Smart Research Training: Developing 21st-Century Investigative Skills Through Artificial Intelligence

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Abstract

The research aimed to strengthen students' investigative competencies and transform training processes through the integration of artificial intelligence (AI). A program was developed to train students in the use of AI tools, promoting an understanding of their principles and fostering critical thinking for their application in research. Investigative processes were transformed by using AI to optimize repetitive tasks and analyze large volumes of data, identifying patterns and trends. The study evaluated various AI tools and incorporated them into research-related courses. An evaluation battery was designed to measure investigative competence, applying descriptive statistics to characterize participants' competence levels. The most applicable AI tools were SciSpace, Consensus, and Claude, used for data management, decision-making, and scientific article writing. The results of the pilot program showed a significant improvement in investigative competencies, with 83.27% of students reaching a high level of competence. It was concluded that the integration of AI has great potential to transform research, although it should be accompanied by ethical and social reflection on the impact of these technologies.

Keywords: AI and research, research integrating AI, AI tools for education.

The rapid evolution of artificial intelligence (AI) technologies has fundamentally transformed the landscape of scientific research and higher education, creating unprecedented opportunities to enhance investigative competencies among university students. As Jordan and Mitchell (2015) emphasize, machine learning techniques and data analysis can revolutionize scientific research, enabling faster and more robust discoveries. The integration of AI tools into academic research processes has become not merely advantageous but essential for preparing students to navigate an increasingly complex and data-driven research environment.

The development of investigative competencies represents a cornerstone of contemporary university education, encompassing critical thinking, problem-solving abilities, and collaborative skills that are indispensable for understanding and addressing real-world challenges. According to Sumarni et al. (2021), "the ability to conduct research is an indicator of the teacher's professional competence" (p. 1), while Velandia Mesa et al. (2019) consider that "scientific and research training is essential in professional education" (p. 25). Traditional research methodology courses, while foundational, require enhancement through innovative technological approaches to meet the demands of modern scientific inquiry.

Recent advances in natural language processing (NLP) and machine learning have produced powerful AI tools that demonstrate remarkable capabilities in supporting various aspects of the research process. As highlighted by Vivek Agrawal et al. (2024), AI-driven tools using natural language processing simplify tasks like literature review, manuscript writing, and reference generation, enabling researchers to deepen their work and foster innovation in their respective fields. Specifically, applications like SciSpace, Consensus, and Claude offer significant advantages in data management, decision-making, and scientific article writing, though Segovia and Baumgartner (2023) caution that their inferences must be verified to ensure validity and prevent plagiarism.

However, successful implementation requires careful consideration of ethical implications. As Bostrom and Yudkowsky (2014) emphasize, there is a crucial need to consider the ethical implications of AI use, particularly regarding privacy, fairness, and its impact on employment, ensuring that technological advancement serves to enhance rather than replace human expertise in scientific research.

Literature Review

Investigative competencies are essential in the 21st century, associated with critical and creative thinking, problem-solving, and teamwork—crucial elements for understanding the complexity of reality and adapting to the modern world. For this reason, "research methodology" is taught in most higher education programs, as the scientific method is fundamental for good academic performance. According to Sumarni et al. (2021), "the ability to conduct research is an indicator of the teacher's professional competence" (p. 1). Velandia Mesa et al. (2019) consider that "scientific and research training is essential in professional education" (p. 25). Moreno (2021) concludes that developing investigative competencies in university teachers is crucial.

In many educational programs, a final report, dissertation, capstone project, or thesis is required to obtain a degree, which demands mastery of investigative competencies. Likewise, university professors must produce research to advance academically, which also involves these competencies. They are essential not only in scientific research but in various professional areas that require continuous updating and improvement, such as education, medicine, technology, engineering, law, and business.

Various studies highlight the need for valid and reliable measurement instruments to diagnose levels of investigative competencies, forming the basis for training. Castro Morera (2011) points out that "more research is needed, as there is little evidence supporting the technical robustness of such measures" (p. 109). Ceballos and Tobón (2019) argue that "although the topic is relevant, there are few methodological references for its development and evaluation" (p. 3). Monsalve et al. (2019) emphasize the need to "evaluate and strengthen investigative competencies in teachers, and to promote the design of diagnostic instruments" (p. 40). In her review of higher medical education, Castro-Rodríguez (2021) found "few studies that assessed investigative competencies through measurement instruments" (p. 2). Gómez-Sánchez et al. (2019) observe an "incipient development of instruments for evaluating competencies and skills" and conclude that "greater conceptual clarity and the construction of instruments for evaluating investigative competencies and skills in undergraduate students are needed" (p. 43). Farfán Córdova (2022) considers that the instruments "have been scarcely developed and analyzed, and various dimensions defined by the authors have not been incorporated, with only some selected for study" (p. 25).

