Understanding Engineering through the Engineering Journal of the Colombian University of Los Andes

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***Abstract*—The University of Los Andes, founded in Bogota - Colombia in 1948, was the country's first private university independent from political parties and religious groups. Los Andes is an autonomous, independent, and innovative institution that started out with seven programs, 79 students, and 16 professors. Today, the university has 33 undergraduate programs, 51 masters, 15 doctoral programs, and more than 17,000 students. Among all, the school of engineering has 9 undergraduate programs, 13 masters, one doctoral program, and 38% of all students in the university. The school of engineering was ranked second among Colombian universities, making it a national reference in the field. The purpose of this study is to understand the concept of engineering at University of Los Andes through the papers published in its engineering journal, created and edited by University of Los Andes' school of engineering since 1991. All the issues of Los Andes Journal of Engineering were analyzed, using their section, title, and abstract as the unit of the Content Analysis. The analysis presented a comprehensive description of the journal themes, emerging from the data set. The sample included 43 issues created since 1991, mostly twice per year. The analysis also took into account the categorization defined by the editors for triangulation of the themes emerged from this analysis. Five main engineering topics were found in the articles: traditional fields focused on discipline-based contributions, studies about specific engineering topics, generic skills, boundary publications in which articles showed a connection between engineering and non-engineering disciplines or challenges, and understanding the significance of engineering history and philosophy. The majority of the articles published since 1991 have a technical approach; however, a wider variety of approaches were found in the second half of the journal life, where historical, policy, and opinion-oriented articles were published.**

Keywords—Journal of Engineering; Content analysis; Engineering definition.

I. INTRODUCTION

The notion of what engineering knowledge and work means has change throughout the years. A tension between practical and theoretical approach to how engineering should be taught has been present since its very beginning [1]; a technical approach was the main goal for training engineers before 1900 [2]. In fact, the connection between engineering and engine words in English, in contrast to other languages such as Spanish, in which the machine does not have a similar word (engine: *motor*, engineering: *ingeniería*), has created a stereotype in which the engineer's profession is strongly linked with fixing machines. Furthermore, in languages like Spanish, besides an inexistent connection with handcraft, there is a direct link with ingenuity (*ingenio* and *ingeniería*), which connects its meaning with formal science [2]. The tension moved towards the need for more scientific training when Engineering was driven by military and civil needs [2], [3] and research for innovation was a priority. The documentation and publication of engineers work have made possible to track the notion of what engineer meant and how this notion has changed along centuries.

Particularly in Colombia, having Spanish as the official language, has made the connection between engineering and ingenuity stronger than the link between engine and engineering; although the tension between a practical and a theoretical approach has been also present. The study of historical archives allows illustrating those engineering definitions and stereotypes that are constantly evolving through time. One way to study this changing notion of what engineering means can be performed through Content Analysis, tracking key words and notions through periodical documents such as academic journals related to engineering [4].

The case of the University of Los Andes illustrates a specific Colombian example of how the notion of engineering has change, within a tension between practical and scientific-research needs. University of Los Andes was funded in 1948 aiming to address the need of quality education from an independent point of view, providing an atmosphere of pluralism, tolerance, and respect of ideas in a critical and ethical way [5]. One of the larger programs within the university was, and still is, engineering accounting for more than 28% of undergraduate programs and more than 26% of graduate programs [6].

The Engineering Journal of University of Los Andes was the ninth Colombian journal related to technology, created during a time where Colombian universities where focused on teaching, and researching was a secondary part of some professors work [7], [8].

The purpose of this study is to analyze how the authors and editors of the journal of engineering conceive engineering knowledge. This analysis may suggest how the school of engineering at university of Los Andes conceives what engineering knowledge is. The research questions that guide this study are:

What topics are prioritized in the journal of engineering?

How do the topics have varied through time?

How do the topics prioritized connect to some definitions of engineering found in literature?

II. METHOD

This study used Content Analysis as the qualitative approach for analyzing how the editorial committee of the Journal of Engineering understands what engineering is and what does engineering research imply, by revising what has been published in the journal during its 25 years of existence. This technique is used to systematically extract information, aiming to produce an objective and holistic interpretation of a sample of commonly verbal material [4]. Using Content Analysis a large body of qualitative information can be reduce to themes or categories that allows to quantify and consolidate particular data for frequency and prioritization analysis that yield to meaningful findings related to a culture, individual perceptions, or group interactions [4].

