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ARTICLE

ACTIVE METHODOLOGIES IN HIGHER EDUCATION: A SYSTEMATIC MAPPING IN THE CONTEXT OF ENGINEERING COURSES

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ABSTRACT: Active learning is all pedagogical alternatives that place the focus of learning on the students. With the mediation of competent teachers, the students learn by discovery, by investigation, and by problems. Such methodologies commonly promote more content retention and comprehension once the students are engaged in activities, whether through research, group collaborations, discussion, and problem-solving. This work aimed to verify the temporal evolution of active learning methods in higher education Engineering courses, based on a systematic mapping of the literature. We observed which are the main researchers in this field, their geographic location, and which methodologies are preferred in the context of these courses. From the results, we observe a growth in scientific publications on active learning methodologies and Engineering Education, especially in the last five years of the period analysed (between 2015 and 2020). We also see research in this field on all continents, with a predominance of studies led by American and European researchers. In the mapped studies, the inverted classroom and problem-based learning were the most identified methodologies. It indicates a concern of teachers in this area to promote activities with high involvement, which allow the development of personal and professional skills and competencies, even during their training period.

Keywords: active learning; Engineering Education; Project-Based Learning; Problem-Based Learning; Flipped Classroom.

METODOLOGIAS ATIVAS NO ENSINO SUPERIOR: UM MAPEAMENTO SISTEMÁTICO NO CONTEXTO DOS CURSOS DE ENGENHARIA[1]

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RESUMO: As metodologias ativas podem ser entendidas como alternativas pedagógicas que colocam o foco do aprendizado nos estudantes. Com mediação de docentes competentes, os alunos aprendem a partir da descoberta, da investigação e por problemas. Tais metodologias comumente promovem uma maior retenção e compreensão de contéudos ensinados, uma vez que o aprendiz se encontra engajado nas atividades, seja por meio de pesquisa, colaborações em grupo, discussão e resolução de problemas. Este trabalho teve como objetivo verificar a evolução temporal do uso de metodologias ativas, no contexto dos cursos superiores de Engenharia, a partir de um mapeamento sistemático da literatura. A partir de um protocolo de pesquisa estabelecido, buscou-se verificar quais os principais pesquisadores desta área, sua localização geográfica e quais as metodologias preferidas no contexto destes cursos. A partir dos resultados, foi possível observar que o crescimento do número de publicações científicas sobre metodologias ativas no contexto da Educação em Engenharia, em especial nos últimos cinco anos do período analisado (entre 2015 e 2020). Pode-se notar a realização de pesquisas neste contexto em todos os continentes, com predomínio de estudos liderados por pesquisadores americanos e europeus. Nos estudos mapeados, a sala de aula invertida e a aprendizagem baseada em problemas foram as metodologias mais identificadas. Isso indica uma maior preocupação dos professores da área em promover atividades com elevado envolvimento, que permitam o desenvolvimento de habilidades e competências pessoais e profissionais, ainda no período de formação.

Palavras-chave: metodologias de ensino; Educação em Engenharia; aprendizagem baseada em projetos; aprendizagem baseada em problemas; sala de aula invertida.

METODOLOGÍAS ACTIVAS EN LA ENSEÑANZA SUPERIOR: UNA CARTOGRAFÍA SISTEMÁTICA EN EL CONTEXTO DE LOS CURSOS DE INGENIERÍA

RESUMEN: Las metodologías activas pueden entenderse como alternativas pedagógicas que ponen el foco del aprendizaje en los alumnos. Con la mediación de profesores competentes, los alumnos aprenden a partir del descubrimiento, la investigación y los problemas. Estas metodologías suelen promover una mayor retención y comprensión de los contenidos enseñados, ya que el alumno participa en actividades, ya sea a través de la investigación, la colaboración en grupo, el debate y la resolución de problemas. Este trabajo tuvo como objetivo verificar la evolución temporal del uso de las metodologías activas en el contexto de los cursos de educación superior en Ingeniería, a partir de un mapeo sistemático de la literatura. A partir de un protocolo de investigación establecido, se buscó verificar cuáles son los principales investigadores en esta área, su ubicación geográfica y cuáles son las metodologías preferidas en el contexto de estos cursos. A partir de los resultados, se pudo observar que el crecimiento en el número de publicaciones científicas sobre metodologías activas en el contexto de la Enseñanza de la Ingeniería, especialmente en los últimos cinco años del período analizado (entre 2015 y 2020). Se puede observar la realización de investigaciones en este contexto en todos los continentes, con un predominio de estudios dirigidos por investigadores americanos y europeos. En los estudios mapeados, el aula invertida y el aprendizaje basado en problemas fueron las metodologías más identificadas. Esto indica una mayor preocupación entre los profesores de la zona por promover actividades con alta implicación que permitan el desarrollo de habilidades y competencias personales y profesionales durante el periodo de formación.

Palabras clave: metodologías de enseñanza; enseñanza de la ingeniería; aprendizaje basado en proyectos; aprendizaje basado en problemas; aula invertida.

INTRODUCTION

Active methodologies can be understood as teaching methods that actively involve students during the learning process. Through meaningful actions and activities, students reflect on what they are doing and what they are learning. Alternatively, such approaches can be mentioned in the literature as inductive teaching. These methods are similar because the student assumes greater responsibility and protagonism for their learning, which may be based on research and/or collaborative activities, involving discussion and problem-solving. The teacher is a facilitator of learning, not acting as a primary source of knowledge, evaluating, and observing his students' progress, and providing the necessary assistance at specific times. As a result of student engagement, there is greater retention and understanding of the content covered, as well as greater attention and concentration on the proposed activities (Hernández-de-Menéndez et al.; 2019; Prince, 2004; Prince and Felder, 2006).

Despite recent and modern, active methodologies were already highlighted by classic authors in Education at the beginning of the 20th century, such as John Dewey and Lev Vygotsky, in the context of school education for children and young people. The first emphasized the importance that the knowledge passed on in the classroom should always be introduced by real situations, which would generate students' interest in learning since education should be considered as a life process and not as a preparation process for a future life (Williams, 2017). The second one indicated interactive activities such as productive discussions, constructive feedback, and collaboration with others, as fundamental for the construction of knowledge, with the teacher being the main promoter and motivator of this type of interaction (Kurt, 2020). Both characteristics emphasized by these authors are fundamental pillars of active methodologies applied in current times.

Even with the different advantages and good results of using active methodologies, most teachers still prefer traditional methodologies, especially teachers in the areas of Science, Technology, Engineering, and Mathematics (STEM) (Stains et al. 2018). The main reasons given by teachers are the insufficient time to prepare classes with new methodologies, limited resources, lack of institutional support, difficulty in approaching content and making assessments using such approaches, students' resistance to participating in the proposed active activities, in assuming responsibility for their learning and being forced to carry out group activities (Deslauriers et al., 2019; Felder, 2010; Henderson et al., 2007).

Despite these facts, universities and professors in their initiatives, have considered the different benefits of active methodologies and have invested in environments and situations conducive to their adoption in higher education curricula (Hernández-de-Menéndez et al.; 2019). The need to train professionals with technical skills combined with problem-solving skills, present in the day-to-day activities of professions, encourages the use of these approaches with university students, in the most different areas. The development of skills and abilities valued by the labor market, such as critical thinking, analysis, problem-solving, leadership, teamwork, and the use of information and communication technologies, among others; are also attractive consequences of the use of active methodologies (Prince and Felder, 2006).

The Covid-19 pandemic, social distancing actions, and the sudden deployment of remote learning have also accelerated the use of active approaches. In this context, professors were challenged to maintain attractive and quality teaching through computer screens, cell phones, and TVs. The use of methods of greater student engagement, together with technological tools, has a high potential for maintaining performance and learning, even in times when face-to-face meetings were not possible (Donitsa-Schimdt and Ramot, 2020; Palmeira et al., 2020; Singhal et al., 2020).

Considering this context, the general objective of this work is to verify the temporal evolution, in Brazil and the world, of the use of active methodologies in the context of higher education courses in Engineering, through a systematic mapping of the literature. Specifically, we seek to identify the main researchers involved in research in this area in recent years, and their geographic location, in addition to verifying the Brazilian presence in these researches. Based on a brief analysis of the titles, abstracts, and keywords of the listed works, the aim is to identify which active methodology is most used by professors of higher education courses in Engineering. Thus, the aim is to understand how such

methodologies have entered the classrooms of these courses and how teachers and students have received this change in the teaching-learning process.

MATERIALS AND METHODS

This work consists of a systematic mapping, which according to Kitchenham and Charters (2007), corresponds to a secondary study aimed at identifying and classifying a theme/content related to a research topic. Its results allow a broad investigation of the chosen theme, enabling the investigation of the main characteristics, conclusions, and gaps in the literature, as well as the suggestion of new studies and the use of new methods, approaches, and/or approaches. Performing systematic mapping requires the construction of a research protocol, consisting of seven basic steps (Petersen et al., 2008; Petersen et al., 2015), illustrated in Figure 1.

