International Journal of Learning, Teaching and Educational Research
Vol. 22, No. 4, pp. 286-309, April 2023
https://doi.org/10.26803/ijlter.22.4.17
Received Feb 2, 2023; Revised Apr 15, 2023; Accepted Apr 22, 2023

Formation and Consolidation of Research Seedbeds: A Systematic Literature Review

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Abstract. Formative research, in the context of the teaching-learning processes of higher educational institutions, is a pedagogical strategy in which professors and students participate, using research as a teaching strategy for students to develop discovery-based learning. Formative research includes various strategies, such as the implementation of research seedbeds. Research seedbeds are communities of extracurricular learning and voluntary participation, wherein students, through a guided and progressive exercise, develop competencies for research through training activities, extracurricular workshops and research projects. This systematic literature review focuses on research seedbeds as a pedagogical strategy within the context of the formative research of higher educational institutions. Using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology, this paper covers 17 articles published in Scopus and Web of Science databases. The analysis of the current state of knowledge about research seedbeds allows the identification of the critical factors for the formation and consolidation of research seedbeds. Based on the literature review, these factors have been grouped into the following dimensions: (i) factors related to the formation of research seedbeds; (ii) factors related to the organization of research seedbeds; (iii) factors related to the dynamics of the management of research seedbeds; and (iii) factors related to the stakeholders of research seedbeds (institution, professor/tutor and students). Additionally, the study suggests several directions for further research in this domain.

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Keywords: Research Seedbeds; Systematic Literature Review; Formative Research

1. Introduction

Science, technology and innovation are necessary elements for the social and economic progress of the world (Organization of Ibero-American States for Education, Science and Culture, 2012). In this context, research, as a social process that aims to discover new knowledge from evidence, forms the basis of progress. In many countries, research is developed, disseminated and used through various organizations and institutions that make up national innovation systems. A national innovation system can be defined as "the set of organizations and institutions of a country that influence the development, dissemination and use of different types of knowledge and innovations" (Colciencias, 2016, p. 5). According to the Organization for Economic Cooperation and Development (OECD) (1997), the performance of a system of science, technology and innovation is the result of complex relationships among its stakeholders, whereby the flows of knowledge and technology among people, companies, higher educational institutions and research institutes are essential for innovation and technological development processes. Thus, the governing institutions of science, technology and innovation systems are not only expected to guarantee the quality and socio-economic relevance of research, but also to be able to create opportunities to improve interactions among the stakeholders at national and international levels and promote competitiveness by building capacities in strategic areas (Science and Technology Options Assessment, 2014). One of the fundamental stakeholders in the system of science, technology and innovation is the higher educational institutions, which play a fundamental role in the creation of new knowledge through scientific, technological, humanistic and social research. To meet this goal, higher educational institutions must develop the research skills of their professors and students, through the incorporation of research as a differentiating element of learning within the curriculum and the institution (Lopez et al., 2022).

Research, in the context of the teaching-learning processes of higher educational institutions, can be analyzed considering two large dimensions: formative research and productive research of knowledge (also called "research training") (Campos, 2020; Peláez & Montoya, 2019). The productive research of knowledge aims to generate scientific knowledge in order to contribute to the knowledge of different disciplines, a responsibility that falls mainly on the research professors of educational institutions. Formative research is a pedagogical strategy, developed as part of the teaching-learning process, in which both professors and students participate; research is used as a teaching strategy for students to develop discovery-based learning (search, construction, organization and construction of knowledge) (Restrepo-Gómez, 2007).

Formative research is mainly used to "train professionals with self-development skills, which allows them to continue learning throughout their lives so they can use research methods to problematize and assume critical and creative thinking towards reality" (Peláez & Montoya, 2019, p. 22). According to Calderón (2015), formative research is carried out under the supervision of a research professor, as

students participate actively and proactively in the construction of their own knowledge. Moreover, formative research is a space for research training that is orientated towards reflection and problem solving. For Arenas et al. (2021), the objective of formative research is to strengthen the skills necessary to build scientific knowledge. In this way, higher educational institutions benefit from formative research since it is a means by which the curriculum and practical pedagogy complement the research through a variety of strategies (López et al., 2022). Many authors agree that students must be the protagonists of their training process, and that the curricula must contain, besides the specific competencies of the academic program, competencies that aim at strengthening students' research capacity (Rubio et al., 2015). A significant aspect of formative research, besides the training in research-related competencies, is the ability to identify potential researchers and link them to research processes, through research incubators or seedbeds. Formative research includes various strategies for its implementation. These can include, for instance, the development of class sessions based on Problem-Based Learning, the inclusion of research-related subjects in the curricula, the establishment of links between professors and students through projects and extracurricular spaces, case study, exploration of bibliography, the development of research competencies through research seedbeds, active learning, project-based learning and many others (Silva et al., 2008).

The present study focuses on research seedbeds as a pedagogical strategy within the context of formative research in higher educational institutions. Research seedbeds are working groups comprising of a research tutor with proven research experience and a group of students, with the aim of developing one or more projects, within a certain line of research (Garza et al., 2021). The research seedbeds form communities of extracurricular learning and voluntary participation, wherein students, through a guided and progressive exercise, develop competencies for research by completing training activities, extracurricular workshops and research projects. A seedbed promotes early formation in research, through an alternative model whereby the student is the protagonist. According to McErlain (2020), the participation of university students in research projects through research seedbeds forms the "pedagogy of the 21st century" (p. 2).