In particular, Archival Research uses published documents as sample for the Content Analysis. This is a convenient sample due to its public nature, providing a suitable approach to historical and cultural analysis [4]. This type of research was appropriate for this study because it allowed using the entire universe as sample (all Engineering Journal issues published) for revising what topics and approaches to those topics the editorial committee of the Journal prioritized.

A. Unit of Analysis

The unit of analysis used for this Content Analysis was a paper published within the Engineering Journal regardless of it academic or organizational nature, which means that every paper in every issue of the journal was taken into account for the analysis. 25 years (since 1991 to the present), 43 issues (mainly 2 issues per year), and 579 papers were used in the analysis, and within each paper, the title, section, and abstract were revised. Fig. 1 shows the distribution of papers and issues through all years of publications.

B. Codification System

In order to conduct the Content Analysis, themes were used as codes, which allowed extracting the main idea of the article, using short sentences of phrases [4]. Although this study uses themes as main categories, it is not consider a Thematic Analysis because it tends to quantify information in order to seek objective and holistic information, instead of qualifying for a more interpretative approach [9]. However, according to Braun and Clarke [10], Thematic Analysis is a broad and flexible methodology that helps to conduct qualitative designs such as Content Analysis [10], the latter being the method used in this paper. The authors assert that conducting a rigorous thematic analysis requires some coding considerations, which are taking into account for this study due to the thematic nature of the coding schema.

One consideration was what counts as a theme: Three types of themes were selected for coding. First, the section of the journal where the article was located was coded as the explicit focus of the paper; second, the topic of the paper was coded as engineering content; and lastly, the type of paper (i.e. historical, technical, policy or opinion oriented) was coded as the implicit focus of the paper. This differentiation allowed analyzing the organization consistency within sections, the differences between types of articles, and the relation between type of articles and their content. Also, the type of analysis that was performed accounted for a rich description of the data set, which means that the analysis allowed obtaining a general view of the entire Journal of Engineering instead of focusing on one particular aspect. In addition, the analysis performed was inductive [10], letting that the themes emerged directly from the data. Because of this inductive approach, the categories used such as Technical, Opinion, or Dossier were defined by the Journal itself. Another consideration was to use latent themes [10] due to the characteristics of Content Analysis. According to Vaismoradi and colleagues [9], this methodology expects a rich interpretation of the data. This process of coding is also constructionist due to its inductive and latent nature, and the evolving definitions of journal sections through years, which is explained within the results section of this paper.

As part of the Content Analysis, these themes emerging from the data were also quantified in order to identify the frequency in which the categories appeared in the journal, and the percentage in which the topics and types of publications were published.

The analysis performed in this study guided an identification of what counts as engineering according to the Journal of Engineering of University of Los Andes, which includes the understanding of what is considered an engineering technical work, an academic issue, and an opinion regarding engineering fields.

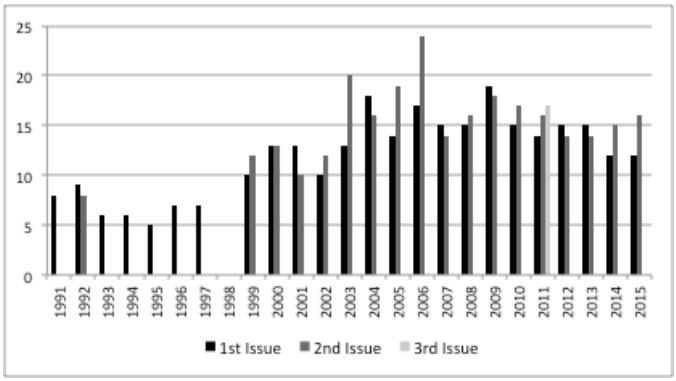

Figure 1 Distribution of Articles

1) Implicit Focus Analysis

This analysis included emerging categories based on article structure, which included empirical or theoretical approach, research-based publications or opinion-based papers, new research findings or historical approaches for understanding engineering field development, and technical or policy analysis.