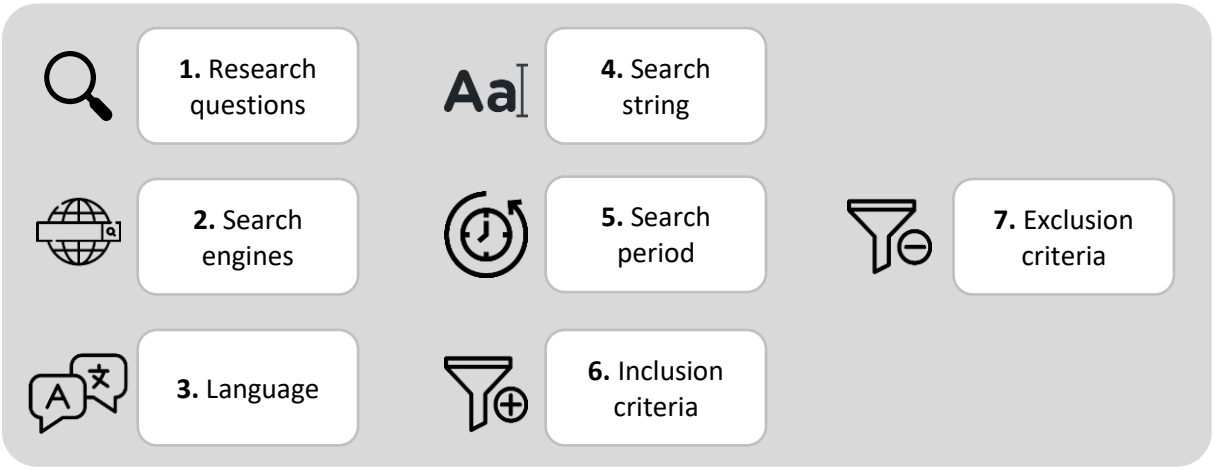


Figure 1 – Seven basic steps of the systematic mapping research protocol (Source: Adapted from Petersen et al., 2015)

For this work, such steps were defined as follows:

1. Research questions: initially, 4 research questions were defined to be answered in this systematic mapping:
   - Is it possible to observe a growth in the use of active methodologies in Engineering courses, based on the publications found by the established research protocol and for the selected period of study?
   - Which journals are the main vehicles for disseminating works involving active methodologies in higher education courses in Engineering? Who are the authors and how are they connected in the production of such works?
   - What is the geographic distribution of the researchers who published works in this period? Is it possible to establish a profile of the Brazilian presence in this research?
   - When evaluating the titles, abstracts, and keywords of the selected works, is it possible to identify the active methodologies most used/reported by researchers?

2. Search engines: Web of Science (WoS) and ScienceDirect (SciDir). Such platforms were chosen because they include journals that publish results in the areas of Engineering.

3. Language: English. The choice of this language considers its majority use in scientific publications and the mandatory use of the listed search engines.

4. Search string (or descriptors): ("active learning") AND ("education") AND ("engineering"). The search terms include English words commonly used in publications that address active methodologies and education in the context of higher education courses in Engineering.

5. Research period: 2005 to 2020. It is believed that the fifteen-year interval is interesting to investigate established research questions. At the same time, it will be possible to establish a scenario before the Covid-19 pandemic, which may have stimulated the use of active methodologies.

6. Inclusion criteria: works that have the search strings in the title, abstract, and keywords will be considered.

7. Exclusion criteria: only original research papers will be considered ("Article type - Research articles" filter in Science Direct and "Document type - Articles" filter in Web of Science).

With the application of this protocol, data extraction was performed, resulting in a list of primary studies. The data in this list were summarized in graphs and tables, prepared using the following computational tools:

- BibExcel (Persson et al., 2009): a tool for analyzing bibliographic data, extracted from search engines in textual form, which can be converted into electronic spreadsheets, for quantitative analysis and graph generation.
- Pajek (Nooy et al., 2018): a tool for generating collaboration networks between article authors, from files generated in the analysis with the BibExcel tool.
- GPS Visualizer: online tool for producing maps, based on location data from the authors of the studies listed in this systematic mapping.
- WordCloud: an online tool for producing a cloud of words present in the titles, abstracts, and keywords of the listed studies.

This data synthesis sought to find answers to the research questions established for this systematic mapping. Such responses include verifying the advancement of the presence of the theme of active methodologies in higher education courses in Engineering over the last few years; the identification of the main vehicles for disseminating such research and which are the main researchers involved and the identification of the active methodologies preferred by professors in the field of Engineering.

RESULTS AND DISCUSSION

The application of the established research protocol found 433 original research papers, with 55 results obtained from Science Direct (SciDir) and 378 results obtained from Web of Science (WoS). We verified the existence of 17 repetitions, which were found in both search engines, but they were withdrawn and considered only once. Thus, the final number considered was 416 publications, which are indicated in Appendix A (title and year of publication).

The temporal distribution of publications is presented in Figure 2, considering the established search period, between 2005 and 2020. This figure differentiates the works found in each search engine, in addition to indicating the accumulated total of publications each year. The years with the highest total number of published works were 2019, with 73 publications (17.5% of the total), 69 from WoS and 4 from SciDir; and 2020, with 71 publications (17.1% of the total), 57 from WoS and 14 from SciDir.

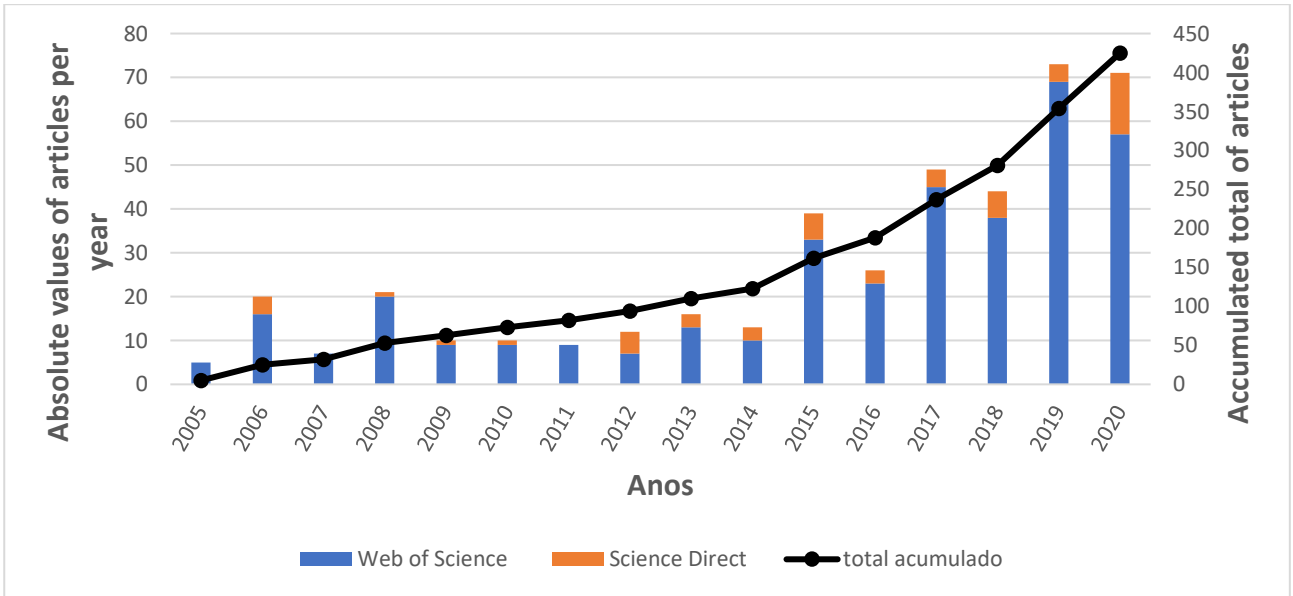


Figure 2. Evolution of the number of scientific publications on active methodologies in higher education engineering courses, considering the established research protocol (Source: Authors, 2023).

It is possible to observe a significant increase in the number of works published from 2015. Until that year, the total number of published works was 153, which is equivalent to 36.8% of the publications found in this mapping. Between 2015 and 2020, 263 scientific articles were published on active methodologies in higher engineering courses, corresponding to 63.2% of the works mapped and 1.72 times the number of works identified between 2005 and 2015.

Such results are indicative of the growth of the presence of active methodologies in the classrooms of higher education courses in Engineering, with an acceleration of their uses and the reports present in the international scientific literature after 2015 and with peaks in the last two years of the period of survey considered (2019 and 2020). The repetition of this research protocol, in a later period, may be interesting to find out how the extension of the Covid-19 pandemic may have affected this growth, considering the context of social isolation and remote teaching.

The works mapped here were published in 124 different scientific journals. Figure 3 highlights the five journals with the highest number of publications in this mapping and the respective number of works published in these journals.