Background on the use of AI in research

The integration of Artificial Intelligence (AI) technologies into scientific research and education has revolutionized various fields by enhancing efficiency, accuracy, and innovation. AI-driven tools, such as those using natural language processing (NLP), simplify tasks like literature review, manuscript writing, and reference generation, enabling researchers to deepen their work and foster innovation in their respective fields (Vivek Agrawal et al., 2024).

In education and scientific research, AI applications like ChatGPT, Scite, and Litmaps offer significant advantages, although their inferences must be verified to ensure validity and prevent plagiarism (Segovia & Baumgartner, 2023).

The role of AI in education and physical training is notable, with intelligent computer-assisted instruction (ICAI) systems, AI-driven wearable devices, and motion capture systems greatly enhancing the precision and effectiveness of training programs (Min, Mao, & Junqing, Chen, 2023). For instance, a training assistance system for runners has been developed, integrating Zigbee wireless transmission technology, the Megawin microcontroller, infrared detection, and voice recognition, to improve athletic performance through motion data analysis and feedback via a user-friendly interface (Zheng, Yuanjun, 2022; Yongchao, Xu, 2022).

In biomedical sciences, AI algorithms, particularly convolutional neural networks (CNNs), are employed in research to analyze stem cell images, predict cell types, and improve therapeutic outcomes. This demonstrates the potential of AI in disease risk prediction, diagnosis, and treatment (Kim & Hong, 2024). The use of AI in biotechnology extends to identifying pharmacological targets, image screening, and predictive modeling of pathological states, underscoring its broad applicability in scientific research (Ang, Tiing Leong et al., 2023).

Despite these advances, the use of AI in scientific writing raises concerns about data gaps, factual inaccuracies, and potential biases, necessitating human verification to maintain research integrity (Ang, Tiing Leong, 2023).

Overall, the integration of AI technologies into scientific research and education, exemplified by tools like SciSpace, Consensus, Claude, and Gemini, highlights a paradigm shift toward collaborative intelligence, where AI and human expertise combine to achieve greater scientific rigor and innovation.

Material and methods

This is a mixed, descriptive research study, developed in three phases. The first phase involved defining and identifying an assessment battery for evaluating investigative competencies. In the second phase, AI tools applicable to research processes were assessed. In the final phase, the training cycle was developed through an active learning plan for teaching research with AI integration (Figure 1).

The study was designed and implemented with a master's-level postgraduate course (20 students) in a virtual format to analyze the relevance of the training cycle using the active learning plan in research teaching with AI integration, test the assessment battery, and evaluate its functionality.

The results helped students become familiar with AI usage. The goal was for students to develop research projects integrating AI technologies, using these as tools to address research problems and construct a proposal.

To implement the active learning plan in teaching programming languages with AI integration, a set of activities is proposed, as shown in Figure 1.

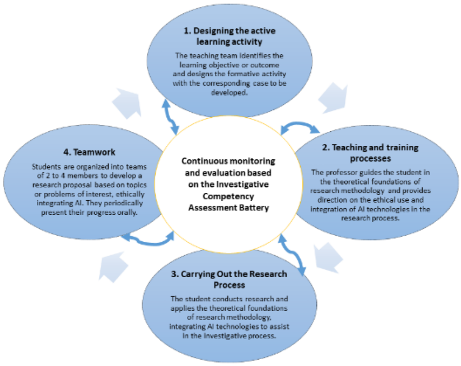

Figure 1. Training cycle through active learning plan Integrating AI for research teaching.
Source: Own elaboration.

Assessment battery for research's skills and competencies

Research is a complex activity that requires multiple skills and competencies. A competency involves knowledge and the ability to apply it within a specific environment or context, which also implies attitudes.

In the research context, investigative skills refer to specific abilities required to perform particular tasks within the research process. These include selecting research techniques, using statistical software for data analysis, writing and presenting reports, as well as the ability to search for and analyze information, among others.

On the other hand, investigative competencies integrate skills, knowledge, attitudes, and values essential for effectively and ethically conducting a research process. These competencies are broader and encompass various aspects of research, such as study design, data collection and analysis, and the communication of results.

While investigative skills enable the execution of specific tasks, investigative competencies provide a general framework that guides the researcher through the entire research process. Both are fundamental for success in research.

According to the works of Ruiz-Bolívar (2014), Tapia et al. (2018), Shiroma-Tamashiro (2019), and Rubii et al. (2019), it is established that becoming a researcher requires the development of a series of essential competencies for professional practice. These competencies include:

- Planning research projects using various approaches and methods.
- Searching for, processing, and organizing relevant information using digital tools.
- Critically evaluating scientific literature in their field or area of expertise.
- Defining the research design, which involves designing and selecting instruments and applying data collection techniques.
- Analyzing data both qualitatively and quantitatively using digital technologies.
- Writing research reports following accepted editing standards at both national and international levels.
- Making decisions aimed at achieving established objectives.
- Working in teams, with oral and written communication skills, and demonstrating leadership.

