

Article

Digital Transformation of Engineering Ethics Awareness Education: A Visual Analysis Based on CiteSpace

Lihui Xiong¹ and Yu Sun^{1,*}¹ Yunnan Normal University, Kunming, Yunnan, 650500, China

* Correspondence: Yu Sun, Yunnan Normal University, Kunming, Yunnan, 650500, China

Abstract: Through in-depth analysis of relevant research literature from 2017 to 2024, the digital transformation path of engineering ethics education in the context of new engineering disciplines in China was further clarified. Based on the data on engineering ethics awareness and digital transformation of education collected from CNKI, data analysis and processing were conducted using CiteSpace visualization software, and a knowledge network map of authors and research institutions was constructed. By using knowledge maps such as "engineering ethics", "new engineering disciplines", and "course education", the research hot-spots and their evolution trends in this field were revealed, providing direction guidance for future research.

Keywords: engineering ethics; new engineering disciplines; course education

1. Introduction

The construction of the "New Engineering" framework places comprehensive demands on Chinese engineering universities, requiring them not only to solidify and advance their core professional and technical foundations but also to place greater emphasis on enhancing students' humanistic literacy and systematically incorporating professional ethics education throughout the cultivation process of engineering and technical talents [1]. Within this context, the digital transformation of engineering ethics awareness education emerges as a critical and timely imperative for contemporary engineering education, reflecting evolving societal expectations and the complex challenges posed by rapid technological advancement. This transformation calls for continuous innovation in pedagogical approaches, including the integration of digital tools, adaptive learning environments, and interactive platforms, aimed at elevating teaching quality and effectiveness. Such innovations enable educators to develop a new generation of high-caliber engineering professionals who possess not only strong technical expertise but also a profound ethical consciousness and social responsibility, equipping them to proactively address and adapt to the multifaceted needs of future societal development. Importantly, this transformation transcends mere internal reform within educational institutions; it embodies a broader, more holistic vision that seeks to harmonize cutting-edge scientific and technological progress with enduring humanistic values, thereby fostering a more ethically grounded and socially responsive engineering culture throughout society as a whole.

2. Data Sources and Research Methods

This study centers on a comprehensive review of research literature published in Popular Science Journals since the beginning of the 21st century, utilizing the China National Knowledge Infrastructure (CNKI) database as the primary data source. To ensure a targeted and relevant dataset, keyword retrieval was systematically conducted based on carefully selected themes, including "Engineering Ethics", "Emerging Engineering Educa-

Published: 30 July 2025



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tion", and "education Digital Transformation". The temporal scope of the search was confined to the period from January 1, 2017, through December 31, 2024, resulting in a collection of 1,219 documents, among which 1,016 are Chinese Academic Journal publications. To analyze this corpus, the study employed CiteSpace software (version 6.3.R1), a powerful bibliometric visualization tool designed for mapping knowledge domains and detecting emerging trends [2]. Leveraging bibliometric methodologies, CiteSpace facilitated the generation of keyword co-occurrence networks and cluster maps, which enabled both quantitative statistical analysis and intuitive visual representation of key thematic hotspots and their evolutionary trajectories within the global scholarly discourse surrounding Emerging Engineering Education and Engineering Ethics. This methodological approach provides an in-depth and holistic visualization of the ongoing digital transformation in engineering ethics education in China, revealing critical patterns, research foci, and potential future directions [3].

3. Bibliometric Analysis

3.1. Time Distribution

Historically, following the initiation of the Emerging Engineering Education construction in 2017, research activity on Engineering Ethics witnessed its first significant peak (Figure 1). This surge was closely associated with a series of programmatic documents issued by the Ministry of Education, including landmark policies such as the "Fudan Consensus" and the "Tianjin University Action Plan". These initiatives systematically integrated ethics education into the engineering talent training system, encouraging universities across China to establish specialized ethics courses and foster interdisciplinary research collaborations that bridge technical and humanistic disciplines [2]. In 2019, the strategic adoption of the "National Science and Technology Ethics Committee Establishment Plan" by the Central Commission for Deepening Overall Reform marked a milestone in the formalization and institutionalization of science and technology ethics governance. This plan catalyzed comprehensive organizational construction and policy reinforcement aimed at guiding ethical considerations in scientific and technological development at a national level. However, the outbreak of the Covid-19 pandemic disrupted the research landscape, causing significant delays in the publication and dissemination of research outcomes, with many findings deferred until 2022 [4]. Despite these challenges, the overall trajectory reflects a strengthening emphasis on embedding ethical awareness within engineering education as a foundational element of cultivating responsible and innovative engineering professionals.