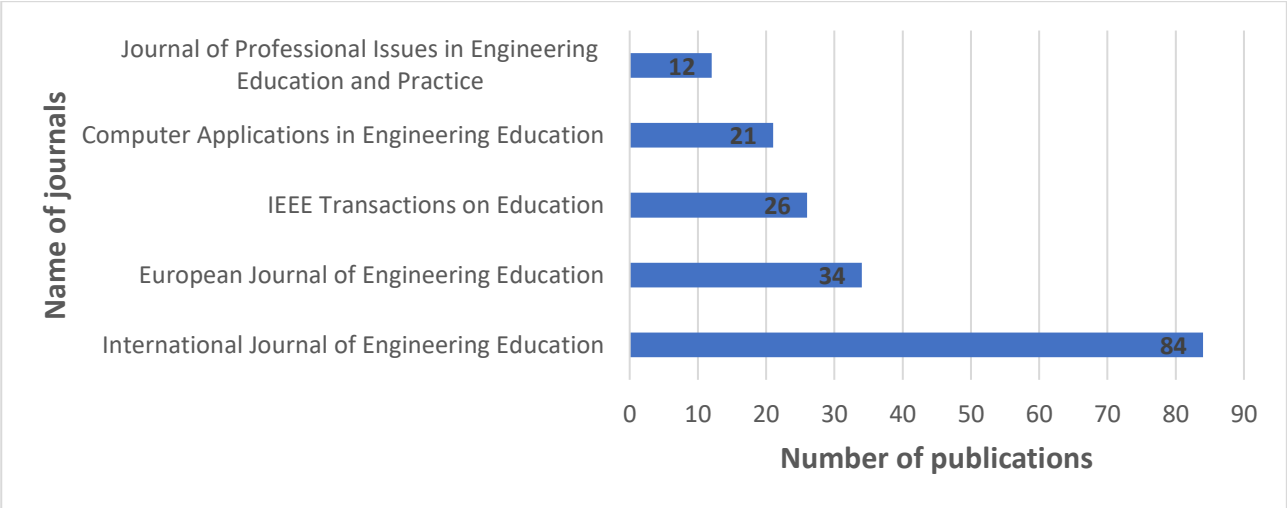


Figure 3. Journals with the highest number of scientific publications on active methodologies in higher education courses in Engineering, considering the established research protocol. (Source: Authors, 2023)

The journal that presented the largest number of papers was the International Journal of Engineering Education (IJEE / ISSN: 0949-149X) with 84 articles, which corresponds to 20.1% of the mapped publications. Then, with 34 papers (8.2% of the total), there is the European Journal of Engineering Education (EJEE / ISSN: 0304-3797). Both journals currently publish six editions per year and have in their scopes the dissemination of scientific research focused on the development of education focused on Engineering, on a global and continental level.

The journals IEEE Transactions on Education (IEEE ToE / ISSN: 0018-9359) and Computer Applications in Engineering Education (CAE / ISSN: 1061-3773) were, respectively, the third and fourth journals with more publications in this mapping. IEEE ToE is linked to the Institute of Electrical and Electronics Engineers (IEEE) and seeks to carry out educational research linked to higher education courses in Electrical, Electronics, and Computer Engineering. This result highlights the presence of this area of Engineering among those that most disseminate their results of active methodologies in the scientific literature. The CAE journal, on the other hand, addresses studies on the use of computers, the Internet, tools, and software, in the context of Engineering education, which also highlights the initiatives of teachers to include new technologies, combined with active methodologies, in the context of student training.

Figure 4 shows the five authors most present in the analyzed studies. This survey considered both the position of the main author and co-author of the works. In the 416 works analyzed, 671 researchers were involved, which corresponds to an average of 1.61 researchers involved per work.

Maura Borrego (University of Texas at Austin, USA) was the researcher with the largest number of papers, with 6 participations, 4 of which as first author. Shane Brown (Oregon State University, USA) was second, with 5 participations, 2 as lead author. Jeffrey Rhoads (University of Purdue, USA), Noboyuki Ogawa (Gifu National College of Technology, Japan), and José Manuel Lopez-Guede (Universidad del Pais Vasco, Spain) complete the list. An interesting fact common to such researchers is their initial training in Engineering and the carrying out of further studies, seeking to integrate active methodologies into the courses they belong to.

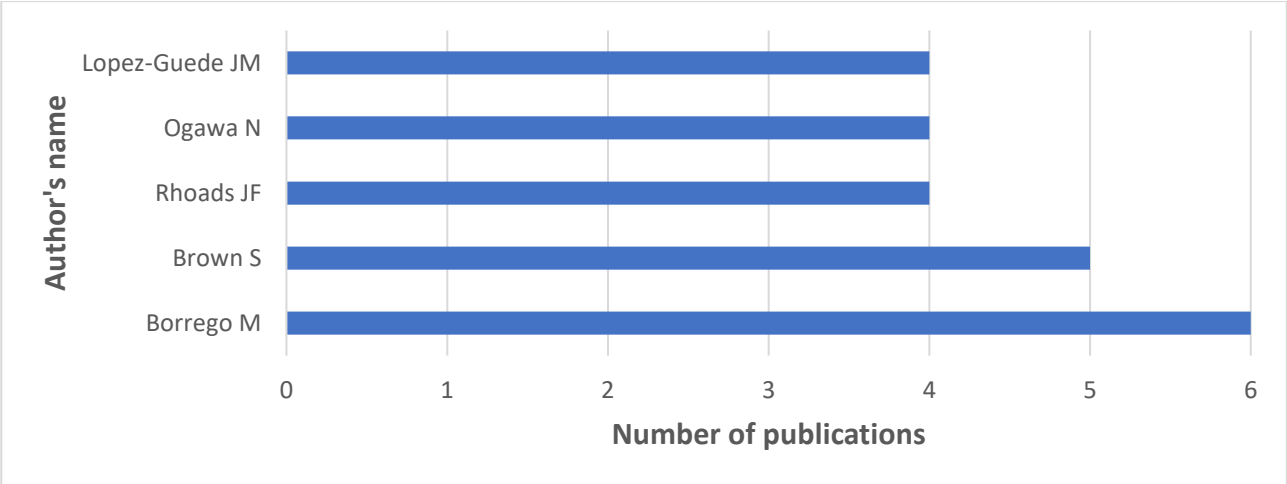
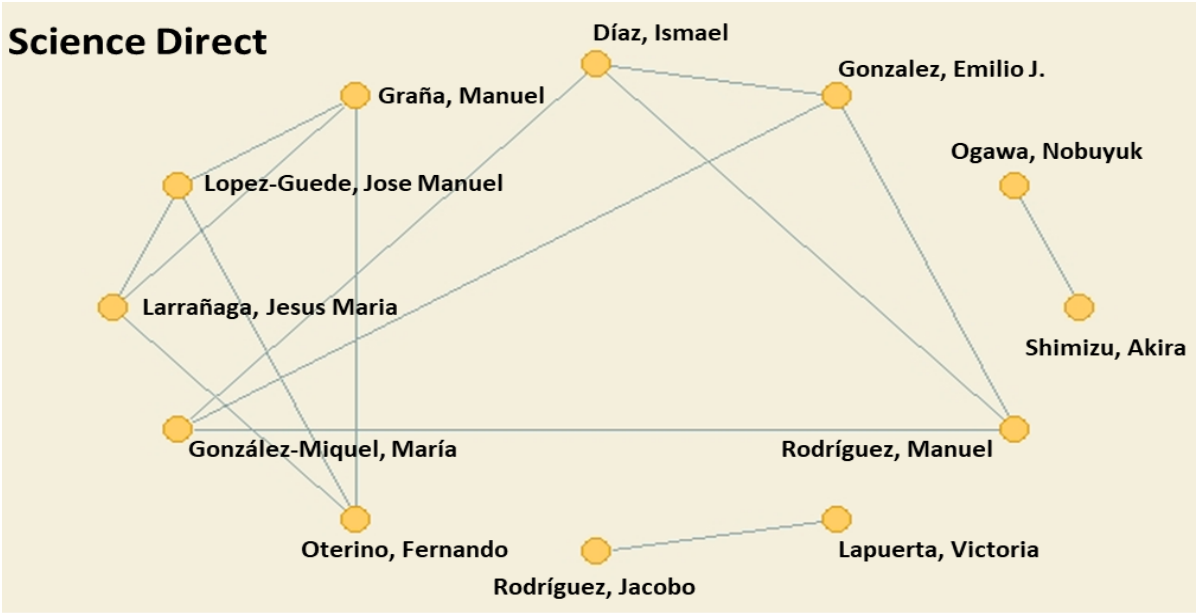


Figure 4. Authors with the highest number of participations in works, considering the established research protocol (Source: Authors, 2023)

Figures 5a and 5b show the connection networks between the authors involved in the studies listed in this mapping, divided by search engine (Science Direct and Web of Science, respectively). A link indicates that an author has published at least one paper with another. It is not possible to present all 671 researchers involved in these figures of all existing connections. In this way, the most frequent connections are displayed in the figures.