Based on this analysis, the table 1 outlines the assessment battery for research's skills, organized into 5 dimensions and 22 items.

Table 1. Structure of the assessment battery for research's skills

Dimension	Skills and competencies	Items
Formulating the research problem (description, identification, and formulation)	Identifying research topics of interest that require scientific investigation	1
	Formulating the research problem	2
	Delimiting the research problem	3
	Formulating research objectives	4
	Critically evaluating the state of knowledge in the area (state of the art)	5

Building theoretical foundations for research (state of the art and theoretical framework)	Constructing the theoretical framework for the research	6
	Reviewing literature and other data-generating sources relevant to the research	7
Designing the methodology	Specifying the type of research	8
	Selecting the population and sample using probabilistic and non-probabilistic methods	10
	Determining instruments and techniques for data collection	11
	Developing instruments for data collection	12
	Incorporating information and communication technology resources	13
	Analyzing quantitative data	14
	Analyzing information using qualitative methods	15
	Applying mixed research methods	16
	Interpreting the main research findings	17
Constructing research results	Writing academic or scientific reports	19
	Applying editing and bibliographic standards	20
	Drafting conclusions and discussing the results	21
	Formulating recommendations for future research	22
Coherence between components and verification of scientific rigor	Relating the components of the research	9
	Considering coherence between components and scientific rigor criteria	18

To identify and evaluate artificial intelligence (AI) technologies applicable to research, it is crucial to conduct a critical evaluation, as some AI technologies lack transparency, raising concerns about their reliability in academic research, as highlighted by Danler et al. (2024). Drawing on the research of Ojha & Bhaskar (2024), which conducted a comparative analysis of AI technologies based on parameters and criteria such as machine learning algorithms and natural language processing (NLP) models, further insights were gathered.

Additionally, the work of Hind et al. (2024) and Mojadeddi & Rosenberg (2024) on the impact of AI technologies in research was analyzed. Discussions with researchers about their preferred AI technologies for supporting research led the authors to identify and select three AI technologies to support the training and development of investigative competencies. Table 2 describes the selected AI technologies and the reasons for their selection.

Table 2. AI technologies selected for integration into research training

Technology	Identified Capabilities	Technological Criteria
SciSpace	AI suite with multiple services: online or user-provided literature review, document interaction, AI-assisted writing, data extraction, synthesis generator, AI detector, data extraction from PDFs or videos.	NLP based on Open AI Model Copilot.
	Its potential for research lies in its ability to analyze and synthesize literature.	
	Citation generator: creates bibliographic references in various formats, generated from SciSpace or manually added.	
	Literature Review: Provides insights into searches with follow-ups for deeper investigation on the topic of interest.	
	Offers predefined and personalized filters. Multilingual support.	

Concensus	Powerful for searching results and articles. Interface includes filters for personalized searches based on user preferences.	NLP powered by OpenAI GPT-4.
	The interface includes filters to make the search more personalized, depending on what you want to find.	GPT-4- powered scientific summaries
	Classification of relevant findings in articles.	
Claude IA	AI language model that assists with brainstorming, code writing, text, and research work.	Claude 3.5 Sonnet
	Ranked as the No. 1 AI for research assistant skills due to its strong ability to synthesize large volumes of textual or other types of data. It offers precision and fluency in language.	NLP by Anthropic
	It provides accurate responses and generates well-structured content from previously constructed data or documents.	SOC II Type 2 certified.
	Multimodal input capabilities with text output.	
	It allows users to upload images (such as tables, charts, and photos) along with text prompts for richer context and more complex use cases.	
Gemini	Gemini is not limited to text, unlike ChatGPT. It can work with images, audio, and other sources of information, making it more comprehensive.	DeepMind Architecture
	It has greater analytical capacity in complex contexts, allowing for more contextualized and analytical responses, which can be useful for report writing and research assistance.	PLN Google Gemini
	Gemini provides real-time responses. Being connected to the Google ecosystem, it offers access to real-time updated information.	
	It provides access to sources via links, allowing for verification of information origins and offering greater transparency.	

Results

The AI tools identified as having the highest applicability for research were SciSpace, for scientific data management and collaboration; Consensus, for group decision-making; and Claude, for assistance in data analysis, scientific article writing, and qualitative data analysis. A pilot program was conducted, which resulted in improved investigative competencies.

Data analysis from the application of the investigative competency assessment scale included the analysis of items, descriptive statistical data for each item, reliability estimation, validity estimation, and descriptive statistical data of the total scale distribution.