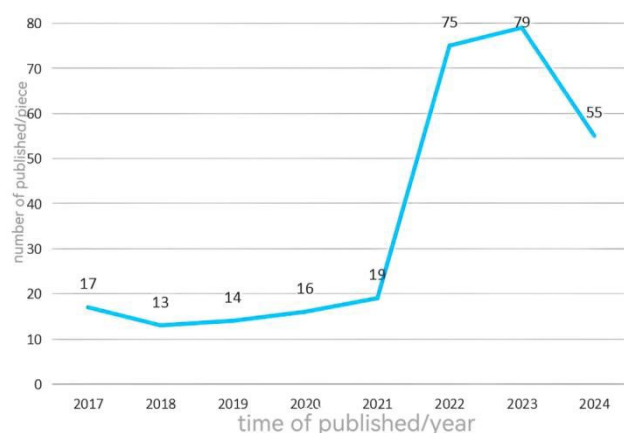


Figure 1. Publication Trends in Engineering Ethics Awareness in CNKI.

3.2. Keyword Highlighting and Atlas Analysis

Through comprehensive analysis of keyword highlighting, it is possible to systematically identify topics that have garnered widespread attention and have become focal points within a specific academic field. In this study, CiteSpace software was employed to select the "Keyword" node for conducting keyword co-occurrence analysis based on a substantial dataset of 1,185 records. This process generated a detailed visualization map that reveals not only the frequency but also the relational patterns among key terms, facilitating a deeper understanding of the structural dynamics of the research domain [5]. As presented in Table 1, within the context of Emerging Engineering Education, the study highlights core keywords along with their respective word frequencies and centrality metrics related to educational Digital Transformation, systematically organized by publication year. These representative keywords and their associated articles serve as critical indicators of the evolving research hotspots and provide valuable insights into the developmental trajectory and thematic shifts of this interdisciplinary field. Such analyses enable scholars and educators to pinpoint emerging trends, assess the influence of various research strands, and inform future investigations aimed at enhancing the integration of digital technologies within engineering ethics education.

Table 1. High-Frequency Keyword Co-occurrence Frequency and Centrality from 2020 to 2024.

Number	Frequency	Centrality	Year	Keyword
1	134	1.06	2020	Engineering ethics
2	72	0.52	2020	Emerging Engineering Education
3	55	0.25	2021	Curriculum ideological and political education
4	15	0	2022	Teaching reform
5	12	0.02	2022	Case teaching
6	10	0	2020	Engineering education
7	9	0.01	2021	Talent development
8	6	0.01	2022	Case teaching
9	5	0	2024	Instructional design
10	5	0	2024	Instructional design

A keyword centrality exceeding 0.1 is generally considered to indicate strong influence. Table 1 presents high-frequency keywords, their co-occurrence frequencies, and centrality data in Engineering Ethics awareness research under the context of Emerging Engineering Education from 2020 to 2024. In terms of frequency distribution, "Engineering Ethics" (134 occurrences) and "Emerging Engineering Education" (72 occurrences) dominated in 2020. This high-frequency concentration directly reflects the policy orientation of the Ministry of Education's Guidelines for Research and Practice Projects on Emerging Engineering Education. Specifically, these projects refer to Emerging Engineering Education initiatives that follow the recommendation, submission, review, and approval processes outlined in the Guidelines for Research and Practice Projects on Emerging Engineering Education [6]. As a strategic initiative promoting China's transformation from a large engineering education system to a globally competitive one, Emerging Engineering Education research and practice projects also represent an upgraded version of the Excellence Plan [7]. Data show that in 2021, "curriculum ideological and political education" ranked third with 55 occurrences, reflecting the growing integration trend between ideological and political education and specialized courses under policy guidance. That same year marked the comprehensive implementation of the Guiding Outline for Curriculum Ideological and Political Education Construction in Higher Education Institutions, which required embedding value cultivation into knowledge transmission. This institutional arrangement spurred numerous interdisciplinary studies combining "Engineering Ethics" and "curriculum ideological and political education". After 2022, the trend toward fragmentation of research hotspots became increasingly evident, with practical themes such

as "teaching reform" (15 occurrences) and "case teaching" (12 occurrences) sharply declining in frequency, and by 2024, only marginal expressions like "teaching practice" (5 occurrences) and "instructional design" (5 occurrences) remained [8].

3.3. Keyword Timeline Analysis

Keyword timeline analysis serves as an effective bibliometric tool to systematically track the frequency, emergence, and evolutionary trends of specific keywords or thematic topics over an extended period, thereby providing valuable insights into the dynamic development of a research field [9]. As illustrated in Figure 3, the keyword timeline knowledge map reflects the scholarly focus on Emerging Engineering Education and Engineering Ethics awareness across recent years. Notably, in 2020, foundational keywords such as "Emerging Engineering Education", "Engineering Ethics", and "curriculum ideological and political education" surfaced prominently, indicating sustained and widespread research interest in these core areas [10]. Despite this focus, a 2020 survey conducted by the China Association for Science and Technology revealed that a considerable number of science and technology professionals still exhibited insufficient awareness and understanding of scientific and technological ethics, highlighting persistent gaps and challenges within the field. Progressing into 2021, new keywords emerged, including "collaborative education", "talent development", and "ethical guidelines", which underscore an increasing academic and policy emphasis on addressing the complex ethical challenges posed by rapid scientific and technological advancements [11-13]. Between 2022 and 2023, the continuity of topics such as "teaching reform", "engineering education", "responsibility ethics", and "scientific and technological ethics" further signals ongoing efforts to refine and adapt educational strategies in response to evolving societal and technological contexts. In the broader framework of the Digital Transformation of Engineering Ethics education, it is imperative to continually adapt and align educational practices with the developmental demands of the contemporary era. Emerging Engineering Education, in particular, advocates for a strong interdisciplinary integration, fostering both innovation and practical skillsets, while Digital Transformation represents a transformative force driving comprehensive educational reform [14]. Together, these trends highlight a multifaceted approach aimed at cultivating ethically conscious, innovative engineering professionals equipped to navigate the complexities of modern technological society.