It is interesting to note that the interaction between these authors is not intense, which indicates the need for more local studies, which report experiences at each university or each course in which they are involved. Even the authors with more publications, shown in Figure 3, have few collaborations. Maura Borrego and Noboyuk Ogawa have a single frequent collaboration, while José Manuel Lopez-Guede has three frequent connections, all of which are of the same nationality. Shane Brown and Jeffrey Rhoads do not appear in these networks, since their work was always carried out with different professionals, infrequent in the dissemination of results through articles.

(a)



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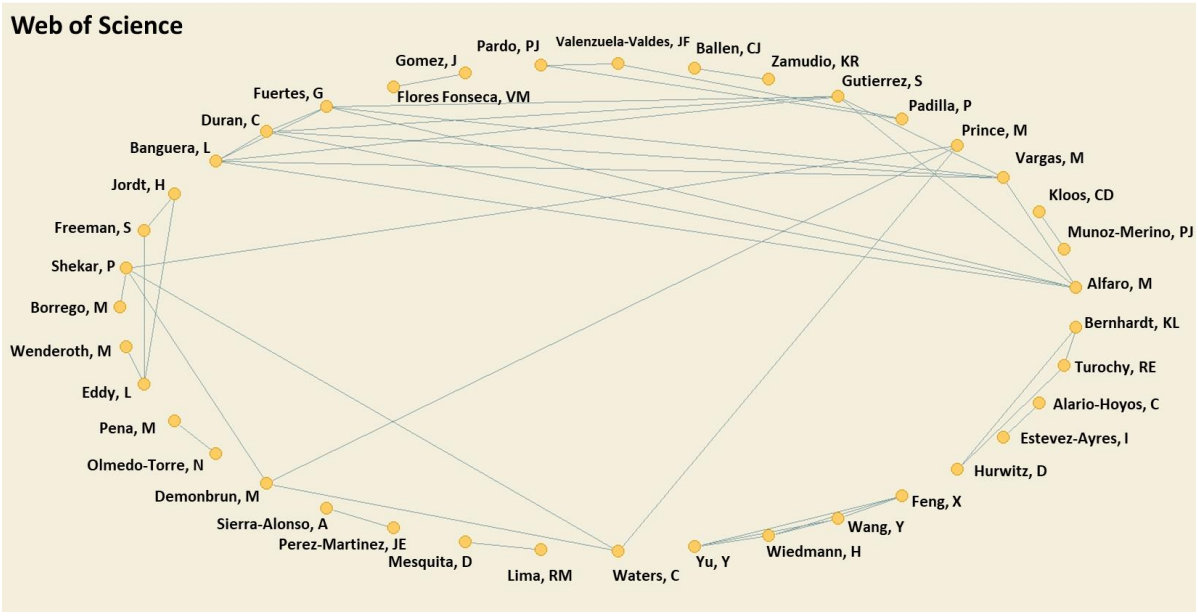
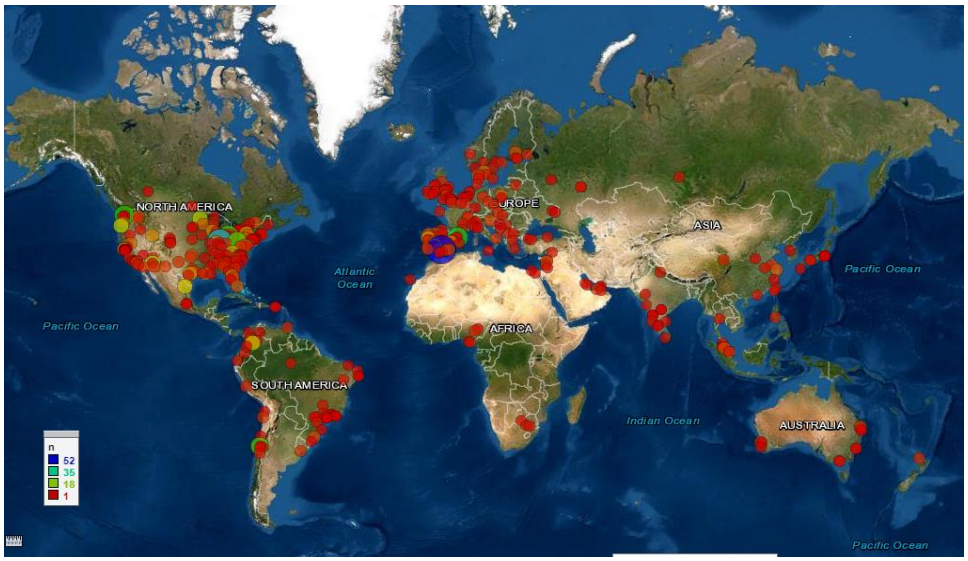


Figure 5. Connection networks between authors participating in the works, divided according to the search engine: (a) Science-Direct and (b) Web of Science. (Source: Authors, 2023)

When we look at the list of authors with the most works and the most frequent connection networks, it is possible to assess that there is a predominance of American and European authors, especially Spanish ones. This assessment can be confirmed in Figure 6, which shows the geographic location of the researchers involved in the work listed in this mapping. This evaluation was carried out only for works obtained by the Web of Science search engine, since the search results on this platform, in textual format, provided such information, while Science Direct did not.

(a)



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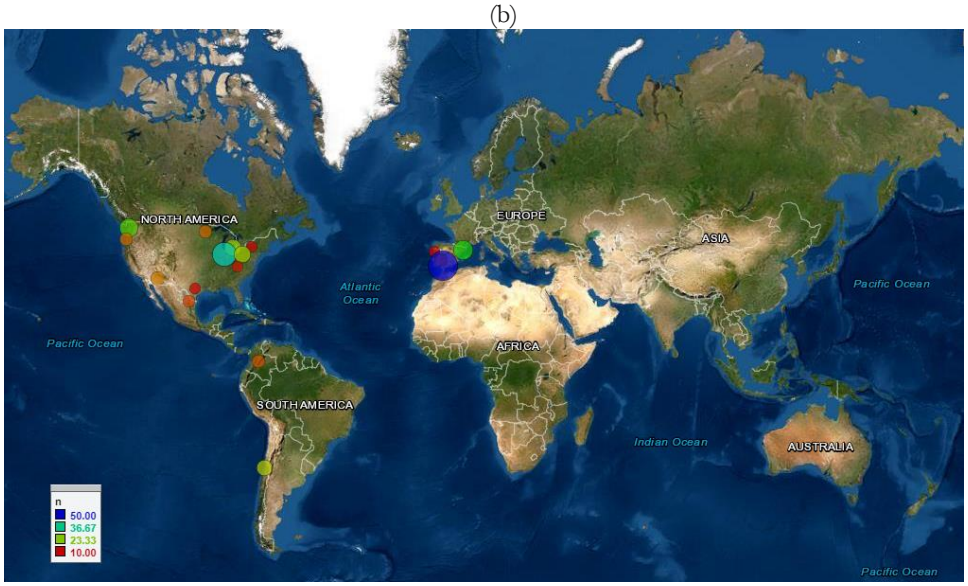

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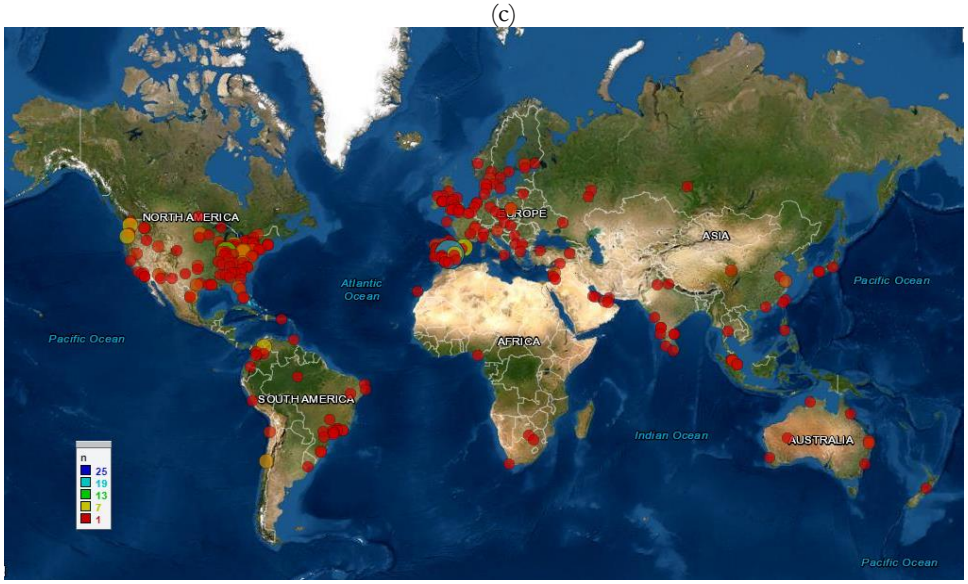


Figure 6. Location map of researchers involved in the research listed in this systematic mapping, from the Web of Science. Circle size and colors indicate quantities in each city/region. (a) location of all authors involved; (b) locations that presented 10 or more works; (c) places of origin of the first authors. (Source: Authors, 2023)

Observing all the authors (Figure 6a), it is possible to assess the predominance of the point cloud over the United States and Europe. Colored circles with a larger diameter indicate the locations

with the greatest presence of researchers. Madrid (Spain) with 59 repetitions; West Lafayette (United States) with 39 repetitions; and Barcelona (Spain) with 29 repetitions are the cities with more authors participating in the listed surveys.