Despite the relevance of formative research in the field of teaching-learning processes and scientific seedbeds, as a strategy for students to develop the research skills of students under the leadership of a research professor, the subject has not been widely developed in the academic literature. Thus, there is a need to identify the current status of the existing scientific knowledge on this topic and propose recommendations for future research. In this context, the objective of this literature review is to analyze the current state of research seedbed studies and identify the critical factors for the implementation of research seedbeds in the context of formative research in higher educational institutions. Specifically, this systematic literature review aims to answer the following research questions: RQ1. What is the current state of research seedbed studies, as a formative strategy in higher educational institutions, in the literature up to December 2022?

RQ2. What are the key factors for the formation and consolidation of research seedbeds? A literature review can be described as a way to collect and synthesize previous research (Knopf, 2006), which is especially useful for integrating perspectives and facilitating theory development (Onwuegbuzie et al., 2012). The literature review is not only a report that summarizes articles from a specific line of research; it also provides a description and critical evaluation of a line of research (Parajuli, 2020). Furthermore, they can help to identify knowledge gaps and provide recommendations for future research.

To the best of our knowledge, this article is the first literature review applied to the study of research seedbeds. This article is expected to serve as an input for the development of strategies of formative research based on scientific seedbeds, as well as providing recommendations for future research on this topic. The rest of the article is structured as follows. Section two presents the definition of research seedbeds. Section three explains the methodology applied to the literature review and section four presents the results of the literature review. Finally, the conclusions and recommendations for future research are discussed.

2. Theoretical Foundation

Research seedbeds are defined in different ways in educational institutions. Some also refer to them as *scientific seedbeds* or *research circles*. According to García (2010), the research seedbed "is an alternative training space to the curriculum…that uses the professor-book-student triad methodology" (p. 265). Research seedbeds involve activities based on reading, speaking, writing, attendance at conferences and academic and cultural events, the organization of events, the construction of joint projects and other proposals for reflective intervention. For Molineros (2010), they are "groups that acquire instruments for the development of research, in a space that promotes conversation and dialogue and where new knowledge and learning methods are discovered" (p. 212). Giraldo (2002) explains that the seedbeds are interdisciplinary learning communities that converge in the formation of a research culture and the promotion of the scientific spirit in the educational field.

Seedbeds promote a space in which students and professors from different disciplines can converge with the same research purpose (Pavón & Carrillo, 2018). The research seedbeds are a strategy based on methods that allow students and professors to participate, prioritizing freedom and innovation to develop learning more effectively than formative work in the classroom. In particular, this strategy allows professors to conduct research with the support of young researchers while, at the same time, developing competencies that will help students strengthen their research skills (Medina, 2018).

In terms of their formation, research seedbeds usually have the same structural and functional form. They are comprised of (i) a research tutor (in charge of supervising and guiding students in research activities); (ii) a coordinator-student (who supports the research tutor and maintains close coordination with the students of the seedbed, consistently supporting them in the fulfillment of the duties assigned during the research project); and (iii) members (students who

carry out projects or other research activities within the seedbed and who are the main stakeholders seeking to develop their potential for scientific contribution).

Based on the literature, scientific seedbeds have various objectives. According to Molina et al. (2012), they are "groups that promote research capacity, interaction between professors, researchers and students to strengthen academia, scientific and social development of the community, promote discipline, teamwork, interdisciplinarity and participation in research networks" (p. 212). For Giraldo (2002), the seedbed "is an alternative of integral formation, based on motivation, participation and learning of the theory, practice, research methodology and other related knowledge, in order to train its members in a culture of research…" (p. 58). Similarly, Pepper and Terán (2019) stated, "the seedbeds are ideal spaces where students understand the daily work of a researcher, who acts as a tutor, create together learning communities around a research topic" (p. 272). The main objective of these learning communities is:

> *To educate political, ethical, critical and reflective citizens, through the establishment of new relationships with knowledge, to change the passive-traditional role of the learner to a participatory-critical role. These spaces also promote scientific and research culture, building scenarios for research training. (Universidad de Antioquía, 2019, p. 29-30)*

Moreover, research seedbeds aim to identify talents among students and train new researchers, so that students and professors "learn research by doing research". Seedbeds are organized as academic communities for the research systems of the higher educational institutions, through their link with the research groups, making them the training cells of the generational change of researchers. Similarly, they are linked to students, since their work areas are derived from the interests that arise in students in the formal development of their studies, always framed in the institutional lines of research. Appendix 2 provides three examples of the characteristics of scientific seedbeds in Latin America (Colombia and Peru).

3. Methodology

In this study, we conducted a systematic literature review to identify, synthesize and analyze previous studies using the Preferred Reporting Items for Systematic Reviews and the Meta-Analyses methodology (PRISMA, 2020). According to Pahlevan-Sharif et al. (2019), the PRISMA checklist represents one of the most comprehensive checklists to assess current and future trends in any field. It sets out the necessary steps to conduct a literature review that is replicable for other researchers and that generates reliable data. In addition, the application of the PRISMA checklist contributes to a clearer picture of the execution, quality and rigor of systematic literature reviews. The PRISMA methodology has four stages. In the first stage, the researcher determines the objectives of the review and formulates research questions. In the second, the researcher establishes the literature review protocol, which includes the definition of databases, search terms, and literature selection criteria. In the third stage, the researcher performs the search in the databases, and the search results are filtered according to the selected criteria. In the fourth stage, the results are analyzed to collect relevant information, and prepare summary tables and a map of the literature and references. Finally, the researcher carries out the thematic analysis methodology,

which is "a form of pattern recognition within the data, where emerging themes become the categories for analysis" (Fereday & Muir-Cochrane, 2006, p. 82).

