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A Systematic Mapping of Variables Studied in Research Related to Education in Informatics And Computing

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Abstract : Previous theoretical studies (reviews and systematic mappings) have only focused on certain variables of the education of Informatics and Computing such as game-based learning, project-based learning, and problem-based learning. Therefore, the objective of this article was to carry out a systematic mapping (2010-2019) to determine which variables are studied in research related to the education of informatics and computing. We performed a systematic mapping to IEEE Xplore (2010-2019). The protocol corresponds to the PRISMA guidelines for systematic reviews and its contextualization to the performance of systematic mappings. When applying the protocol, 160 articles were finally selected of which 154 are indexed in Scopus (96.25%) and 132 indexed in Scopus and WoS (82.5%). The results highlight that the most studied variables are teaching programming, teaching software engineering, teamwork, collaborative learning, educational technology, assessment, project-based learning, problem-based learning, and game-based learning. There is evidence of a cause-effect relationship (multiple correlations) between the dependent variables: teaching of software engineering and teaching of programming with the independent variables: didactic models based on m-learning, e-learning, and b-learning, project-based learning, problem-based learning, artificial intelligence, and educational technology. It concludes by identifying the principal's studies (higher scientific productivity) and the most studied variables in the didactics of Informatics and Computing.

Keywords : systematic mapping; Informatics; computer education; engineering education; software engineering teaching; programming teaching.

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1. Introduction

Engineering education with an emphasis on Informatics and Computing is the subject of growing publications at the international level. The importance of integrating teamwork, collaborative learning, educational technology use, project-based learning, and gamification to promote the teaching of software engineering and programming, in a general sense, are recurrent in the scientific literature [1]. Determining the variables most used in engineering education allows directing the pedagogical bases for curricular transformation in careers related to these areas of knowledge.

Engineering education began to consolidate in the mid-20th century. Various institutes and associations

(American Society for Engineering Education, European Society for Engineering Education, and the International Technology and Engineering Educators Association) joined forces to design their models and recommendations for engineering education.

In this sense, new teaching and learning methodologies were systematized according to the type of engineering, for example, Electrical engineering, Industrial engineering, Computer Engineering, Computer Science, Information Systems, among others. A fundamental theme in engineering education is the design and use of educational technology to train engineers from and towards new technologies. Engineering education is constantly evolving due to its link with the development of new technologies, procedures, and methodologies of each engineering [2], [3].

Engineering education establishes essential variables for the training engineer, for example, interdisciplinarity, problem-based learning, project-based learning, and teamwork [4], [5]. The particular characteristics of computer engineering teaching are: computational and engineering thinking (1), role-based teaching of software engineering (2), engineering modeling teaching (3), hands-on data fluency and management courses (4), and human-agent/machine/robot/computer interaction experiences (5) [6].

Engineering education with specific on Informatics and Computing is not a new topic. In the last decade, a new paradigm has been developed, focused on teamwork, competency-based learning, and preparation to adapting to various technological, social, and cultural environments [4], [5], [7]. However, in the teaching of Computer and Informatics, there is not a didactic strong established as in another engineering, although there are theoretical and empirical studies but are still insufficient. Despite the decades dedicated to engineering education study with an emphasis on Informatics and Computing, there are still shortcomings in the main variables that intervene in the effectiveness of its teaching [8]. In this sense, current trends propose the design of a software Table 1

In these studies, various variables related to the teaching of Computing and Informatics are studied, highlighting active learning, game-based learning, collaborative learning, flipped classroom, b-learning, creativity, problem-based learning, project-based learning, cloud computing, industry-based instructional design, e-learning, and m-learning [8], [9].

In December 2020, the Association for Computing Machinery [3] published an update of the paradigms for computer science education highlighting the evolution from knowledge-based learning to competency-based learning and the need to unify efforts in the transformation of the teaching of this engineering. This implies the need to explore which variables have been most studied in the last decade.

In the literature (Appendix A), 26 variables are studied for engineering education with an emphasis on Informatics and Computing. The authors designed various methodologies to train engineers who can meet the demands of the computer and software industry. However, even when there is a diversity of articles, it is interesting and contradictory that most were designed in case studies, which shows the need for experimental study.

The analysis of the literature (Table 1 and Table 2) in Scopus and Web of Science (WoS) reaffirms systematics and mappings reviews lack to study the variables for engineering education with an emphasis on Informatics and Computing. The above also motivated the realization of this mapping.

Related study

Several reviews and systematic mappings indexed in Scopus or WoS (Table 1 and 2) analyze some variables present in engineering education, although they do not group or classify them.

In the analysis of Table 1 and 2, only three mappings were carried out in Informatics and Computing, specifically software engineering, fundamentally analyzing the game-based learning variable. In turn, only four systematic reviews are related to this area of knowledge, which only analyze the variables of computational thinking, problem-based learning, and game-based learning. The reviews and systematic mappings analyzed to give an overview of some variables studied in engineering education with an emphasis on Informatics and Computing, however, there is a lack of study that includes analysis of other variables such as collaborative learning, flipped classroom, b-learning, creativity, industry-based instructional design, didactics in laboratories, teaching programming, curricular study, artificial intelligence, motivation, academic plagiarism, social networks, peer reviews, learning management system, Bloom's taxonomy, and educational technology [3]. Therefore, it is necessary to identify the most studied variables in Informatics and Computing teaching.

Therefore, the objective of this study is to carry out a systematic mapping (2010-2019) to determine the most studied variables in the teaching of informatics and computing. The added value of this mapping consists of grouping and classifying the main variables studied in studies in engineering education with an emphasis on Informatics and Computing.