The American and European predominance over the other continents is even more evident in Figure 6b, which restricts the locations that presented at least 10 repetitions. In this condition, it is noted the lack of points in Asia, Oceania, and Africa, in addition to a large reduction in the presence of works from South America. In this last region, the works carried out in Chile and Colombia stand out, which in terms of the same location, presented more papers than Brazil.

Figure 6c shows the location of the first authors. The European and American predominance remains evident, considering that these regions have a research network on the subject and investments in science already consolidated, making them the main international references (Reis et al., 2017). The presence of researchers leading publications on all continents is an encouraging fact, in the sense that active methodologies are already widespread worldwide and that there is a concern on the part of Engineering professors to bring them to the classroom.

Figure 7 shows a clipping of the maps for the South American continent to highlight Brazil. When comparing the map of all authors (Figure 7a) and the map of first authors (Figure 7b), there is a lot of similarity, which indicates that Brazilian researchers, in different regions, led research related to active methodologies aimed at Engineering courses. Numerically speaking, 40 researchers participated in such works, and 17 of these have a Brazilian researcher as the first author. Four of the five Brazilian regions had at least one participation in works on active methodologies. Only the Midwest region did not have representatives. The highest concentration of articles was seen in the South and Southeast regions, with papers coming from both capitals and cities in the interior. Despite this optimistic approach, it is believed that Brazil can still evolve in carrying out research and implementing active methodologies in Engineering courses. It is important to point out that the protocol of this research only collected works published internationally and that many researchers may choose to disseminate their research nationally, through journals and events in the country, whose papers were not captured in this survey.

(a) (b)

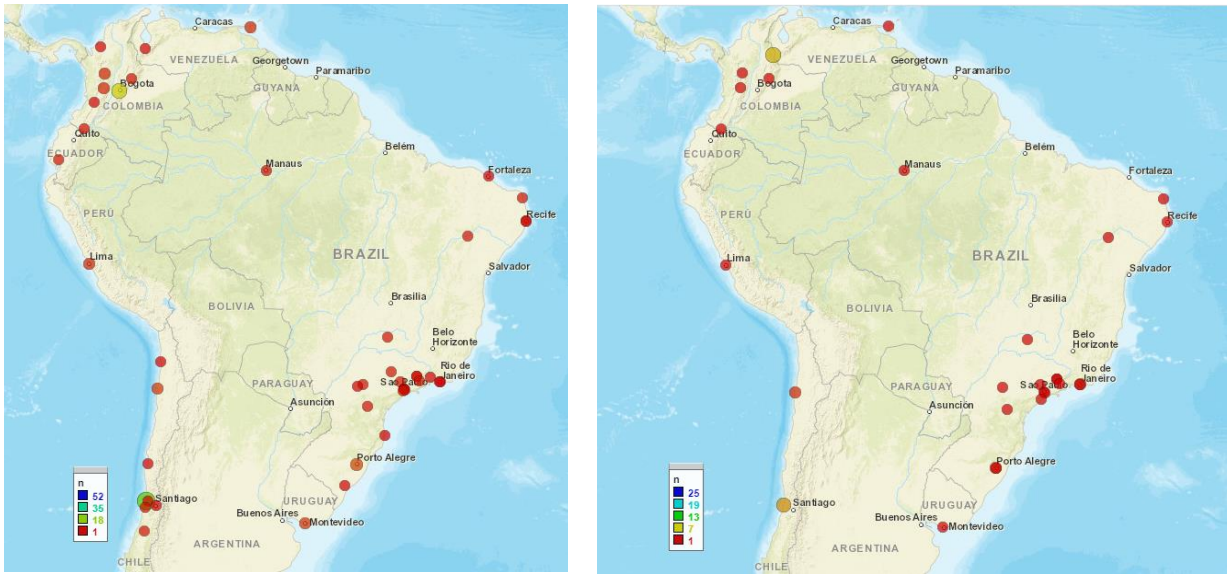
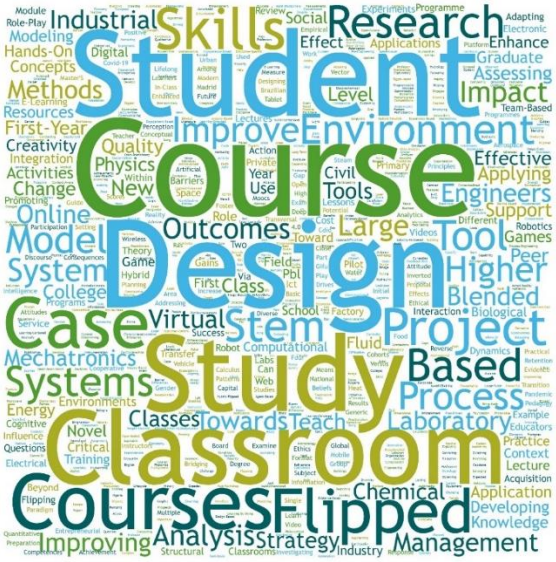


Figure 7. Location of Brazilian and South American researchers involved in the research is listed in this systematic mapping, from the Web of Science. Circle size and colors indicate quantities in each city/region. (a) location of all authors involved; (b) places of origin of the first authors. (Source: Authors, 2023)

Finally, Figure 8 shows three-word clouds obtained from the texts of the titles (Figure 8a), abstracts (Figure 8b), and keywords (Figure 8c) of the papers. The assembly of these word clouds disregarded the terms "active learning"; "education" and "engineering", which were used as research criteria in the present studies and would inevitably be present in high quantity in these word clouds. We

tried to verify the terms with more repetitions and that could be indicative of the active methodologies reported by the authors in each study. Words with larger fonts are indicative of greater repetitions.

(a)



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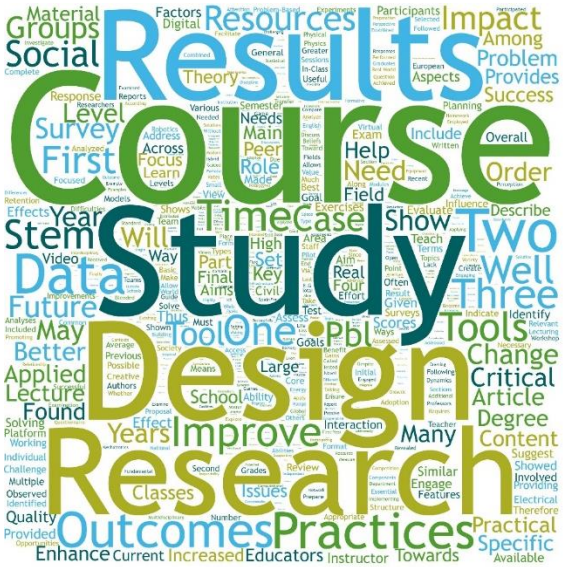

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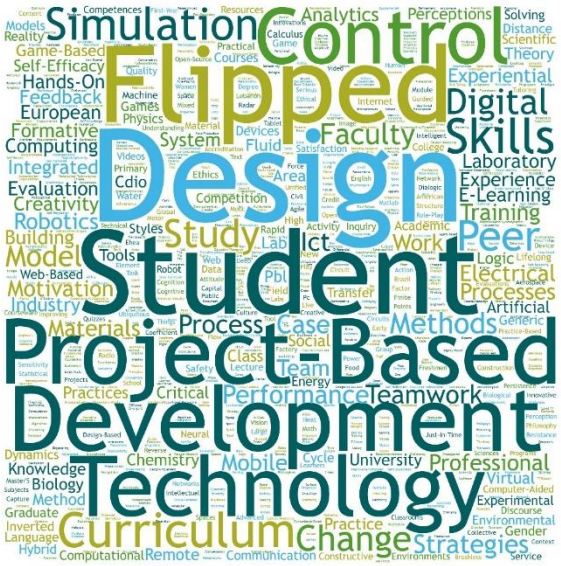

Figure 8. Word clouds are obtained from (a) titles; (b) abstracts and (c) keywords of all papers listed in this mapping. Words with larger fonts had a higher number of repetitions. (Source: Authors, 2023)

In the analysis of these results, we tried to group the words into categories to list indicative reasons for their repetition in the evaluated texts. The categories were:

- Words with many repetitions that describe elements of the university, which are inevitably used in the description of the environment in which the publications were carried out. The terms "student" (estudente); "course(s)" (cursos); "classroom" (sala de aula); "practices" (prácticas); "strategies" (estratégias); "curriculum" (currículo); "higher education" (ensino superior);
- • Words with many repetitions that describe elements of scientific works: common words of the language of scientific articles, such as "study" (estudo/trabalho); "research" (pesquisa); "outcomes" (resultados); "results" (resultados, resulta em); "impact" (impactos); "change" (mudanças); "analysis" (análise); "improving" (melhorias).