3.1 Literature Review Objective

This systematic literature review explores the way in which research seedbeds have been previously researched in terms of the authors, journals, research design, population and geographical location. Additionally, this literature addressed the following research question: What are the critical factors for the formation and consolidation of research seedbeds?

3.2 Literature Review Protocol

In terms of the protocol used in this study, the search was conducted in the Scopus and Web of Science databases. The study protocol considered the term "research seedbeds" in all fields. The search strategy included academic articles published in English and Spanish up to December 2022. The search identified 60 papers (52 in Scopus and 8 in Web of Science), which were individually reviewed in detail. We discarded duplicated papers as well as others according to the acceptance/rejection criteria listed in Table 1. The result was 51 articles (45 in Scopus and 6 in Web of Science).

Table 1: Article acceptance and rejection criteria

Criterion	Acceptance	Rejection
Year of publication	Publication of journal articles up to December 2022	None
Language	English or Spanish	Other languages
Type of reference material	Journal articles and conference papers	Reviews, books
Article topic	Research seedbeds as a formative strategy	Other topics related to research seedbeds

3.3 Literature Screening

The article selection process was conducted in April 2023. We carefully analyzed the 51 articles identified and made the decision to include three further articles identified from the references of those papers. Figure 1 depicts the flowchart of the literature screening process adapted from the PRISMA flowchart (PRISMA, 2020).

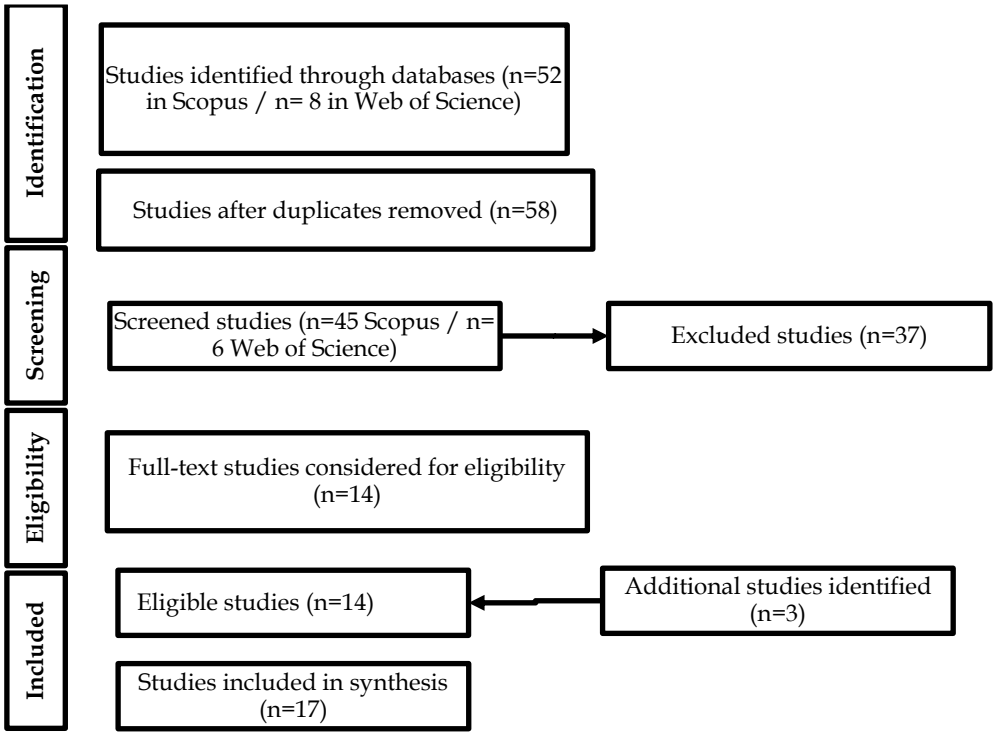

Figure 1: PRISMA Flowchart of the article selection process

3.4 Synthesis Analysis

We analyzed the articles using the Analyze Results Tool by Scopus (i.e. research fields, journal, years, authors, and citations). In addition, an in-depth review process of the 17 papers led us to conduct the analysis of the authors, the journals with the greatest number of publications, research designs and type and geographical locations of the population. Appendix A provides detailed information on the 17 articles.

The results revealed a small number of research works related to scientific seedbeds as a pedagogical strategy, but with a noticeably growing interest in 2022 (Figure 2). Of the 17 articles, 12 are focused on studying the experience of educational institutions in Colombia. This greater interest in the educational institutions of Colombia for studies related to research seedbeds is possibly due to the fact that this country has pioneered the consolidation of research seminars as a strategy to promote research education (Bolívar et al., 2015). Research seedbeds have existed in the universities of Colombia since the 1990s. They differ from teaching groups in that their development is based on the meeting of groups integrated into research networks and in the fact that they have achieved the consolidation of political exercises and conversations with government entities. They have also woven community processes and have an important presence in the Colombian Ministry of Science, Technology and Innovation (Gallardo-Cerón & Duque-Castaño, 2022). Moreover, Colombia founded the Colombian Network of Research Seedbeds, a pioneering organization in formative research processes that generates a movement on a national scale to promote scientific culture among young university students (López-Ríos et al., 2016).