2. Materials And Methods

To achieve the objective, a systematic mapping was carried out applying the PRISMA protocol. The following are described: the designed phases (1), the review protocol (2), the research questions (3), the description of the analyzed database (4), the inclusion, exclusion, and classification criteria (5), and validity control (6).

A. Phases of systematic mapping

This section describes the procedure involved in conducting the scientific literature review.

Phase I: Objective. Extract the academic information related to the variables that have been considered from engineering education with an emphasis on Informatics and Computing during the period 2010-2019. Research questions, objectives, keywords, inclusion and exclusion criteria, and the data extraction process are formulated.

Phase II: Objective: analyze, classify, and group the variables present in engineering education with an emphasis on Informatics and Computing. The general tasks are: identify relevant study, evaluate the quality of the articles, determine the relevant study, evaluate the quality of the articles, determine the main variables of each study, and perform statistical analysis Phase III: Objective. Reveal from theoretical and empirical study (mainly quasi-experiments and case studies) the relationships between the variables studied in engineering education with an emphasis on Informatics and Computing.

Phase IV: The objectives are:

Present and analyse the results obtained (systematic mapping) in the research groups: Development and Innovation in Educational Processes and Distance Education

Table 1 : Systematic Mapping

Articles	VARIABLES	Period	Type of Engineering
[10]	Active learning; game-based learning; teamwork; assessment and problem-based learning	2000-2012	General
[11]	Game-based learning; project-based learning and teamwork	It does not declare a period. Search in certain databases (ACM Digital Library, IEEE Xplore, Scopus, SpringerLink, Science Direct, and Wiley International)	General
[12]	Game-based learning	2012-2017	Software Engineering
[13]	Game-based learning	1974-2016	Software Engineering
[14]	Cloud computing	2012-2016	General
[8]	Game-based learning, project-based learning, and problem-based learning	2013-2018	Software Engineering
[4]	Active learning; game-based learning; teamwork; assessment and problem-based learning	2000-2012	General

Table 2 : Systematic Reviews

Study	VARIABLES	Period	Type of Engineering
[15]	Flipped learning	2000-2015	General
[16]	Game-based learning	1995-2015	Software Engineering
[7]	Sustainability	It does not declare a period. Search in Scopus	General
[9]	Computational thinking	2010-2018	Computer's science
[17]	software visualization	2011-2017	Computer's science
[18]	Problem-based learning	2000-2019	Informatics and Computing
[5]	Interdisciplinarit y	2005-2016	General
[19]	Argumentation	It does not declare a period. Explore in database (EBSCO, ERIC, Scopus, Engineering Village; Digital Dissertations)	General
[20]	Role of single-board computers	2010-2020	Informatics and Computing
[21]	Soft skills from the perspectives of European universities.	2010-2020	General

Drafting of the scientific articles.

A. Review protocol

The protocol corresponds to the PRISMA guidelines for systematic reviews [22]; [23] and its contextualization to the performance of systematic mappings [14], [24].

The method starts with three research questions, then the search process is determined; the selection criteria; the data extraction protocol, and the documentation review. To reduce bias, the study was developed by three researchers. The implementation of the protocol was carried out between November 2019 to March 2020.

B. Research questions

To determine them, scientific workshops were held with experts using the brainstorming technique. The following research questions were defined:

Question 1: What are the variables that have been studied in the papers (2010 to 2019) related to engineering education with an emphasis on Informatics and Computing? How is the relationship between the independent and dependent variables?

Question 2: What type of studies and its classification (experimental and non-experimental) predominate in the papers found?

Question 3: Which universities and research centers have the highest impact index?

Question 4: What is the scientific productivity of the countries from the first authors of each research?

C. Data source

Scientific information search techniques were used in the IEEE Xplore Database, in which journals, conference proceedings, and standards related to informatics, computing, electrical and electronic engineering, and related fields are indexed. The journals present in this database (IEEE Xplore) are in turn indexed in Scopus or WoS. In the specialized search, a strategy was applied that included the combinations of the logical operators AND and OR.

The keywords were computer science education, computer teaching, higher education, engineering education, university teaching, methodologies, methods, experimental studies, didactic experiences, case studies, academic-industry relationship, training, teaching, educational experiments, educational resources, educational research, educational indicators, open educational resources, technology education, the computer uses in education, education informatics and educative technology. It is important to note that all search strings included these keywords and their relationship to computer-related engineering (Computer Engineering, Computer Science, Cybersecurity, Information Systems, Information Technology, Software Engineering, Informatics Engineering, among others).

D. Inclusion-exclusion criteria and classification

Inclusion criteria

- The results obtained (articles in journals and conferences proceedings) must correspond to
- The 26 taxonomies declared above.
- Experiential papers in engineering education, with an emphasis on Computer Science and Computing.
- Peer-reviewed English-language articles.
- Studies published from January 2010 to December 2019.
- Exclusion criteria
- Level of a description.
- Relationship with the object of study.

Classification (theoretical foundation)

Keywording technique was used [24], allowing the analysis of the abstract and keywords. This process included the identification of social constructivism as a pedagogical foundation to analyze the papers and determine their variables and relationships.

Quality criteria

To ensure the quality of the selected papers, criteria were developed and each article was scored, with the 160 selected being the ones with the highest score.

Among the most used criteria are the following: Are the solutions based on experiment or case study? Is the study properly designed to achieve the objectives? Is the foundation of the problem stated and is there coherence between the elements that make up the study?

E. Threats of validity

Internal validity. Each evidence found was discussed under a procedure or scheme that involved: keywords, description of the proposal, type of study, and the strategy used.