- Words related to engineering and technology: terms such as "desgin" (projeto); "development" (desenvolvimento); "technology" (tecnologia); "digital" (digital); "simulation" (simulação); "systems" (sistemas); "tools" (ferramentas); which are words commonly present in the vocabulary of engineers and which may be embedded in the disciplines in which the active methodologies were applied.
- Words related to skills and competences developed by students: they may have been used to describe the main results expected and obtained with the implementation of active methodologies. Terms like "skills" (habilidades); "analysis" (capacidade de análise); "management" (capacidade de gerenciamento); "communication" (comunicação); "groups" e "teamwork" (trabalho em grupo); creativity" (criatividade) are the most prominent in this category.
- Words related to active methodologies: "flipped" (inverted, which refers to the flipped classroom); 'Project-based" and "PBL" (problem and project-based learning); were the most repeated terms regarding active methodologies. Secondarily, the terms "blended" (blended teaching); "peer" (about peer learning)" and "case" (about case studies). Such approaches can be considered the most used and reported by the authors of the publications listed in this mapping.

The results regarding the preferred and most cited active methodologies in the texts coincide with those seen by other authors in previous bibliographic studies (Jesiek et al., 2011; Reis et al., 2017; Wankat et al., 2014; Xian and Madhavan, 2014), which presented different search protocols, considering the searched terms, the search engines, and the analyzed search period. In this sense, Engineering professors have given preference to the use of methods that facilitate the integration between theory and practice, a common demand of students in these courses, who in traditional teaching, suffer from distance from the classroom of true professional reality.

The skills and abilities developed with these methodologies, also identified in the evaluated terms, are a direct result of the use of active teaching and contribute to the student's personal and professional development. In addition, they are in line with the new focus of university education, where not only dealing with technical content is important but engaging and promoting meaningful learning are also fundamental for the success of graduates (Ríos et al., 2010; Hernández-de- Menéndez et al.; 2019).

CONCLUSÕES

The implementation of the proposed research protocol resulted in a list of 416 scientific publications, obtained from the Science Direct and Web of Science platforms. The analysis of this list allowed the verification of the temporal distribution of publications, which allowed observing a strong growth in the dissemination of scientific works linked to active methodologies in the context of higher education courses after 2015. In this period, 63.2% of the works mapped were published, with 2019 and 2020 together representing 34.6% of the total number of publications. It was also noted that 124 journals received the listed publications, with 20.1% of them published by the International Journal of Engineering Education (IJEE / ISSN: 0949-149X).

The mapping of researchers and their location indicated the predominance of research carried out by Americans and Europeans, with emphasis on Spanish researchers. Maura Borrego (University of Texas at Austin, USA), Shane Brown (Oregon State University, USA), Jeffrey Rhoads (University of Purdue, USA), Noboyuki Ogawa (Gifu National College of Technology, Japan), and José Manuel Lopez-Guede (Universidad del Pais Vasco, Spain) were the researchers who most participated in publications in the analyzed period. It was possible to observe research carried out on all continents, which indicates that professors of Engineering courses have been open to the use of active methodologies and that future perspectives can be interesting, in the sense of favoring learning in these courses. Brazil also participates in international research on the subject, with 40 researchers as authors and co-authors of these publications, from four of the five regions of the country. There is a predominance of researchers located in the South and Southeast of the country, being both in capitals and in the interior of the states.

From the evaluation of the terms present in the titles, abstracts, and keywords of the studies listed in this mapping, it was possible to observe that the most present active methodologies were the

flipped classroom, problem-based learning, and project-based learning. Such methodologies are easily adaptable to the reality of the contents of Engineering courses and facilitate the integration between theory and practice, which can motivate teachers to seek its implementation, in a moment of transition between traditional teaching and active teaching.

As recommendations for future research, we believe that a short-term evaluation of the use of active methodologies in Engineering courses is important, as a way of identifying the effects of the pandemic and remote teaching on its implementation in the classroom. The identification of the growth of new methodologies, which surpass those identified in this work, can also be a result identified in this repetition. The inclusion of other platforms and other scientific works, not just articles, are also possible modifications in the methodology proposed here and that allow obtaining different insights about active teaching in Engineering. Finally, crossing the results obtained from Engineering courses with other undergraduate courses is a possibility to increase the set of methodologies that can be used with engineers. An analysis of the reality of each area of Engineering is also another interesting aspect of future research.

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CONTRIBUTION OF THE AUTHORS

Author 1 – Project coordinator, methodology, data collection, data analysis, original draft writing.
Author 2 – Supervision, active participation in data analysis, and review of final writing.
Author 3 – Project administration, Funding acquisition, supervision, final writing review.

CONFLICT OF INTEREST DECLARATION

The authors declare that there is no conflict of interest with this article.

APPENDIX A - LIST OF MAPPED WORKS

Title	Ano
A Combined Strategy of Additive Manufacturing to Support Multidisciplinary Education in Arts, Biology, and Engineering	2020
Effectiveness of blended instructional design based on active learning in a graphic engineering course	2020
Flipped learning and threshold concepts in the Turbomachinery section of Fluid Engineering course	2020
Improving learner engagement in MOOCs using a learning intervention system: A research study in engineering education	2020
Students' attitude toward sustainability and humanitarian engineering education using project-based and international field learning pedagogies	2020
A computer-aided educational tool for vector control of AC motors in graduate courses	2020
A Flipped Classroom Approach to Teaching Empirical Software Engineering	2020
A Guide to Student-active Online Learning in Engineering	2020
A Project Based Approach for Teaching Product Development to Graduate Students	2020
A Project Based Learning Approach for Teaching Artificial Intelligence to Undergraduate Students	2020
Active Learning Augmented Reality for STEAM Education-A Case Study	2020
Active Learning is About More Than Hands-On: A Mixed-Reality AI System to Support STEM Education	2020
Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math	2020
Active, experiential and reflective training in civil engineering: evaluation of a project-based learning proposal	2020
An effective blended online teaching and learning strategy during the COVID-19 pandemic	2020
An Exploratory Analysis of the Implementation and Use of an Intelligent Platform for Learning in Primary Education	2020
Applying Multiple Modes of Assessment to Evaluate the Team Work Competence	2020
Assessing evaluation: Why student engages or resists to active learning?	2020
Attaining competencies in Programme Outcomes through Open-Ended Experiments	2020
Barriers and levers driving change in a STEM science subject in the Australian higher education sector: a focused study	2020
BLDC Motor-Driven Fluid Pumping System Design: An Extrapolated Active Learning Case Study for Electrical Machines Classes	2020
Blending Inverted Lectures and Laboratory Experiments to Improve Learning in an Introductory Course in Digital Systems	2020
Challenges of teaching food microbiology in Brazil	2020
Combining the project-based learning methodology and computer simulation to enhance the engagement in the context of Environmental Engineering courses	2020
Developing pre-laboratory videos for enhancing student preparedness	2020
Development of Case-Based Learning (CBL) in Engineering Technology Education	2020
Development of the student course cognitive engagement instrument (SCCEI) for college engineering courses	2020
Digital device-based active learning approach using virtual community classroom during the COVID-19 pandemic	2020
Educational Test Bed 4.0: a teaching tool for Industry 4.0	2020
Effective Pedagogical Strategies for STEM Education from Instructors' Perspective: OER for Educators	2020
Engaging in homework development: TARSIS platform as an innovative learning methodology	2020
Engineering Education for Sustainable Development: Evaluation Criteria for Brazilian Context	2020
Engineering Faculty Members' Perceptions of University Makerspaces: Potential Affordances for Curriculum, Instructional Practices, and Student Learning	2020
How drawing prompts can increase cognitive engagement in an active learning engineering course	2020
Implementing studio-based learning for design education: a study on the perception and challenges of Malaysian undergraduates	2020
Improving performance in a large flipped barrier mathematics course: a longitudinal case study	2020
Initial implementation of active learning strategies in large, lecture STEM courses: lessons learned from a multi-institutional, interdisciplinary STEM faculty development program	2020
Integrated Image-Based Computational Fluid Dynamics Modeling Software as an Instructional Tool	2020