As for academic journals, the 17 articles were published in 16 journals. The only journal that includes two publications is the Estudios Pedagógicos Journal, which aims to contribute to the understanding of pedagogical phenomena. In the case of the Estudios Pedagógicos Journal, both publications had 14 citations. The rest of the journals account for 15 publications with 11 citations. The most cited article was that by Arenas et al. (2021) (12 citations in Scopus). These authors described the characteristics of the formative research process among students, professors and coordinators of industrial engineering. They showed that the formative research process has improved the perception of the quality of academic programs, for the specific case of industrial engineering. In addition, they demonstrated a significant increase in scientific production. Martinez-Daza et al. (2021), who studied the perceptions represented in the attitudes, knowledge and uses of ICTs in students ascribed to the research seedbed in a virtual business administration program, and Garza et al. (2021), who studied the processes of knowledge management in research seedbeds based on an analysis of the experience of the leaders of the research seedbeds, had three citations each. Finally, Vega-Monsalve (2019) had two citations. This author analyzed the formation and consolidation strategies used by two undergraduate research seedbeds and found that the success of the process lies in the execution of four moments. These moments are motivation, work dynamics, the performance of the leader-professor, and institutional support. Finally, the author proposed some strategies for other scenarios. In terms of the number of publications, only Martínez-Daza (2022, 2021) participated in the publication of two articles among the articles included in the analysis.

As for the study population, we identified articles that focused on analyzing the experience of people linked to the social structure and evolution of the seedbeds, including students, coordinators, professors and, in some cases, entrepreneurs. In some papers, the study only focused on students, while in other cases, multiple units of analysis were considered in the same study.

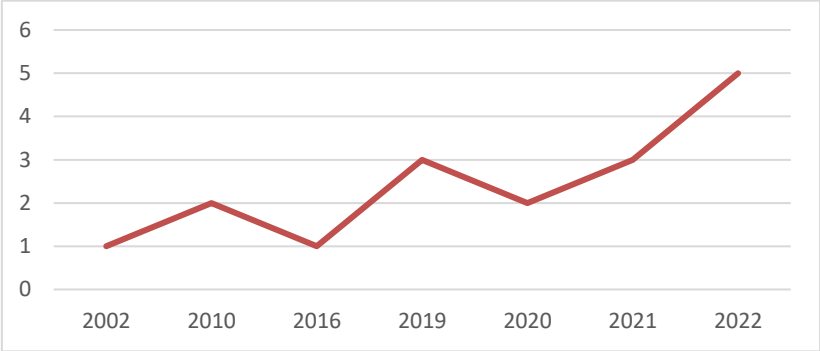

Figure 2: Number of publications per year

4. Findings

4.1 Research Seedbeds as a Formative Strategy

The first studies on research seedbeds were essays about the dynamics of a specific seedbed in a particular educational institution (Corpas-Iguarán, 2010; García, 2010; Giraldo, 2002; Villa et al., 2020). Later, new qualitative research

studies appeared. One study was based on the case study and ethnography strategy on the research seedbed in Public Health and Epidemiology of the Universidad de Antioquia. The authors analyzed the identity (history of the seedbed, evolution and strategic direction), significant learning (experiences, motivations, fears and research culture, work methodology and academic progress of the managers of the seedbeds) and challenges (reflection of the work and perspectives of the seedbeds) (López-Ríos et al., 2016). Another focused on the characteristics of the training research process in a seedbed in the field of industrial engineering in the I.U. Pascual Bravo (Colombia) (Arenas et al., 2020). A further study analyzed the formation and consolidation strategies used by two research seedbeds at the Universidad de Manizales (Colombia) (Vega-Monsalve, 2019). Furthermore, one study described an experimental laboratory model that linked the students and researchers of the university with public and private organizations, NGOs, communities and people who required technologies to solve their problems (Chang & Alvarez, 2019). More recently, Valerio (2022) described how research seedbeds are a tool used to generate research culture in the Universidad Hispanoamericana de Costa Rica. They found that, as the hotbed transformed over time, the students developed investigative skills and made improvements in terms of "cooperative learning, leadership, responsibility, computer skills, and even conflict resolution" (para. 19).

The previous literature includes only three quantitative studies. The first of these, with a clearly descriptive scope, identified the perception of nursing students regarding formative research at the Universidad Nacional Mayor de San Marcos in Peru (Rivas-Díaz et al., 2020). The second, based on the hierarchical clustering technique, analyzed the perceptions represented in the attitudes, knowledge and uses of ICTs in students ascribed to the research seedbed in a virtual business administration program (Martinez-Daza et al., 2021). The third one studied a purposive sample of 102 students in Perú to analyze the effectiveness of formative research in strengthening their enquiry competences, using a pre- and post-test approach (Campos-Ugaz et al., 2022).