External validity. Those articles that did not argue or were not sufficiently explicit in the validation of their results were discarded. Two investigators performed the inclusion, exclusion, and comparison analysis. The third author, from his expertise in the sociology of education, contributed to the interdisciplinary analysis.

Conclusion validity. A form was developed to extract the relevant data and information and it was classified using the Keywording technique [24].

Construct validity and bias in the selection of studies. A review protocol addressed above was designed, which involved the three authors and the exchange with experts.

3. Results

In the application of the protocol [14], [24] 2755 results were first obtained and finally, it was reduced to 160 articles (see Fig. 1). To access the 160 selected studies, please consult https://bit.ly/3mGaENW Studies that designed experiments or case studies were prioritized. The general process of the study according to the four defined phases is illustrated in Fig. 1.

A. Output data resulting from Phase 1

The 160 articles «Phase II» (see Fig. 2) were grouped according to their origin (Journals or Conference proceedings). Of the 160 studies selected from the IEEE Xplore (see Fig. 3 and Fig. 4), 154 are indexed in Scopus, representing 96.25%.

In turn, 132 of the papers were published by the journals: IEEE Transactions on Learning

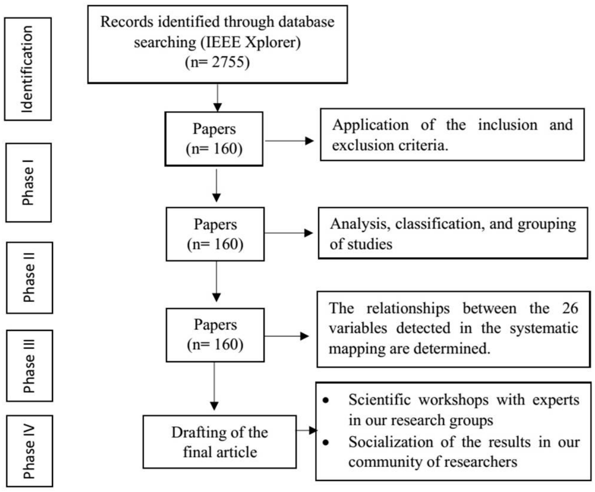

Fig. 1: Research flow and protocol synthesis to perform systematic mapping

Technologies and IEEE Transactions on Education, both indexed in Scopus and WoS, representing 82.5%.

Variables studied (2010 to 2019) in engineering education with an emphasis on Informatics and Computing (Question 1)

The 160 papers were classified and grouped according to their variables and the country of origin of the first author. The paper's code is shown in Appendix A. Next, the analyzed articles are listed using the following taxonomic structure «main variable dependent on each study» - «country of the first author» - «Article » (coding, see Appendix A.).

The variables are:

- Active Learning: United States (I-1, I-2, I-3, I-4, I-157); Spain (I-5, I-6) and New Zealand (I-13).

- Game Based Learning: United States (I-8); Brazil (I-9. I-10, I-11); Peru (I-12); Spain (I-13); Austria (I-14); Taiwan (I-15); Spain (I-16).

- Collaborative learning: Spain (I-13, I-17, I-18); Taiwan (I-9, I-15); Greece (I-20, I-159); Australia (I-22, I-23); China (I-24, I-150, I-151).

- Flipped classroom: United States (I-25, I-26); South Korea (I-28, I-29); The United Kingdom (I-30).

- B-learning: Spain (I-31, I-32, I-33); United States (I-34, I-35); Chile (I-36); Australia (I-37).

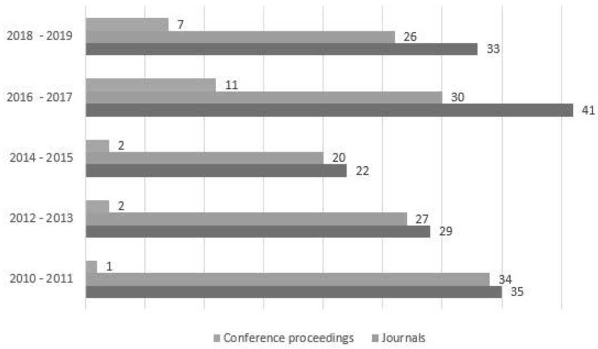

Fig. 2: Evidence analyzed in the decade of 2010 – 2019 (n=160)

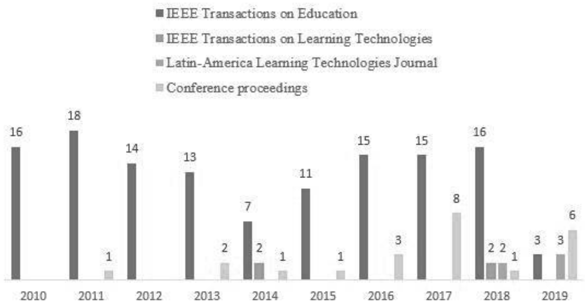

Fig. 3: Relationship between journals and scientific conferences (n = 160)

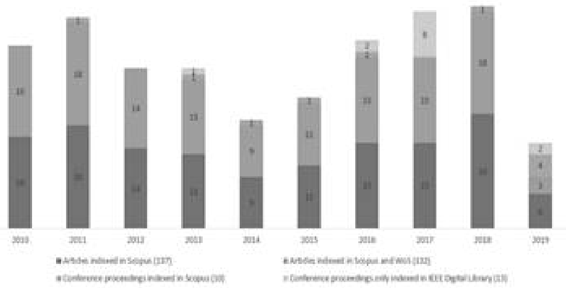

Fig. 4: Indexing of the 160 articles

- Problem-based learning: United States (I-1 I-3, I-4, I-34, I-39); Australia (I40, I-141), Spain (I-5, I-6, I-42); Croatia (I-43); Hungary (I-44); South Korea (I-45); Mexico (I-46); Brazil (I-47).