2) Engineering Content Analysis

This analysis was based on word counting using Wordle[1]. A systematic search for keywords were performed using all the abstracts and cleaning non-relevant words such as connectors, common words, other non-related words such as size, number, or large, and similar words in which case all forms for the same construct were taken into account with the same word (e.g. risk and risks). This cleaning process had an iterative method that started with 10 maximum words as constraint for Wordle, and within each iteration the following actions were performed:

1. Clean non-relevant words shown in Wordle
2. Include all keywords shown in a category list
3. Increment the maximum words allowed in 10

This procedure was repeated until no new engineering keywords were shown, which was during the 21st iteration were 220 maximum words were allowed and 150 keywords were included into the category list. Finally, these keywords were coded in to the final Engineering Content sub-themes by contrasting with the original abstracts.

C. Reliavility and Validity

According to Smith [10], reliability in Content Analysis is related to repeatability, homogeneity, and stability. In this study, stability was achieved due to the large number of articles analyzed. Because 579 were coded using three types of codes, and a maximum of 38 sub-themes (within Engineering Content coding), the stability was reached rapidly, reaching at least 8 data points per emerging category and 3 data points per observable category. In addition, the creation of the implicit focus category allowed controlling for homogeneity within sections, which was not consistent within the explicit sections of the journal. Finally, the method presented in this paper allows for repeatability, which was tested by analyzing a set of the data, and as a second stage analyzing the entire data. Likewise, the method is repeatable for other journals because the unit of analysis and the three types of themes apply to general journal structure.

Similarly, Smith [10] asserts that validity in Content Analysis is related to mitigating sampling bias and the ability to predict subsequent events. This study addressed this validity because there were no sampling (the entire universe of data points were selected), a triangulation with computational word frequency was performed, and the same researcher performed the codification of the entire data set.

III. Results

After cleaning and consolidating the 579 data points, the first categorization (explicit focus) was analyzed, emerging 12 sub-themes shown in table 1, first column. This type of coding was taken from the journal section classification. This structure evolved through the years, displaying some changes related to the importance and consistence of certain information along the journal life. The journal started with three sections: Academic information, related to programs, commencements and theses; Opinion, which included some articles related to the state of engineering research and education within the university and country; and Technical, which focused on the engineering fields' work, and remained until today. Although some categories had few data points (at least 3), this code was observable and was performed by the journal committees their selves, therefore there was no error involved in the process.

Table 1 Coding Schema

Explicit Focus	Implicit Focus	Engineering Content		
1. 20 Years 2. Dossier 3. Editorial 4. In Memoriam 5. Index 6. Academic Info. 7. Memory 8. Opinion 9. Point of View 10. Technical 11. PhD & Ms. Theses	1. Technical 2. Opinion 3. Policy 4. Historical 5. Non-research	1. Agriculture & Agroindustry 2. Bioengineering 3. Competitiveness & Innovation 4. Computer Science 5. Construction 6. Consulting 7. Contamination 8. Design 9. Education 10. Electronics 11. Energy Management and Resources 12. Engineering Disciplines (e.g. Mechanical, Chemical, etc.)	13. Engineering Research 14. Environment 15. Free Trade Agreement (FTA) 16. Globalization 17. Hydraulics 18. Housing 19. ICT 20. Industrial Processes 21. Infrastructure 22. Interdisciplinary 23. Journal 24. Materials 25. Memorable people	26. Mining 27. Mobility 28. Power 29. Profession 30. Resources 31. Risk Management 32. Seismology 33. Software 34. Technology 35. Telecommunications 36. University 37. Urban Planning 38. Water Management and Treatment

[1] http://www.wordle.net/advanced

After almost ten years with this organization, the journal changed its structure, creating new sections such as Dossier, specialized in a specific technical topic for each issue (See Editorial from issue 39); and Memory, which focused on historical studies related to the Dossier's topic for each issue. Other sections evolved like the Editorial, which evolved from Opinion passing through Points of view, having all the same characteristic: an opinion based sections, less rigorous than the Technical or Dossier. This sections included opinions about the journal itself, engineering as a profession, and some known engineers. Finally, some sections disappeared due to their non-research focus, such as Academic information, which included conferences information, dates for engineering program application, and lists of titles of Master thesis, PhD dissertations, academic programs, courses, research groups, and journal issues.

These changes in structure show an increased focus on technical matters, some variability within opinion-related sections, an emerging section with an historical perspective and the closure of non-research spaces within the journal. These changes gave to the journal a more research-oriented perspective, leaving the academic logistics to other ways of communication, and maintaining technical focus as the principal engineering research approach.