More recently, the literature has evolved from descriptive studies to studies that seek to conceptualize the work developed in the seedbeds, as is the case with Garza et al. (2021). These authors analyzed the processes of knowledge management in the research seedbeds based on an analysis of the experience of the leaders of research seedbeds in different academic programs of the Corporación Universitaria Minuto de Dios (Colombia) (Garza et al., 2021). The authors proposed a knowledge management model for research seedbeds that facilitate their implementation in higher educational institutions that develop this teaching-learning strategy. In addition, Gallardo-Cerón and Duque-Castaño (2022) analyzed research seedbeds focused on creating a space for the recognition of people with outstanding abilities (with high potential for creative and productive practices oriented to the common good). Finally, Martinez-Daza (2022) systematized the pedagogical strategy and evaluation of a virtual research seedbed through five stages: planning, design, implementation, tutoring and evaluative monitoring.

Previous literature demonstrates that research seedbeds have several advantages as a pedagogical strategy. For example, González and Villalba (2017) reported that seedbeds allow their student members "a real, controlled and guided participation of the teaching-learning binomial that prioritizes freedom, creativity and innovation for the development of new mental schemes and learning methods" (p. 9). Similarly, seedbeds promote an early training in research, through an alternative model whereby the student is the protagonist (López-Ríos et al., 2016). Garza et al. (2021) stated that students develop research, cognitive, collaborative, methodological-professional and ICT skills through the seedbeds. Finally, Rodrigo et al. (2019, cited by Garza et al., 2021) highlighted that the inclusion of integrative projects as a pedagogical strategy (integration, socialization of knowledge, cooperative learning, leadership, responsibility, conflict resolution) demonstrates that the student who participates in the project, as a protagonist of discovery and creation, is an individual who reaches a level of commitment to the truth and knowledge that is not noticed in other conventional pedagogical methods (p. 165).

4.2 Critical Factors for the Formation and Consolidation of Research Seedbeds

While there are diverse experiences of scientific seedbeds, no scientific research has yet systematized all of the knowledge. According to Garza et al. (2021), "…seedbeds are a permanent and interdisciplinary space that changes over time and self-manages based on the continuous learning of the cohorts of students that are part of it" (p. 161); thus, it is necessary to know the knowledge management process in the research seedbeds. For this reason, based on the systematic literature review, the present study aims to identify the critical factors related to the formation and consolidation of the research seedbeds, enabling them to generate the expected results, based on the experience of different cases presented in the literature. It is also important to consider that the optimal results of the research seedbeds depend on the commitment and "coordinated gearing" of the leading professor, the students and the institutional support of the university (Vega-Monsalve, 2019). These factors have been grouped into the following dimensions:

(i) factors related to the formation of research seedbeds; (ii) factors related to the organization of research seedbeds; (iii) factors related to the dynamics of the management of research seedbeds; and (iii) factors related to the stakeholders of research seedbeds (institution, research tutor and students). Figure 3 summarizes the factors identified, which are explained below.

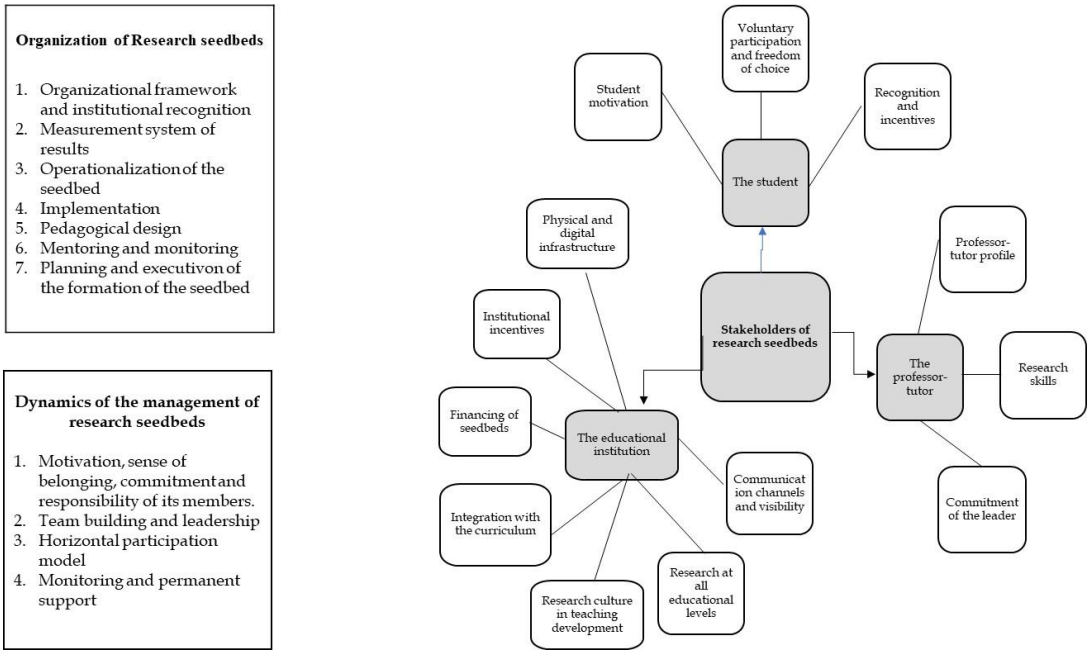

Figure 3: Critical factors for the formation and consolidation of research seedbeds

Factors related to the formation of research seedbeds

The literature suggests the following critical factors for the formation of research seedbeds (Vega-Monsalve, 2019):

a) Have a work path that guides the meetings and poses challenges and indicators for evaluating the group's progress.
b) Be clear with the students. Present them with the project scope, the time invested in their participation, and the benefits that are perceived when participating.
c) Invite them to a group meeting in which information about the process is explained and all their questions are answered.
d) Clearly establish the profiles of the members of the seedbed.
e) Take advantage of the introductory research courses to present the final research reports made by the students who participated in the seedbed.
f) Tell students about the achievements of the seedbeds, to increase their interest in the topic when the opportunity arises.
g) Ensure that information about upcoming opportunities to participate in a research seedbed is disseminated through several channels and well in advance.