Introducing First-Year Medical Students to Product Innovation and Entrepreneurship	2020
Learning Portfolios and Proactive Learning in Higher Education Pedagogy	2020
Lecture-Free Classroom: Fully Active Learning on Moodle	2020
Motivators and barriers in undergraduate mechanical engineering students' use of learning resources	2020
Multiple Features Fusion Attention Mechanism Enhanced Deep Knowledge Tracing for Student Performance Prediction	2020
Peer-graded individualised student homework in a single-instructor undergraduate engineering course	2020
Revisiting a Measure of Engineering Design Self-Efficacy	2020
Scalable and Practical Teaching Practices Faculty Can Deploy to Increase Retention: A Faculty Cookbook for Increasing Student Success	2020
Self-Efficacy Versus Gender: Project-Based Active Learning Techniques in Biomedical Engineering Introductory Computer Programming Courses	2020
Social-Driven Propagation of Active Learning and Associated Scholarship Activity in Engineering: A Case Study	2020
Staff perceptions of implementing project-based learning in engineering education	2020
Student Perspective on Technology Enabled/Enhanced Active Learning in Educational: Rasch Measurement Model	2020
Student Perspectives on the Learning Resources in an Active, Blended and Collaborative (ABC) Pedagogical Environment	2020
Sustainability coursework: student perspectives and reflections on design thinking	2020
Sustainable and Flipped STEM Education: Formative Assessment Online Interface for Observing Pre-Service Teachers' Performance and Motivation	2020
The Development of Social Capital in an Active, Blended, and Collaborative Engineering Class	2020
The effectiveness of computer-based simulations for numerical methods in engineering	2020
The role of structures in architecture: the multidisciplinary experience of active learning in a master of science	2020
Using videos to improve oral presentation skills in distance learning engineering master's degrees	2020
Developing rigor with Critical Discourse Analysis to examine educators' transition toward active learning	2020
A Novel Framework for Active Learning in Engineering Education Mapped to Course Outcomes	2020
Application of escape lab-room to heat transfer evaluation for chemical engineers	2020
Active learning in control education: a pocket-size PI(D) setup	2020
Challenge-Based Learning in Aerospace Engineering Education: The ESA Concurrent Engineering Challenge at the Technical University of Madrid	2020
A serious game for teaching the fundamentals of ISO/IEC/IEEE 29148 systems and software engineering – Lifecycle processes – Requirements engineering at undergraduate level	2020
Development of educational contents on circular economy and critical raw materials challenges	2020
She Space: A multi-disciplinary, project-based learning program for high school girls	2020
A collaborative working model for enhancing the learning process of science & engineering students	2020
Active Learning Classes (in KOSEN Colleges of Japan) Using ICT and Tools for Obtaining Biological Information to Enhance the Creativity of Engineering Design Students	2020
Introduction to systems engineering and sustainability PART I: Student-centred learning for chemical and biological engineers	2020
A "learning small enterprise" networked with a FabLab: An academic course 4.0 in instrumentation and measurement	2020
Redefining Quality in Engineering Education through the Flipped Classroom Model	2020
Grounded Idea Generation: An Analysis Framework for Project-Based Courses	2020
A learning analytics tool for the support of the flipped classroom	2019
A learning-Centered Paradigm for Engineering Graphics and Design: Engineering Technology Students' Skill Gains and Capstone Preparation	2019
A Peer Review System for BIM Learning	2019
A Reverse Engineering Role-Play to Teach Systems Engineering Methods	2019
A third approach beyond the false dichotomy between teacher- and student-centred approaches in the engineering classroom	2019
Action research: a methodology for transformative learning for a professor and his students in an engineering classroom	2019

Active learning for the promotion of students' creativity and critical thinking An experience in structural courses for architecture	2019
Active Learning via Problem-Based Collaborative Games in a Large Mathematics University Course in Hong Kong	2019
Active Teaching and Learning as a Remedy for Engineering Education Problems	2019
Adapting team-based learning for application in telecommunications engineering using software-defined radio	2019
An interactive computational strategy for teaching the analysis of silo structures in civil engineering	2019
Antecedents of student retention: the influence of innovation and quality of teaching in Brazilian universities	2019
Best teaching practices in the first year of the pilot implementation of the project DrIVE-MATH	2019
CDIO Project Approach to Design Polynesian Canoes by First-Year Engineering Students	2019
Changing an Engineering Curriculum through a Co-Construction Process: A Case Study	2019
Collaborative PBL to Teach Calculus to Engineering Students: The Important Role of Collaborative Professors	2019
Comparison of Engineering Skills with IR 4.0 Skills	2019
Cooperative Learning and Embedded Active Learning Methodologies (R) for Improving Students' Motivation and Academic Results	2019
Despite Similar Perceptions and Attitudes, Postbaccalaureate Students Outperform in Introductory Biology and Chemistry Courses	2019
Development and Implementation of Design-Based Learning Opportunities for Students To Apply Electrochemical Principles in a Designette	2019
Didactic games as student-friendly tools for learning hydraulics in a technical university's undergraduate curriculum	2019
Educational Effect of Participation in Robot Competition on Experience-Based Learning	2019
Effects of the flipped classroom instructional strategy on students' learning outcomes: a meta-analysis	2019
Empowering Engineering Students in Ethical Risk Management: An Experimental Study	2019
Enhancing Railway Engineering Student Engagement Using Interactive Technology Embedded with Infotainment	2019
Enhancing students' written production in English through flipped lessons and simulations	2019
Examining Project Based Entrepreneurship and Engineering Design Course Professional Skills Outcomes	2019
Examining the impact of four teaching development programmes for engineering teaching assistants	2019
Experiences on the Design, Creation, and Analysis of Multimedia Content to Promote Active Learning	2019
ezCADD: A Rapid 2D/3D Visualization-Enabled Web Modeling Environment for Democratizing Computer-Aided Drug Design	2019
Flipped classroomcomparative case study in engineering higher education	2019
Flipped Learning in Engineering Education	2019
Gamified experimental physics classes: a promising active learning methodology for higher education	2019
Impact of implementing a long-term STEM-based active learning course on students' motivation	2019
Impact of Mobile Learning in the Cloud on Learning Competencies of Engineering Students	2019
Impactful engineering education through sustainable energy collaborations with public and private entities	2019
Implementation and Comparative Analysis of Mobile Phone Application for Learning and Teaching in Mechanical Engineering Education	2019
Implementing Student-Created Video in Engineering: An Active Learning Approach for Exam Preparedness	2019
Independent learning as class preparation to foster student-centred learning in first-year engineering students	2019
Integrating quantitative and qualitative research methods to examine student resistance to active learning	2019
Introducing a New ICT Tool in an Active Learning Environment Course: Performance Consequences Depending on the Introduction Design	2019
Learning to Do Knowledge Work: A Framework for Teaching Research Design in Engineering Education	2019
Learning-by-doing: experience from 20years of teaching LCA to future engineers	2019
New Partially Flipped Electromagnetics Classroom Approach Using Conceptual Questions	2019
Pedagogical strategies for enhancing machine design teaching in a mechanical technology programme	2019
Practitioner's guide to social network analysis: Examining physics anxiety in an active-learning setting	2019
Professional Development Program to Promote Active Learning in an Engineering Classroom	2019
Promoting Lasting Change in Teaching Practices Through a Summer Immersion Faculty Development Program	2019

Redesigning a Freshman Engineering Course to Promote Active Learning by Flipping the Classroom through the Reuse of MOOCs	2019
Reengineering engineering education at the University of los Andes The REDINGE2 pilot project	2019
Reinvigorating Classroom Engagement and Performance in an Advanced Energy Systems Course	2019
RESHAPING ENGINEERING LEARNING TO PROMOTE INNOVATIVE ENTREPRENEURIAL BEHAVIOR	2019
Scenario-based eLearning to promote active learning in large cohorts: Students' perspective	2019
Self-Regulated Learning for Web-Enhanced Control Engineering Education	2019
Smaller Classes Promote Equitable Student Participation in STEM	2019
Stimulating students' engagement in mathematics courses in non-STEM academic programmes: A game-based learning	2019
Student Active Learning Tool for Producing Open Resources in Microwave Engineering Education	2019
Student Perceptions of an Active Learning Module to Enhance Data and Modeling Skills in Undergraduate Water Resources Engineering Education	2019
Students & x2019; and Instructors & x2019; Perceptions of Five Different Active Learning Strategies Used to Teach Software Modeling	2019
Students' Attitude Towards Problem-Based Learning: A Case Study	2019
Students' interest towards STEM: a longitudinal study	2019
The Development of the INFEWS-ER: A Virtual Resource Center for Transdisciplinary Graduate Student Training at the Nexus of Food, Energy, and Water	2019
The role of collaborative interactions versus individual construction on students? learning of engineering concepts	2019
Towards Open-Source and Collaborative Project-Based Learning in Engineering Education: Situation, Resources and Challenges	2019
Training engineers for innovation: Pedagogical initiatives for new challenges	2019
Understanding engineering educators' pedagogical transformations through the Hero's Journey	2019
Using blended learning to redesign a groundwater management lecture series: benefits and outcome	2019
Using Photovoice to Enhance Mentoring for Underrepresented Pre-Engineering Students	2019
Virtual learning for safety, why not a smartphone?	2019
Motivational impact of active learning methods in aerospace engineering students	2019
Reprint of: Motivational active learning: An integrated approach to teaching and learning process control	2019
Virtual/Remote Labs for Automation Teaching: a Cost Effective Approach	2019
Curriculum change for graduate-level control engineering education at the Universidad Pontificia Bolivariana	2019
A classroom-based simulation-centric approach to microelectronics education	2018
A Comparison of Flipped and Traditional Classroom Learning: A Case Study in Mechanical Engineering	2018
A simulation tool to promote active learning of controlled rectifiers	2018
Active Learning in Flipped Life Science Courses Promotes Development of Critical Thinking Skills	2018
An efficient constructive e-alignment for onsite-online learning	2018
An Empirical Study on the Impact of Lab Gamification on Engineering Students' Satisfaction and Learning	2018
An interactive and blended learning model for engineering education	2018
Blended induction program for electronic engineering freshmen	2018
Characterizing Engineering Learners' Preferences for Active and Passive Learning Methods	2018
COMM151: A PROJECT-BASED COURSE TO ENHANCE ENGINEERING STUDENTS' COMMUNICATION SKILLS	2018
Computer applications for education on industrial robotic systems	2018
EDLE: an integrated tool to foster entrepreneurial skills development in engineering education	2018
Effective Learner-Centered Approach for Teaching an Introductory Digital Systems Course	2018
Effects of Learning Analytics on Students' Self-Regulated Learning in Flipped Classroom	2018
Engaging students as partners in developing online learning and feedback activities for first-year fluid mechanics	2018
Enhancing automatic control learning through Arduino-based projects	2018
Enhancing Entrepreneurship Education in a Master's Degree in Computer Engineering: A Project-Based Learning Approach	2018