- Project-based learning: Spain (I-5, I-6, I-48, I-49, I-50); United States (I-13, I-51, I-52, I-53, I-54); China (I-55); Australia (I-41, I-56); South Africa (I-57); Ireland (I-58); Brazil (I-59, I-60, I-148, I-154, I-158); Hungary (I-44); Taiwan (I-61, I-62); Argentina (I-63); Israel (I-64); India (I-38).

- Creativity: United States (I-39; I-65); China (I-21).

- Cloud computing: Spain (I-66); Italy (I-75); Australia (I-22).

- Instructional Design Based on Industry: United States (I-67); Taiwan (I-68, I-69); Slovenia (I-70); Brazil (I-71); Sweden (I-72).

- E-learning: Spain (I-41, I-49, I-63, I-73, I-74); Italy (I-75); United States (I-76); the United Kingdom (I-77); South Africa (I-57); Australia (I-37, I-155); Republic of India (I-78).

- M-learning: South Korea (I-28); China (I-79); Spain (I13).

- Teaching in laboratories: United States (I-80, I-81, I-82); Spain (I-83, I84); Taiwan (I-85, I-86); Australia (I-56, I-87); Turkey (I-88); Iran (I-35); Belgium (I-89); Portugal (I-90).

- Teaching Software Engineering: Taiwan (I-61, I-86, I-91); Spain (I-17, I-74, I-92); United States (I-8, I-26, I-34); Brazil (I-9, I-107); Canada (I-94); Serbia (I-95); Slovenia (I-70); Austria (I-96); Finland (I-97).

- Teaching programming: Spain (I-5, I-6, I-66, I-92, I-98); Mexico (I-46, I-99, I-100, I-101, I-156); Taiwan (I-86, I-102, I-103); Germany (I-104, I-105); United States (I-106); Ireland (I-107); Greece (I-108); Australia (I-141); Argentina (I-63); Croatia (I-43); United Kingdom (I-77); South Korea (I-45); Portugal (I-109, I-149); Colombia (I-110); Romania (I-111); Turkey (I-112); Canada (I-113); China (I-27).

- Curricular study: Spain (I-50, I-114); United States (I-106, I-115); Australia (I-40); New Zealand (I-116); Germany (I-117); Croatia (I-118).

- Assessment: Spain (I-50, I-66, I-119, I-120, I-121); Sweden (I-122); Canada (I-152); Brazil (I-47); Jordan (I-123); United States (I-124).

- Artificial intelligence: United States (I-125, I-126); India (I-78); China (I-127); Serbia (I-128); Spain (I-13, I-98, I-129); South Korea (I-45); Austria (I-130); Italy (I-75); Australia (I-131); Germany (I-132).

- Motivation: Spain (I-129, I-133, I-134); United

States (I-25, I-132, I-135, I-136); Taiwan (I-137); Estonia (I-138); Australia (I-139); South Africa (I-140).

- Academic plagiarism: Slovakia (I-141); New Zealand (I-142).
- Social networks: United States (I-115); Spain (I-133).
- Peer reviews: Taiwan (I-91); Canada (I-94).
- Learning management system: Spain (I-33, I-49, I-119, I-143); United States (I-115); Taiwan (I-19).
- Bloom's Taxonomy: South Africa (I-106, I-144); Brazil (I-47).
- Educational Technology: United States (I-3, I-115, I-126, I-145, I-147, I-160); Spain (I-5, I-6, I-146); China (I-24, I-127); Taiwan (I-103); Ireland (I-58).
- Teamwork: United States (I-53); Taiwan (105, I-68); United Kingdom (I-30, I-61); Canada (I-94); Ireland (I-107); Serbia (I-95); Slovenia (I-70); Spain (I-42); Hungary (I-44); Chile (I-36); New Zealand (I-116); Germany (I-104, I-153)

B. Type of predominant studies (Question 2)

It is observed that the evidence tends to empirical support based on case studies. The foregoing strengthens the importance of these types of studies.

The classification used is based on the theoretical and methodological conceptions. This is expressed by the following results:

- Quasi-experiments (N = 35). Longitudinal, of type repeated measures designs (n1 = 25) and Transversal, of type designs of discontinuity in regression (n2 = 10).
- Case study (N= 125).
  - Single case study. Type 1 (n1= 73)
  - Single case study. Type 3 (n2= 17)
  - Multiple case studies. Type 2 (n3= 23)
  - Multiple case studies. Type 4 (n4= 12)

C. Scientific impact and productivity index of the countries (Question 3 and 4)

To answer this question (Question 3), it was decided to analyze the universities that had at least two articles (Table 3). For this, only the origin of the first author was considered. The universities of Spain and the United States are the ones with the highest number of articles, exceeding 200 citations in Scopus (Table 4). The level of impact of these articles and the scientific productivity of the countries (origin of the first author) is illustrated in https://doi.org/10.6084/m9.figshare.19116134.v1 .Regarding the productivity index, the United States, Spain, Taiwan, Brazil, and Australia stand out by their results, coinciding with the universities that have at least two articles.