Factors related to the organization of research seedbeds

The literature suggests the following critical factors related to the organizations of research seedbeds:

a) A clear organizational framework and institutional recognition. For a seedbed to achieve its objectives, it must comply with clearly designed and disseminated parameters: organizational framework, size, agreements, roles, physical environment, external and internal dynamics (López-Ríos et al., 2016).

b) Seedbed planning and operationalization. There must be a clear planning of the work to be carried out, through the planning of the teaching, student guides, call guides for the registration of the seedbed members, registration forms, commitment models, qualification formats, academic performance reports and expected research products (Martinez-Daza, 2022).
c) Implementation of the seedbed. It is essential to prepare a theoretical-practical course whereby students who are part of the seedbed can learn and internalize the scientific method, including the research methodology, the methodological design, the literature review and the scientific writing (Martinez-Daza, 2022).
d) Pedagogical design of the seedbed. Oriented to formulate the instructions and learning activities from the design of research tasks (Martinez-Daza, 2022).
e) Mentoring and monitoring. The professor should design a work plan, based on the needs of the students and the research (Martinez-Daza, 2022).
f) System for measuring the results of the seedbeds. The results of a seedbed can be analyzed from several points of view: individual effects such as life experiences, positioning, stability and productivity achieved over time (López-Ríos et al., 2016), as well as the identification of promising young talent for generational change in research (López-Ríos et al., 2016). It is essential to design an evaluation system that recognizes the formative nature of the seedbeds rather than focusing only on the productive nature (Vega-Monsalve, 2019).
g) Connection to institutional research projects. Final projects may be related to memoirs, working papers, book chapters, academic papers, and participation in academic conferences (Martinez-Daza, 2022).

Factors related to the dynamics of the management of research seedbeds

Based on the literature, the following factors related to the management of research seedbeds are seen as critical:

a) Motivation, sense of belonging, commitment and responsibility of its members. Professors consider that a lack of motivation and responsibility in students affects the correct development of the seedbeds (Garza et al., 2021). The success of the seedbed requires that students, professors and researchers commit to adopting the approach of learning research by doing research (López-Ríos et al., 2016). Generate discipline, commitment and dedication, promoting permanent communication and interaction among the research tutors. Keeping this dynamic is considered a challenge to create a research culture and a sense of belonging (López-Ríos et al., 2016).
b) Team building and leadership. The agreement, dialogue and guidance of people with a vocation and research expertise, but especially with an open mind, are essential elements for the seedbed. Each seedbed contributes to the creation of a space and a special dynamic, whereby collaborative work and interaction for the construction of knowledge prevail (López-Ríos et al., 2016). Teamwork and leadership are characteristics that professors consider necessary for both their students as well as themselves. However, occasionally, the work might be done individually, which does not allow

the generation of teamwork and leadership processes between them (Garza et al., 2021).

c) Horizontal participation model. The seedbed has a horizontal model of participation and management that reaps great benefits because students can work with the research tutors, as collaborative peers (López-Ríos et al., 2016).
d) Monitoring and permanent support. Students report that they need professors who motivate them to feel connected with the process, give reviews and provide feedback in real time. Students not only expect dedication during face-to-face meetings but also through virtual media. Remembering assignments and checking the quality of projects submitted by students are key in the process (Vega-Monsalve, 2019).

Factors related to the institution, research tutors and students

The literature suggests the following critical factors related to the stakeholders of research seedbeds:

a) Student motivation (students). The literature shows that the motivation of students to be part of a seedbed is related to the "sense" that they give to the activities of the scientific seedbed. Students expect to complement their academic careers with more studies or related research (Vega-Monsalve, 2019). Previous students have also identified a feeling of pride with a sense of belonging to a research group (Vega-Monsalve, 2019).
b) Voluntary participation and freedom of choice (students). Be aware that not all the members of the research seedbed continue their formation as researchers, which implies a process of experimentation and free decisions. That is another substantial value of this formative experience in terms of freedom of choice (López-Ríos et al., 2016). Students enter and remain voluntarily in a seedbed based on the motivations, findings and learning experiences generated in them (López-Ríos et al., 2016).
c) Recognition and incentives (students). The study of Sánchez-Lascano et al. (2018) reported that the students did not participate in the research tasks "because they did not have an incentive that accredits them as researchers; they wanted to be recognized after some time performing these tasks" (p. 45). Similarly, Vega-Monsalve (2019) found that it is important for the institution to promote "privilege" and recognition for students who are part of the seedbeds, such as discounts on tuition, scholarships and economic bonuses, among others.
d) Profile of the research tutor (professor). Design a special profile for the professors who will be in charge of this work, recognizing that it is not only necessary that they have training and research experience, but also that they enjoy dealing with students and transmitting their knowledge (Vega-Monsalve, 2019).
e) Research skills of the research tutor (professor). It is essential that the leading professors of seedbeds have a sound understanding of various research methodologies, and know when to use them (Garza et al., 2021).
f) Commitment of the leader (professor). The role of the research tutor as the leader of the process is a key factor related to the "passion" for research and personal commitment of the group.