Exploring Design Elements for Online STEM Courses: Active Learning, Engagement & Assessment Design	2018
FisicActiva: applying active learning strategies to a large engineering lecture	2018
Flipping or flapping? investigating engineering students' experience in flipped classrooms	2018
From Active Learning to Taking Action: Incorporating Political Context Into Project-Based, Interdisciplinary, International Service Learning Courses	2018
Game-Based Learning while Research Activities of Engineering Students	2018
Hybrid Problem-Based Learning in Digital Image Processing: A Case Study	2018
Incorporating Woodwork Fabrication into the Integrated Teaching and Learning of Civil Engineering Students	2018
Investigating the impact of blended learning on academic performance in a first semester college physics course	2018
Moray: Bridging an Ancient Culture of Innovation with Emerging Pedagogies in Engineering	2018
Not hard to sway': a case study of student engagement in two large engineering classes	2018
Pedagogical and technological replanning: a successful case study on integration and transversal skills for engineering freshmen	2018
Perspectives on pedagogical change: instructor and student experiences of a newly implemented undergraduate engineering dynamics curriculum	2018
Pre-Service Teachers' Attitudes Towards Technology, Engagement in Active Learning, and Creativity as Predictors of Ability to Innovate	2018
Response spectrum devices for active learning in earthquake engineering education	2018
Roadmapping towards sustainability proficiency in engineering education	2018
Strategies to improve learning of all students in a class	2018
Teaching customer-centric operations management - evidence from an experiential learning-oriented mass customisation class	2018
Teaching User-Centered Design for More Sustainable Infrastructure through Role-Play and Experiential Learning	2018
The WHATs and HOWs of maturing computational and software engineering skills in Russian higher education institutions	2018
Turning a traditional teaching setting into a feedback-rich environment	2018
US experiences with STEM education reform and implications for Asia	2018
The positive effect of in-class clicker questions on later exams depends on initial student performance level but not question format	2018
Active Learning Strategy at a Collegewide Level in NIT, Gifu College	2018
The effectiveness of a head-heart-hands model for natural and environmental science learning in urban schools	2018
Motivational active learning: An integrated approach to teaching and learning process control	2018
Remote and Virtual Labs for Engineering Education 4.0: Achievements of the ELLI project at the TU Dortmund University,	2018
On the students' perceptions of the knowledge formation when submitted to a Project-Based Learning environment using web applications	2018
A Novel Group Engagement Score for Virtual Learning Environments	2017
Activating learning in engineering education using ICT and the concept of Flipping the classroom'	2017
After the Workshop: A Case Study of Post-Workshop Implementation of Active Learning in an Electrical Engineering Course	2017
Aligning professional skills and active learning methods: an application for information and communications technology engineering	2017
An Action Research Study from Implementing the Flipped Classroom Model in Primary School History Teaching and Learning	2017
An Interactive and Comprehensive Software Tool to Promote Active Learning in the Loop Shaping Control System Design	2017
Application of hands-on simulation games to improve classroom experience	2017
Applying Active Methodologies for Teaching Software Engineering in Computer Engineering	2017
Applying Active Methodologies for Teaching Software Engineering in Computer Engineering	2017
Assessing the effectiveness of a hybrid-flipped model of learning on fluid mechanics instruction: overall course performance, homework, and far- and near-transfer of learning	2017
Augmenting Primary and Secondary Education with Polymer Science and Engineering	2017
Classroom sound can be used to classify teaching practices in college science courses	2017

Creating an Instrument to Measure Student Response to Instructional Practices	2017
Designing Solutions by a Student Centred Approach: Integration of Chemical Process Simulation with Statistical Tools to Improve Distillation Systems	2017
Does Active Learning Contribute to Transfer Intent Among 2-Year College Students Beginning in STEM?	2017
Educational Technology in Flipped Course Design	2017
Engineering Courses on Computational Thinking Through Solving Problems in Artificial Intelligence	2017
Engineering students' experiences of interactive teaching in calculus	2017
Enhancing Diversity in Undergraduate Science: Self-Efficacy Drives Performance Gains with Active Learning	2017
GiveMe Shelter: a people-centred design process for promoting independent inquiry-led learning in engineering	2017
How to facilitate freshmen learning and support their transition to a university study environment	2017
Humanizing Instructional Videos in Physics: When Less Is More	2017
Implementing Project-Based Learning in a Civil Engineering Course: A Practitioner's Perspective	2017
Motivation of Engineering Students Participating in Multinational Design Projects Comparison Based on Gender and Class Status	2017
Paired peer learning through engineering education outreach	2017
PBL Model for Single Courses of Control Education	2017
Physical Physics - Learning and Assessing Concepts in a novel way	2017
Project-based learning in engineering design in Bulgaria: expectations, experiments and results	2017
Social and Environmental Justice in the Chemistry Classroom	2017
Stakeholder Views of Nanosilver Linings: Macroethics Education and Automated Text Analysis Through Participatory Governance Role Play in a Workshop Format	2017
Strengths, Limitations and Challenges in the Implementation of Active Learning in an Undergraduate Course of Logistics Technology	2017
Students' perceptions of the flipped classroom model in an engineering course: a case study	2017
Sustainable Mobility for the Future: Development and Implementation of a Sustainable Transportation Planning Course	2017
Teacher in a problem-based learning environment - Jack of all trades?	2017
Teaching Business Management to Engineers: The Impact of Interactive Lectures	2017
Teaching Evaluation Practices in Engineering Programs: Current Approaches and Usefulness	2017
Teaching Sustainability Using an Active Learning Constructivist Approach: Discipline-Specific Case Studies in Higher Education	2017
The acquisition and transfer of knowledge of electrokinetic-hydrodynamics (EKHD) fundamentals: an introductory graduate-level course	2017
The ICAP Active Learning Framework Predicts the Learning Gains Observed in Intensely Active Classroom Experiences	2017
The philosophical and pedagogical underpinnings of Active Learning in Engineering Education	2017
The positive influence of active learning in a lecture hall: an analysis of normalised gain scores in introductory environmental engineering	2017
Transdisciplinary Collaborative Research Exploration for Undergraduate Engineering Students	2017
Using role-playing games to broaden engineering education	2017
Values Affirmation Intervention Reduces Achievement Gap between Underrepresented Minority and White Students in Introductory Biology Classes	2017
Why research-informed teaching in engineering education? A review of the evidence	2017
Learning Materials Made from Senior Graduates' Viewpoint and the Practical Engineering Credit Point System	2017
Team-based learning for first year engineering students	2017
Automatic Control Education in a CDIO Perspective	2017
Learning Factory: The Path to Industry 4.0	2017
A Contextualized System for Supporting Active Learning	2016
Active Learning and Student Engagement via 3D Printing and Design: Integrating Undergraduate Research, Service Learning, and Cross-Disciplinary Collaborations	2016
An active, collaborative approach to learning skills in flow cytometry	2016
An Undergraduate Research Experience Studying Ras and Ras Mutants	2016

Applying Andragogy to Promote Active Learning in Adult Education in Russia	2016
Assessing faculty professional development in STEM higher education: Sustainability of outcomes	2016
Cooperative or collaborative learning: Is there a difference in university students' perceptions?	2016
Differences in Classroom Engagement of Asian American Engineering Students	2016
ENCOURAGING COLLABORATIVE INTERACTION IN EFL LEARNERS WITH VIDEO ROLE-PLAYS	2016
Evaluating the Effectiveness of Game-Based Learning on Improvement of Student Learning Outcomes within a Sophomore Level Chemical Product Design Class	2016
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