As a second stage for coding, a second type of themes was created using Implicit Focus as label. Under this type of coding, five sub-themes were created (Table 1, second column) according to the focus of the paper. During this process, implicit focus and explicit focus were contrasted to revise consistencies between categories and sections of the journal.

The first sub-theme, Technical, was created to identify the articles that had part or the whole engineering design process involved, which means that could include modeling, testing, creating or adapting technology, or analyzing empirical data. Fig. 2 shows how the percentage of technical papers tended to decrease through time. However, the total number of technical papers remains similar, with an increment during middle years (2003-2007). The majority of papers within this implicit focus category were part of mainly two explicit focus categories: Technical 82%, Dossier 15%.

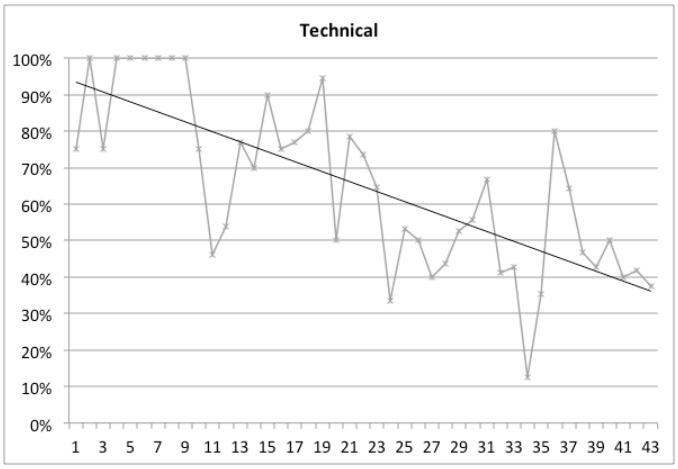

Figure 2 Technical papers published since 1991

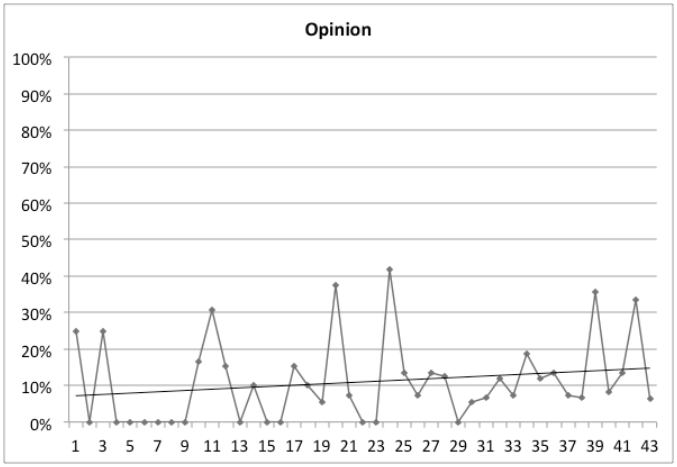

Figure 3 Opinion-related papers published since 1991

The second sub-theme within implicit focus was Opinion. This category included those papers that did not include an empirical or theoretical background as its main focus. Although some of these papers included a literature review, the main objective was to communicate a personal, or group opinion about certain engineering topic. Fig. 3 shows how the percentage of opinion-related papers tended to increase through time. The average of papers with an opinion implicit focus was 1.60 (compared to 8.14 technical); however, this category had a peak on 2006, year in which the journal published several interventions of the Free-Trade Agreement Forum. The majority of papers within this implicit focus category were part of mainly three explicit focus categories: Dossier 52% that included engineering forums interventions, Editorial 19% that included the views of the journal editorial committee, and Opinion 17% that included general authors' views.