The countries that have the greatest influence on the publication of articles associated with the 26 variables are Spain (14.37%), United States (12.5%), Australia (8.12%), Taiwan (8.12%); Brazil (5.62%) China (4.37%) and South Korea (3.75%). The most studied variables are «descending order»: project-based learning; problem-based learning; teaching programming; teaching software engineering; didactics in laboratories; teamwork; collaborative learning, and game-based learning. However, when analyzing the articles (I-30, I-16, I-17, I-34, I-129, I-135, code according to Appendix A) with more than 30 citations in Scopus, the variables that have been most referenced are teaching of software engineering; teaching programming; game-based learning; the motivation; collaborative learning, and artificial intelligence.

D. Relationships between the variables analyzed in engineering education with an emphasis on Informatics and Computing (Phase 2 of the systematic mapping)

To determine an approach to a relationship between the variables, a network was designed (https://doi.org/10.6084/m9.figshare.19116140.v1). For this, a square and identical matrix were made with the 26 variables responding to the type of flow that is evidenced between the links of the nodes. From each analyzed article, it was determined what are its variables and the cause-effect relationship established between them. When analyzing the network (see https://doi.org/10.6084/m9.figshare.19116140.v1), the variables with the greatest influence are programming teaching; teaching software engineering; problem-based learning; teamwork; project-based learning; flipped classroom; e-learning; assessment, and educational technology. From the analysis of the network obtained, the following stand out:

- The variables with the greatest relationships between them are problem-based teaching (12 variables); teaching programming (12 variables); teaching software engineering (11 variables); teamwork (11 variables); project-based learning (10 variables); educational technology (8 variables); assessment (8 variables), and flipped classroom (8 variables).

- The strong cause-effect relationship between the dependent variables: teaching of software engineering and teaching of programming with the independent variables: didactic models based on m-learning, b-learning, and e-learning; project-based learning; problem-based learning and educational technology. The above is a sample of current technological and pedagogical trends in engineering education, with an emphasis on Computer Science and Computing.

- In this sense, the empirical evidence associated with the fact that a teaching-learning process supported by face-to-face or b-learning modalities and designed based on project-based or problem-based learning contributes to creating spaces of interactivity and essential collaboration for this type of professional.

- Cause-effect relationships between the independent variables: activities and didactic models based on m-learning, b-learning, or e-learning, with the dependent variables: game-based learning; social networks, Bloom's taxonomy and, motivation.

- There is an increase in the use of b-learning and e-learning and a gradual and progressive introduction of mobile learning (m-learning) in engineering education, integrating them with game-based learning and social networks with an emphasis on Facebook and WhatsApp [25]. The importance of interaction and interactivity strategies mediated by digital educational resources designed by the teacher and the virtual spaces of sMOOC (Social Massive Open Online Course) and social networks is highlighted.

- Cause-effect relationships between the independent variable's artificial intelligence and educational technology and the dependent

Table 3 : Variables Studied in the Universities With the Highest Number of Publications (question 3)

Country	Main universities	Variables
United States	University of Michigan Seattle University University of Nebraska-Lincoln	Motivation; Problem Based Learning and Project-Based Learning
Spain	Universidad Carlos III de Madrid Universidad del País Vasco	Collaborative learning; e-learning; Educative technology; Motivation; Teaching software engineering
Brazil	Universidad Federal de Pernambuco	Industry-based instructional design, assessment, and programming teaching
Taiwan	National Taiwan Normal University	Teamwork and teaching programming
Australia	University of Newcastle University of Wollongong	Didactics in laboratories and collaborative learning
United States	University of Michigan Seattle University University of Nebraska-Lincoln	Motivation; Problem Based Learning and Project-Based Learning
Spain	Universidad Carlos III de Madrid Universidad del País Vasco	Collaborative learning; e-learning; Educative technology; Motivation; Teaching software engineering
Brazil	Universidad Federal de Pernambuco	Industry-based instructional design, assessment, and programming teaching
Taiwan	National Taiwan Normal University	Teamwork and teaching programming
Australia	University of Newcastle University of Wollongong	Didactics in laboratories and collaborative learning
United States	University of Michigan Seattle University University of Nebraska-Lincoln	Motivation; Problem Based Learning and Project-Based Learning
Spain	Universidad Carlos III de Madrid Universidad del País Vasco	Collaborative learning; e-learning; Educative technology; Motivation; Teaching software engineering
Brazil	Universidad Federal de Pernambuco	Industry-based instructional design, assessment, and programming teaching

Table 4 : Impact of Papers From Countries With the Highest Number of Authors (question 4)

Country	Number of papers	Cite score in Scopus	Productivity index (I *)
United States	7	562	80,28
Spain	10	293	29,3
Brazil	3	27	9
Taiwan	4	26	6,5
Australia	2	64	32

variables: problem-based learning; project-based learning; teaching software engineering; teaching programming, and assessment.

As for the artificial intelligence variable, the Intelligent Tutor Systems, ontologies, and learning analytics [26] are used fundamentally and, in the educational technology variable, learning objects, laboratories, and virtual simulators.

4. Discussions

The main results obtained are as follows

- Question 1. The most studied variables (2010 to 2019) in engineering education with an emphasis on Computer Science and Computing are active Learning, Game-Based Learning, Collaborative learning, Flipped classroom, B-learning, Problem-based learning, Project-based learning, Creativity, Cloud computing, Instructional Design Based on Industry, E-learning, M-learning, Teaching in laboratories, Teaching Software Engineering, Teaching programming, Curricular study, Assessment, Artificial intelligence, Motivation, Academic plagiarism, Social networks, Peer reviews, Learning management system, Bloom's Taxonomy, Educational Technology, and Teamwork.

- Question 2. The types of study most reported in the analyzed literature are Case studies (N = 125) and Quasi-experiments (N = 35).