The selection of the 22 items included in the scale was based on the item-total correlation procedure, as shown in Table 2. Additionally, descriptive statistical data and internal consistency reliability of the scale can be analyzed in case a particular item is removed. The criterion for selecting and including an item in a rating scale is $rtt \geq .50$; the item-total correlation ranges from .653 to .876, as shown in table 3.

Table 3. Statistical indicator analysis by item

Items	Media	Standard Deviation	Correlation Method
1	3.73	.998	.733
2	3.74	.990	.826
3	3.79	1.006	.841
4	3.88	1.010	.786
5	3.69	1.000	.820
6	3.79	.999	.842
7	3.61	1.078	.849
8	3.72	1.065	.837
9	3.83	1.018	.852

10	3.97	.985	.829
11	3.83	1.017	.875
12	3.64	1.033	.793
13	3.73	1.049	.653
14	3.39	1.127	.666
15	3.60	1.042	.738
16	3.30	1.018	.703
17	3.79	1.026	.876
18	3.80	1.052	.820
19	4.03	.981	.768
20	3.88	1.032	.723
21	3.30	1.018	.826
22	3.79	1.026	.818

It is concluded that the integration of AI into research training has great potential to transform the way research is conducted. The estimation of the internal consistency reliability level of the applied scale was carried out using three different methods for comparison and verification purposes. These methods were Cronbach's Alpha, Hoyt's method, and Rulon's split-half method (See Table 4).

In the case of estimating the scale's reliability, results ranged between rtt = 0.966 and rtt = 0.952, indicating that the applied scale comfortably meets the reliability level required by psychometric models for this type of instrument. (See Table 4).

Furthermore, the corresponding standard errors of measurement (SEM) were calculated to verify that the error variance implicit in the scale's measurement is less than the true variance, as expressed in the reliability coefficient (Nunnally & Bernstein, 1994).

Table 4. Estimation of the internal consistency reliability of the scale

Reliability Method	Reliability Coefficient	Standard Error of Measurement
Cronbach's Alpha method	0,966	3,44
Hoyt's method	0,958	3,84
Rulon's split-half method	0,952	4,01

Finally, the analysis of the performance of the sample to which the investigative competency assessment battery was applied as a pilot is presented. Descriptive statistics were used to characterize the distribution of total scores, which reflected the level of investigative competency of the study subjects. Statistics related to the shape of the total score distribution were also examined; it was found that the distribution has a slightly negative asymmetry (skewness = -.606). This is further confirmed by comparing the values of the mean, mode, and median, which were 83.27, 90.17, and 90.17, respectively.

It was also observed that the distribution is slightly leptokurtic compared to the normal curve (Kurtosis = .033), as shown in Table 5.

Table 4. Descriptive statistics of the scale application results in the sample.

Statistical Aspect	Value
Mean	83.27
Median	90.17
Mode	90.17
Standard Deviation	18.96
Variance	367.13

Range	91
Maximum Value	97,20
Minimum Value	24
Standard Error of the Mean	1.099

Conclusions and discussions

AI transforms research processes by enhancing efficiency and precision in data collection and analysis. According to Jordan and Mitchell (2015), machine learning techniques and data analysis can revolutionize scientific research, enabling faster and more robust discoveries.

It is important to consider that integrating AI into research training must be accompanied by reflection on the ethical and social impacts of these technologies. The implementation of AI in research is not without ethical and social challenges. Bostrom and Yudkowsky (2014) emphasize the need to consider the ethical implications of AI use, particularly regarding privacy, fairness, and its impact on employment.

The procedure used to estimate the internal consistency reliability of a rating scale was Cronbach's Alpha method (1951), which was utilized in this study. As indicated in the results, the reliability coefficient obtained with this method comfortably meets the requirements demanded by psychometric theory. For comparison and verification purposes, Hoyt's reliability method (1941) and Rulon's split-half method (1939) were also applied, and their results were similar.

Research training must prepare students to adapt to a constantly changing world, where technology plays a key role. AI tools such as Consensus facilitate group decision-making and collaboration in research. According to Wooldridge (2020), AI can mediate collaboration among researchers, optimizing communication and coordination among teams.

Moreover, AI can strengthen investigative competencies by facilitating the analysis of large datasets and identifying patterns and trends (Shneiderman, 2020). AI tools can also automate repetitive tasks, allowing researchers to focus on more critical and creative activities, as is the case with SciSpace.

In the future, it would be valuable to conduct studies with other populations, applying and validating both the methodology and the investigative competency assessment battery. It could also be applied in different educational contexts, at various levels, such as undergraduate and graduate programs, as well as across different disciplines. Additionally, it would be interesting to evaluate the relationships between investigative competencies and academic performance or research productivity of students. Furthermore, the tool could be used to assess the effectiveness of pedagogical practices aimed at improving investigative competencies.

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