The third sub-theme within implicit focus was Policy. This category included those papers that had an explicit policy analysis related to a certain engineering topic. These papers were mainly theoretical, although few had some other complementary focus such as technical, opinion, or historical. Fig. 4 shows how the percentage of policy-related papers tended to increase through time, with the highest rate of all

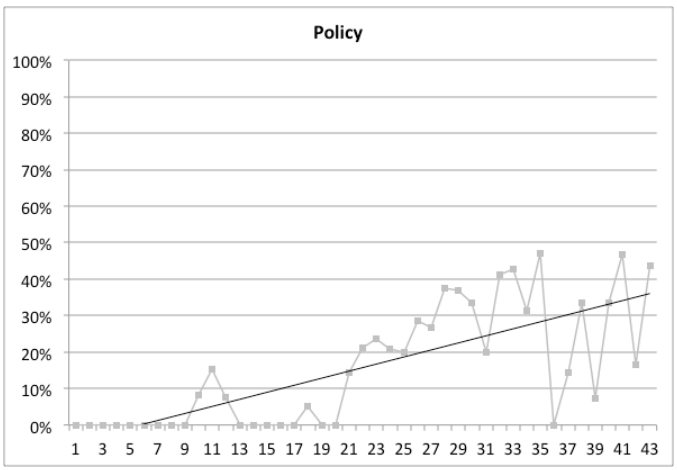

Figure 4 Policy papers published since 1991

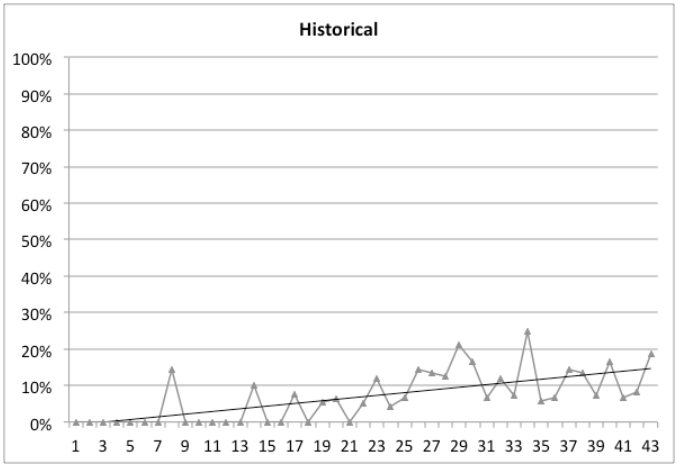

Figure 5 Historical papers published since 1991

implicit focus categories. The average of papers with an opinion implicit focus was 2.49 (the second highest average after technical); however, the majority of policy papers were published since 2006, almost doubling the average (4.08 between 2006 and 2016). The majority of papers within this implicit focus category were part of mainly one explicit focus category: Dossier 94%, which included current and relevant engineering topics, discussed some times during focused forums.

The forth sub-theme within implicit focus was Historical. This category included those papers with a historical analysis, which means that the author had an explicit approach to the engineering content in the past. This approach can be appreciated as a comparison of an engineering field between years or decades, the evolving process of certain engineering issue, or changes in the context related to certain engineering topic. Fig. 5 shows how the percentage of historical papers tended to increase through time, since the early issues of the journal. The average of papers with an historical implicit focus was 1.05 (the second lowest average after non-research); however, the majority of historical papers were published since 2006, almost doubling the average (1.86 between 2006 and 2016).

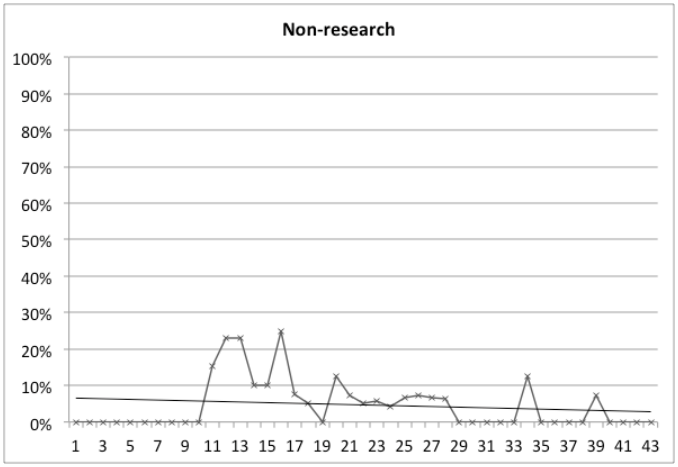

Figure 6 Non-Research papers published since 1991

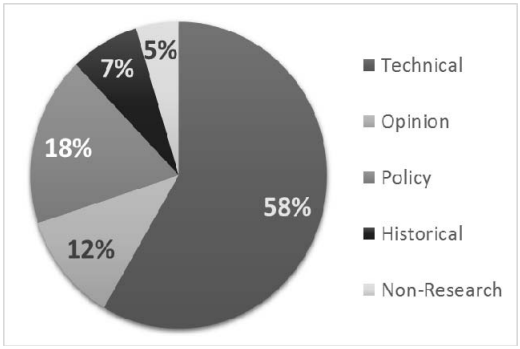

Figure 7 Implicit Focus distribution

The majority of papers within this implicit focus category were part of mainly two explicit focus categories: Memory 47% in which 21 out of 24 papers were historical, and Dossier 36% that had the highest variety of implicit focuses within.