- The methodology for scientific investigate is transversal to all science, supported by quantitative, qualitative, or mixed approaches. However, each science has its peculiarities according to its object of study, laws, and principles. In Educational Sciences are particular methods, instruments, and procedures studying, analyze, and interpret the phenomena inherent to education, didactics, and pedagogy. The mapping reveals deficiencies in the types of educational study carried out in the teaching of Informatics and Computing since they are focused on general study designs. Its causes can be diverse: cognitive, ontological, methodological in scope, or others. Among the particular methods, instruments, or procedures that are used in Education Sciences and that should be promoted in the teaching of Informatics and Computer are:

  Research-oriented to understanding and to change through the design of qualitative study, highlighting narrative and biographical study. The use of strategies as participant observation, in-depth interviews, discussion groups, analysis of documents, and life stories.

  The use of socio-critical studies and action research in education through the self-reflective spiral: planning, action, observation, and reflection. The use of projective and sociometric techniques and discussion groups.

  The development of communicative study focused on change and social transformation. An example is a creation of learning communities.

- Question 3. The universities and investigate centers with the highest impact index are: University of Michigan, Seattle University, University of Nebraska-Lincoln, Universidad Carlos III de Madrid, Universidad del País Vasco, Universidad Federal de Pernambuco, National Taiwan Normal University, University of Newcastle, and the University of Wollongong.

- Question 4. The countries with the highest scientific productivity according to the first authors of each article are the United States, Spain, Brazil, Taiwan, and Australia.

As a result of this systematic mapping, the repeated problems of the teaching of Informatics and Computing are reaffirmed. In a general sense, they are related to curriculum design, business demands, and the relationship between academia and the business context. Therefore, teaching is carried out fundamentally from industry-based instructional design; project-based learning; problem-based learning; collaborative learning; teamwork, and the learning management systems.

There is a coincidence in the need to design a teaching-learning process that provides the student with the conditions to achieve the ability to work in multidisciplinary teams, with creativity, and critical thinking.

In systematic mapping, the artificial intelligence techniques mostly used in the teaching of Computer and Informatics are identified. In this sense, an increase in the use of Intelligent Tutor Systems is shown. The trend relates the use of these systems to the selection of learning strategies; the individual orientation of the student; meaningful learning; motivation; measuring self-regulated learning and collaborative learning [3].

It is recurrent that the main methods and techniques to include in an Intelligent Tutor System are: learning analytics and text mining [27], [28]. Research in artificial intelligence declares the relationship between this variable and the teaching of programming. In this sense, the use of the following techniques stands out: click flow for the collection and analysis of the interaction data of the students in the use of Scratch; learning analytics using App Inventor; data mining through automatic evaluation of learning tasks, and the use of classification techniques [29], [30], [31].

A recurring theme in the literature is the integration between problem- and project-based learning, cloud computing, collaborative learning, and teamwork [18], [32]. The design of learning activities from the integration of these variables promotes: (1) the development of written and oral communication skills through technological tools, (2) peer evaluation [11], [33], (3) self-evaluation [34], (4) social skills [21], (5) entrepreneurial skills [35], (6) knowledge of the English language [36], and (7) leadership and management skills through IT project management tools [37].

Finally, two major areas focused on variables stand out in the literature: teaching software engineering and teaching programming.

Regarding the teaching of software engineering, there is a tendency to weigh a relationship between student learning and the variables: game-based learning; industry-based instructional design; motivation; problem-based learning; project-based learning; teamwork; collaborative learning; learning management systems, and the use of educational technology.

The use of educational technology is oriented CASE tools (Computer-Aided Software Engineering); the use of collaborative environments and the praxis of emerging pedagogies associated with m-learning; b-learning and u-learning, coinciding with international curricular projections [2], [3], [28]. However, it should be noted that in this scenario the variable peer reviews have not been widely used.

In teaching programming, it is reaffirmed that the main difficulties that students have are: algorithmic design; the conceptual model in programming; understanding the object-oriented paradigm; logic for abstraction, and ability of a programming language. The foregoing is consequent due to the insufficient manipulation of the variables: project-based learning; Problem-based learning; motivation; didactics in laboratories and active learning. According to the systematic mapping, the scarce design and use of the educational technology variable (especially didactic resources) also affect, since they fail to integrate different learning styles.

A transversal aspect present in the mapping is that the teaching programming and software engineering is to develop in future «computer» engineer's leadership skills, teamwork, communication, design, and the practice of reflective behavior. For this, the importance of the didactic design of learning activities and curricula that promote competency-based learning is declared in the analyzed literature [38].

In summary, the articles analyzed declare as a fundamental axis the design and use of educational technology developing the integration between (1) intelligent technologies (semantic web for online education; cloud computing, data intelligence, and artificial intelligence); (2) adaptive technologies (e-learning and adaptive systems); (3) disruptive technologies (remote virtual laboratories, simulators, and augmented reality); (4) emerging pedagogies (flipped classroom, b-learning, u-learning, and gamification strategies); and (5) open technologies (repositories, open educational resources, open science, open laboratories, and massive open online courses) [1], [39].

5. Limitations

Due to the nature of the study and its search, selection, and analysis process, our study has several limitations. First, it is the search performed only in the IEEE Xplore. Analyzing the literature present in databases such as the ACM Digital Library, Scopus, and WoS, make it possible to enrich the results of this systematic mapping.

Second, our study was limited to the period 2010-2019. However, during 2020-2021 various articles have published interesting results on engineering education with an emphasis on Informatics and Computing [18], [30], [31], [39], [40]. The continuous analysis of educational trends in careers with a computer profile is essential for the training of our engineers. This systematic mapping is an approach to this pedagogical analysis.