g) Research culture at all levels of education (institutional). For the training of research talent, the university needs to make a commitment and overcome the idea that research training is reserved only for graduate levels (in graduate and doctoral programs), which is a situation that requires a critical view and demands an alternative approach (López-Ríos et al., 2016).
h) Research culture in teaching development (institutional). The management of new knowledge should not focus on few professors; research should be an intrinsic part of the academic activity (Garza et al., 2021).
i) Integration with the curriculum (institutional). The experience of the seedbeds must be integrated with the courses that offer research training in the curriculum (Vega-Monsalve, 2019).
j) Financing of seedbeds (institutional). Financing is related to the participation in events, inclusion of specific budgets, funding for publications, and even economic allocations for those students who are members of the seedbeds.
k) Effective communication channels and visibility of the seedbeds (institutional) (Arango & Gomez-Giraldo, 2019).
l) Institutional incentives for the development of research (institutional). Research must be a fundamental component of the development plan of professors; remunerations must be based on the production and research experience; teaching contracts must include sufficient time to conduct research (Garza et al., 2021); the professor's schedule must allow for the monitoring of student groups (Vega-Monsalve, 2019).
m) Physical and digital infrastructure (institutional). Virtual and physical spaces are needed for the seedbeds to promote meetings and the development of activities (Garza et al., 2021).

5. Conclusions and Recommendations for Future Research

This systematic literature review aimed to know the current state of research seedbed studies as a formative strategy in higher educational institutions, as well as to identify the key factors necessary for the formation and consolidation of research seedbeds, based on previous studies.

The results showed that research is scarce on this topic and the existing studies identified have mainly been developed in higher educational institutions in Colombia. The review allowed us to conclude that, although there are various experiences of scientific seedbeds in higher educational institutions in the Latin American region, no scientific research has systematized all the knowledge. The studies available in the literature show qualitative case studies and ethnography regarding the experience and significant learning of certain research seedbeds. We identified only three quantitative studies. Two of these had a clearly descriptive scope and the third was based on the hierarchical clustering technique to identify the perceptions represented in the attitudes, knowledge and use of ICTs in students ascribed to a research seedbed in a virtual business administration program. Recent qualitative studies have analyzed the processes of knowledge management in the research seedbeds and the systematization of the pedagogical strategy of the seedbeds.

Based on the literature review, the study identified the factors that are most critical for the implementation of research seedbeds, which have been grouped into the following dimensions: (i) factors related to the formation of research seedbeds; (ii) factors related to the organization of research seedbeds; (iii) factors related to the dynamics of the management of research seedbeds; and (iii) factors related to the stakeholders of research seedbeds (institution, research tutor and students).

The relevance of research seedbeds as a pedagogical strategy within the context of the formative research of higher educational institutions leads us to propose a series of recommendations for future research. First, we suggest conducting qualitative exploratory studies (phenomenological, ethnographic and case study) to know the experience of the research seedbeds in different higher educational institutions. The phenomenological studies could be oriented to understand the experience of the three key stakeholders of the scientific seedbeds: the educational institutions, the research tutors and the students participating in the seedbeds. Ethnographic studies could be oriented towards understanding the research culture of scientific seedbeds as a working group. Case studies should be oriented to understand the pedagogical strategy of the seedbeds within the formative research to understand the fundamental elements that lead to their achieving better results in research. Moreover, we suggest studies aimed at analyzing and measuring the achievement of the research skills of students through longitudinal studies. On the other hand, we also recommend deepening research related to the systematization of experiences, knowledge management processes, processes related to the management of the seedbeds, and institutional frameworks that have a greater impact on the seedbeds with better results. Furthermore, we suggest experimental studies that compare the results of the research competitions of the students participating in the seedbeds with those who did not participate in the competition. We also recommend quantitative studies that explain the behavioral intention of those students and research tutors who participate in the scientific seedbeds, based on the Theory of Planned Behavior (Ajzen, 2002), considering attitudes, subjective norms, and perceived behavioral control. Finally, we suggest carrying out quantitative studies that validate the critical factors to obtain superior results through the research seedbeds identified in the present study. In short, there remains a wide field to be developed in terms of scientific research related to research seedbeds as a pedagogical strategy within formative research in higher educational institutions, both at undergraduate and graduate levels.

Funding
This work was not supported by any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of interest
The authors declare that they have no potential conflict of interest.

Ethical approval
The data source for this paper is secondary data and no human experiments were conducted.