Finally, the fifth sub-theme within implicit focus was Non-Research. This category included those publications within the journal that were not academic papers. These publications were primarily lists (Titles of Master theses and PhD's dissertation, programs, research groups, and national indexed journals) but also included academic information (such as information about programs applications and journal organization). This type of publications started on 2002, but decreased over time as Fig. 6 illustrates. The average of papers with a non-research implicit focus was 0.65 that is less than one publication per issue (the lowest average of all categories). The majority of papers within this implicit focus category were part of mainly two explicit focus categories: PhD & Ms. Theses (50%) in which all papers were non-research oriented, and Academic information (25%) in which 7 out of 15 papers were non-research oriented.

Although the percentage of technical articles decreased along the years with a higher rate compared to the changes in other categories (see Fig. 7), the total number of technical papers is the highest (350 out of 579), is the only implicit focus with at least one article per issue, and have the highest percentage of articles per issue, in 38 issues out of 43. This shows how the Engineering Journal has diversified the type of published papers, while maintaining the technical approach as primary focus.

The third and final type of codification performed for the content Analysis was the Engineering Content. This type of coding allowed identifying the main topics present in the journal. The sub-themes that emerged from the papers were consolidated according to Wordle word counting based on abstracts content. Fig. 8 shows the categorized Engineering Content themes, having the font size proportional to sub-theme frequency.

The Engineering Content codes can be consolidated into five main types of themes: A discipline-based contribution, where categories linked to an engineering field were included and the keyword linked to the theme was basically an engineering area of study (e.g. Civil, Mechanical, or Electronical engineering). Articles within these sub-themes

Figure 8 Engineering Content Sub-Themes

were primarily shown within the Dossier and were linked with the principal topic of the issue in which the article was published. A second type of engineering content themes included those related to a specific topic of engineering. For instance, keywords such as housing, telecommunication, materials, agroindustry, water or construction emerged from the abstracts. A third type of sub-themes was related to generic skills such as risk management, design (sub-theme that included keywords like evaluation, optimization, systemic, and sustainable). This category showed an increasing awareness of the importance of some traversal skills. A fourth type of engineering content was the boundary work, which means that engineering issues were linked to non-engineering ones, or interdisciplinary work was conducted. For instance, papers about best pedagogical practices in engineering classroom, or markets and economical research within an engineering field were part of the articles within this type of theme. Finally, a fifth type of sub-themes related to understanding engineering history and philosophy were found. Within this category articles related to research practices within engineering, the engineering profession, memorable engineers and their contributions to engineering were published.

IV. Conclusions

Through this Content Analysis study was possible to delineate how the Engineering Journal of University of Los Andes defines engineering, which topics are considered a priority, and what focus should be prioritized.

One of the main observations was that the journal structure broadens through time; in fact, recent issues have greater diversity of papers taken into account as part of the engineering field compared to older issues. In addition, the ratio of non-technical papers such as opinion, historical, and policy-related papers increased in relation to technical papers. Furthermore, the engineering content included a wider variety of topics, in which traditional engineering content such as materials engineering, urban planning and infrastructure were complemented with less traditional topics such as engineering education, research and profession, ethics, or peace & war. According to the data, the majority of the articles published since 1991 had a technical approach; however, there were a couple of issues where more than 50% of the articles accounted for non-technical studies (e.g. issues 24 and 34). This shows an inclusion of topics that broadens the traditional view of what engineering is to the journal editors.

It is interesting how interdisciplinary topics have become relevant issues within the engineering research. Fields like bioengineering, risk management, education, information security, economy, or climate change are considered to be crucial for society and therefore for the engineering community. This inclusiveness of areas and approaches to interdisciplinary matters is also considered critical within other engineering communities (e.g [11], [12], and [13]), which shows a development of the journal aligned with other engineering communities.

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