Third, the article does not perform a systematic review of each of the 26 variables. This does not limit our results since the fundamental objective is to determine which are the variables most used in engineering education with an emphasis on Informatics and Computing. Therefore, education needs to carry out systematic reviews and mapping of these variables, overcoming the weaknesses of previous research (Table 1 and 2) including this mapping.

5. Conclusions

The study carried out shows the 26 variables most used in engineering education, with an emphasis on Informatics and Computing. For this, the articles published in the IEEE Xplore during the decade from 2010 to 2019 was analyzed.

Answering Question 1, in the period 2010-2019 the most studied variables in engineering education, with emphasis on Informatics and Computing, are project-based learning; problem-based learning; teaching programming; teaching software engineering; didactics in laboratories; teamwork; collaborative learning, and game-based learning.

The most used design types (Question 2) are case studies (N = 125) of type 1 (n = 73) and, secondly, quasi-experiments (N = 35) of longitudinal type, repeated measures designs (n1 = 25).

The universities with the highest impact index (Question 3) are the University of Michigan; Seattle University; University of Nebraska-Lincoln; Universidad Carlos III de Madrid, and Universidad del País Vasco, and the countries with the highest scientific productivity are the United States and Spain (Table 3 and 4).

The analysis of the network flow of the 26 variables(taxonomies), the level of impact of the publications, and their scientific productivity allow us to affirm that the relations between

- teaching of software engineering and game-based learning, the industry-based instructional design, the motivation, the problem-based learning, the project-based learning, the teamwork, the collaborative learning, the learning management systems, and the use of educational technology; programming, and assessment

- teaching of programming and game-based learning, the didactics in laboratories, artificial intelligence, and collaborative learning; m–learning, b-learning, and e-learning with game-based learning, social networks, Bloom's taxonomy, and the motivation

- artificial intelligence and educational technology with problem-based learning; project-based learning; teaching software engineering; teaching programming, and the assessment.

Although it is not the study's aim, some relationships between independent and dependent variables present in engineering education with an emphasis on Computer Science and Computing are shown. Therefore, it is considered pertinent to deepen these relationships in a future study. There is a long way to go in this regard. The feedback of the curricular experiences about Informatics and Computing will suppose a commitment that will value the contribution of these sciences to society. In this regard, the results of this systematic mapping are highlighted.

Recommendations

The challenges present in the scientific literature are diverse. Engineering education with an emphasis on Informatics and Computing, reiterate the following: (1) use of free or proprietary (very expensive) tools and technologies in the classroom, typical of the software industry, for which new methodologies are necessary to the didactic use of these technologies; (2) adequate books, generally, the traditional teaching books for software engineering or programming are very long (more than 300 pages), therefore, the use of educational technology is promoted with the design of electronic and gamified books; and (3) the development of leadership and teamwork skills, to prepare the future engineer in IT project management issues.

Our study shows the main variables studies in engineering education with an emphasis on Informatics and Computing. Based on our academic and scientific experience, teamwork and the varied use of digital educational resources is essential to develop competency-based learning and meaningful learning.

In this sense, we agree with Association for Computing Machinery [3] when recommending the design of didactic models that develop competencies through the integration of knowledge, skills, and meaningful learning. Learning tasks and activities should promote engagement, responsibility, collaborative learning, and student-student, student-content, and student-teacher interactivity [41]. Tasks should promote levels of cognitive skills based on Bloom's taxonomy consistent with the characteristics and complexities of categories and areas of computing. There are different names in the degrees of Computer Science and Informatics (Computer Engineering, Computer Science, Cybersecurity, Information Systems, Information Technology, Software Engineering, Informatics Engineering, among others), all valid in coherence with the conception of each country. The important thing is to determine the general and specific competencies of the university professional. In harmony with this, it is recommended to design models and methodologies that develop these competencies [2], [3]. In Association for Computing Machinery [3] some competencies are recommended but they do not exhaust the possibilities of enriching and invigorating others, about the curricular needs of each program.

To develop the competencies and variables mentioned in this article, procedures typical of the educational study methodology must be used. It is recommended to use methods, techniques, and procedures of Education Sciences and Social Sciences. For example, action research, socio-critical study, the use of life stories -in the teaching-learning process, and the use the sociometric techniques and discussion groups. The use of specific methodologies for teaching Computer Science [42] is also recommended, such as the Multinational, Intercultural, Multidisciplinary & Intensive (MIMI). Finally, from a pedagogical perspective, the suggestions for future studies can be divided into three groups. First, design studies that incorporate methods of educational investigations to enrich the approaches. Second, to diversify the techniques for obtaining information, promoting for this purpose those that allow learning experiences, the socio-critical analysis of educational contexts, and the narratives of action research.