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Appendix 1. Studies in research seedbeds

	Reference	Research topic	Unit of Analysis	Country	Method
1	Giraldo (2002)	Dynamics of the research seedbed of Information Science and Librarianship	Universidad de Antioquía	Colombia	Essay
2	García (2010)	Use of Historic Documentaries that Stimulate Formative Research	Universidad de Antioquía	Colombia	Essay
3	Corpas-Iguarán (2010)	Virtualization of research seedbeds	Not applicable	Colombia	Essay
4	López-Ríos et al. (2016)	Experience, history, culture, difficulties and challenges of a research seedbed in public health	Universidad de Antioquía	Colombia	Ethnography
5	Vega-Monsalve (2019)	Formation and consolidation strategies used by two research seedbeds	Universidad de Manizales	Colombia	Case study
6	Chang & Alvarez (2019)	A model developed by the College of Electrical Engineering at the Universidad Tecnologica de Panama with the objectives of strengthening and incrementing research activities among undergraduate students.	Universidad Tecnologica de Panama	Panamá	Qualitative
7	Guerrero Hernandez et al. (2019)	Experience in an engineering research seedbed	Tecnológico Nacional de México	México	Essay
8	Rivas-Díaz et al. (2020)	Perception of nursing students about formative research	Universidad Nacional Mayor de San Marcos	Perú	Quantitative
9	Arenas et al. (2020)	Characteristics of the training research process in a seedbed in the area of industrial engineering	Institución Educativa Pascual Bravo	Colombia	Case study
10	Arago & Gómez-Giraldo (2021)	Experience in a research seedbed	Universidad de Antioquía Seccional Oriente	Colombia	Qualitative

11	Martinez-Daza et al. (2021)	Perceptions represented in the attitudes, knowledge and uses of ICTs in students ascribed to the research seedbed in a virtual business administration program	Higher education institution	Colombia	Quantitative
12	Garza et al. (2021)	Processes of knowledge management in the research seedbeds based on the analysis of the experience of the leaders of research seedbeds	Corporación Universitaria Minuto de Dios	Colombia	Qualitative
13	Villa et al. (2022)	Pedagogical experiences in a research seedbed	Universidad de Antioquía	Colombia	Essay
14	Gallardo-Cerón & Duque-Castaño (2022)	Analyze research seedbeds based on a space for recognition of people with outstanding abilities	Universidad de Manizales	Colombia	Qualitative
15	Martinez-Daza (2022)	Systematize the pedagogical strategy and evaluation of a virtual research seedbed	Corporación Universitaria de Astuarias	Colombia	Qualitative
16	Campos-Ugaz et al. (2022)	Analyze the effectiveness of formative research in strengthening enquiry competences in university students	University students	Perú	Quantitative
17	Valerio (2022)	Research hotbeds as a research tool to generate research culture	Universidad Hispanoamericana de Costa Rica	Costa Rica	Qualitative

Appendix 2. Examples of Scientific Seedbeds in Latin America

Universidad Nacional del Santa (Peru)	
Objectives	Carry out research on important issues for regional and national development, promoting formative research at the Universidad Nacional del Santa.
Scope	University community.
Required formation	One responsible professor, one student coordinator and a maximum of four students.

Activities	Work meetings, updates, research projects, dissemination of results and activities, academic interaction.
Incentives	Funding in internships, papers and highly specialized events, publication of scientific.
Financing	The university considers within its budget the funds for the projects, which include undergraduate or thesis work, as well as the expenses demanded by the research and the incentives of the professors and students.
	EAFIT
Objectives	a) Promote formative research and actual research among students. b) Promote questions in the university, inside and outside the classroom, that contribute to the development of a learning culture. c) Strengthen the relationship between academia and research, fostering multidisciplinary interaction among students, professors and researchers. d) Generate research culture in the university through the creation of spaces that bring students closer to research and present it as one of their professional options. e) Generate mechanisms that allow the connection of students with research groups as part of the process of generational replacement of professors and researchers. f) Form and facilitate the emergence of a network of research seedbeds at EAFIT University, which also participates in national and international networks. g) Be the channel of interrelation of the research seedbeds with other institutional programs and their partners in the social field.
Scope	EAFIT university community and the people outside of it, as long as they are connected to the seedbed from an inter-institutional agreement.
Required formation	They must have at least one adviser-professor, one coordinator-student and three students who are listed as members and who must be active.
Activities	Working meetings, study groups, research projects, dissemination of results and activities, academic interaction, research days, research forums, seedbed meetings, participation in events.
Incentives	a) Annual research award b) Support the dissemination of research results derived from the work of the seedbeds

	c) Research excellence scholarship d) Certificate of attendance e) Mention in the annual seedbed f) Training g) Use of laboratories
Financing	a) Support the dissemination of research results derived from the work of the seedbeds b) Research excellence scholarship c) Certificate of attendance d) Mention in the annual seedbed e) Training f) Use of laboratories g) Finance research proposals with annual validity
	Universidad de Antioquía (Colombia)
Objectives	a) Promote the research capacity of students b) Change the learning culture c) Debunk research d) Educate reflective and critical citizens e) Contribute to the solution of the social problems of our country f) Articulate teaching-research g) Qualify professor-researcher-student interactions h) Strengthen academic excellence i) Overcome the academic "elitism" of research j) Create a point of convergence, strengthening and developing the research seedbeds as the objective of the RedSIN UdeA. k) Encourage the research work and the integral formation of the academic community as the objective of the RedSIN UdeA. l) Form the generational change of professors, academics and scientists

Scope	University community
Required formation	One coordinator-professor and students
Activities	Research projects, supervision of the training of students, networking, search for funding sources, meetings and events, exchange of experiences, feedback on the work done, open chairs, meetings with seedbed coordinators, journal articles, presentations, exhibitions, cultural exchanges, strengthening of reading and writing skills
Financing	The information related to funding and financial support for the projects is presented in each call promoted by the university.