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Appendix - A

Studies analyzed	ITEMS/CODE
Petersen et al. (2018)	I-1
Shekhar & Borrego (2017)	I-2
Magana et al. (2018)	I-3
Tan & Shen (2018)	I-4
Clark & Dickerson (2018)	I-5
Esteban-Sanchez et al. (2014)	I-6
Arbelaitz et al. (2015)	I-7
Giacaman & De Ruvo (2018)	I-8
Hamman et al. (2017)	I-9
Goncalves et al. (2018)	I-10
Andrade et al. (2016)	I-11
Weilemann et al. (2016)	I-12
Lopez et al. (2019)	I-13
Ibanez et al. (2015)	I-14
Kulmer et al. (2016)	I-15
Bin-Shyan et al. (2013)	I-16
Ibanez et al. (2014)	I-17
Medina-Dominguez et al. (2010)	I-18
Cheng et al. (2016)	I-19
Jong et al. (2013)	I-20
Xu & Xu (2011).	I-21
Ceja & Cervantes (2013)	I-22
Sun & Shen (2014)	I-23
Ellis et al. (2019)	I-24
Tsai et al. (2011)	I-25
Zhang et al. (2016)	I-26
Li et al (2019)	I-27
Redondo (2019)	I-28
Kim et al. (2015)	I-29
Kim & Ahn (2018)	I-30
Souza et al (2018)	I-31
Alonso et al. (2011)	I-32
Ros, S et al. (2012)	I-34
Mason et al. (2013)	I-35
Ojaghi et al. (2012)	I-36
Cabrera et al. (2017)	I-37
Prasad & Reddy (2016)	I-38
McLurkin et al. (2013)	I-39
Peteranetz et al. (2017)	I-40
Merrick (2010).	I-41
Kellett (2012)	I-42
Rengel et al. (2012)	I-43
Boticki et al. (2013)	I-44
Katona & Kovari (2016)	I-45
Shim et al. (2017)	I-46
Ortiz et al. (2013)	I-47
dos Santos (2017)	I-48
Olarte et al. (2016)	I-49
Martin et al. (2017)	I-50
Calvo et al. (2018)	I-51
Mattmann et al. (2012)	I-52
Revelo et al. (2017)	I-53
Fowler & Su (2018)	I-54
Griffeth et al. (2016)	I55
Liu et al. (2014)	I-56
Nikolic et al. (2015)	I-57
Swart (2016)	I-58
Moyne et al. (2018)	I-59
Chaves et al. (2015)	I-60
Seman et al. (2018)	I-61
Chen et al. (2014)	I-62
Chen et al. (2013)	I-63
Todorovich et al. (2012)	I-64
Sabag & Doppelt (2012)	I-65
Zavadzki et al. (2020)	I-66
Vaquero (2011)	I-67
Guardiola et al. (2013)	I-68
Chang et al. (2011)	I-69
Lin et al. (2019)	I-70
Mahnic (2012)	I-71
LeBlanc et al. (2017)	I-72
Broman et al. (2012)	I-73
Llamas-Nistal et al. (2011)	I-74
Fernandez-Aleman et al. (2016)	I-75
Colace & De Santo (2010)	I-76
Kilicay-Ergin & Laplante (2013)	I-77
Cadenas et al. (2015)	I-78
Garg et al. (2018)	I-79

Wen & Zhang (2015)	I 80
Wolf (2010)	I-81
Braun (2010)	I-82
Xu et al. (2014)	I-83
Maseda et al. (2012)	I-84
Redel -Macias et al. (2015)	I-85
Shyr (2010)	I-86
Lee et al. (2010)	I-87
Goodwin et al. (2011)	I-88
Sahin et al. (2010)	I-89
Ionescu et al. (2013)	I-90
Marques et al. (2014)	I-91
Cheng & Lin (2010)	I-92
Simpson & Store (2017)	I-93
Swart et al. (2018)	I-94
Garousi (2010)	I-95
Devedžić & Milenković (2011)	I-96
Porras et al. (2017)	I-97
Portela et al. (2017)	I-98
A nfurrutia et al. (2018)	I-99
Silva -Maceda et al. (2016)	I-100
Rojas -Lopez & Garcia	I-101
Penalvo (2018)	I-109
Tangney et. al (2010)	I-108
Zacharis (2011)	-
Simanca -Herrera et. al (2019)	I-110
Uskov & Sekar (2014)	I-111
Tek et al. (2019)	I-112
Ba niassad et. al (2019)	I-113
Larraza -Mendiluze & Garay - Vitoria (2015)	I-114
Hazen et. al (2012)	I-115
Hoda et. al (2017)	I-116
Zendler et. al (2011)	I-117
Pazur et. al (2017)	I-118
Trenas et. al (2011)	I-119
Poza -Lujan et. al (2016)	I-120

Perez et. al (2017)	I-121
Lavesson (2010)	I-122
Albluwi (2018)	I-123
Parekh et. al (2018)	I-124
Foster (2012)	I-125
Krishnamoorthy et. al (2013)	I-126
Wang et. al (2011)	I-127
Delibasic et. al (2013)	I-128
Munoz et. al (2014)	I-129
LoPresti et. al (2010)	I-130
Lee et. al (2016)	I-131
Pinto et. al (2017)	I-132
Marzo et. al (2017)	I-133
Velazquez-Iturbide et. al (2017)	I-134
Foley et. al (2016)	I-135
Peteranetz et. al (2017)	I-136
Cheng et. al (2016)	I-137
Kori et. al (2016)	I-138
Shahnia et. al (2016)	I-139
Liebenberg et. al (2015)	I-140
Chuda et. al (2012)	I-141
Manoharan (2017)	I-142
Munoz-Organero et. al (2010)	I-143
Swart (2010)	I-144
Simoni (2011)	I-145
Mateo et. al (2013)	I-146
Finelli et. al (2015)	I-147
Medeiros et al. (2019)	I-148
Gómez et. al (2015)	I-149
Zhu et. al (2019)	I-150
Zhu (2019a)	I-151
Lavallee et. al (2014)	I-152
Demuth et. al (2017)	I-153
Portela et. al (2017)	I-154
Billingsley (2019)	I-155
Ceja & Cervantes (2013)	I-156
Peraire (2019)	I-157
Pinto et. al (2017)	I-158
Stylianakis et. al (2013)	I-159
Durant et. al (2015)	I-160