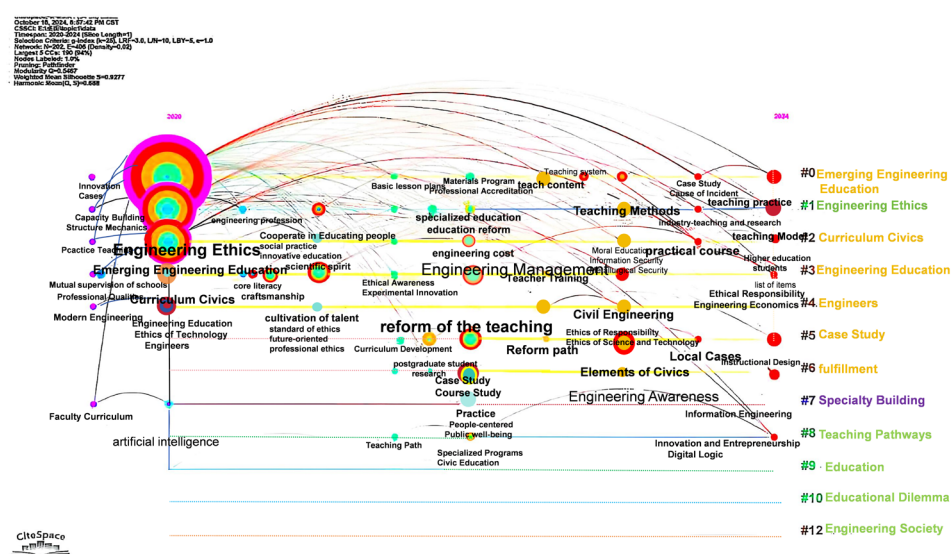


Figure 2. A Keyword Timeline Knowledge Graph of Emerging Engineering Education Engineering Ethics Awareness Research Literature (2020–2024).

4. Conclusion and Discussion

Under the background of the new engineering discipline, the digital transformation of engineering ethics education faces many challenges, mainly reflected in the double dilemma of theory and practice. On one hand, policy stagnation is evident; although "curriculum ideological and political education" appears frequently, it lacks centrality. Most studies merely interpret or restate policy documents without thoroughly exploring the integration of ideological and political elements with course content, resulting in a lack of systematic fusion framework. On the other hand, theoretical innovation remains weak, with foundational research centered on core concepts such as "Emerging Engineering Education" and "Engineering Ethics". Repetitive discussions are common, while new perspectives are rare. Although the number of publications from 2020 to 2023 is substantial, most focus on policy interpretation, current situation descriptions, or case compilations, with limited attention given to detailed aspects such as specific implementation strategies of Digital Transformation and the development of ethical decision-making models, indicating an overall shallow depth of research.

Meanwhile, technological empowerment also poses potential risks of alienation. In Digital Transformation, although MOOC platforms and intelligent assessment systems offer advantages, over reliance on these tools transforms ethics education into mere knowledge transmission, lacking in-depth interactive communication and hindering the development of students' capacity for value judgment, thereby weakening their ability to address real-world ethical issues. Moreover, the digitalization of education involves vast amounts of student personal information, carrying risks of privacy breaches due to technical vulnerabilities, insufficient security protection, or malicious attacks. For instance, in 2021, an off-campus training institution in eastern China illegally acquired student data, highlighting vulnerabilities in data management and underscoring the importance of legal measures for privacy protection. Currently, the Engineering Ethics Education system remains inadequate in its systematic exploration of data ethics.

In addition, the problem of bias in the orientation of educational evaluation should not be overlooked. Current educational assessments rely heavily on quantitative indicators such as publication records and the number of courses developed, causing teachers to treat Digital Transformation as merely a "technical packaging project" that prioritizes form over substance. This approach undermines Teaching Quality and neglects students' learning outcomes and capability development, resulting in a developmental dilemma characterized by "form over content" and a "quantitative evaluation paradox". Therefore, it is essential to thoroughly analyze curriculum needs and establish an assessment system guided by the objectives of Emerging Engineering Education, with a focus on evaluating key competencies to ensure educational quality. At the same time, interdisciplinary collaboration should be emphasized to improve the quality of Engineering Ethics Education and cultivate innovative talents who meet the demands of the new era.

Author Contributions: S.Y. conceived the idea of the study. X.L.H analyzed the data and wrote the paper.

Funding: The undergraduate education reform project of Yunnan Province (JG2024023), the Yunnan Provincial Science and Technology Plan Project(202404AL030001), and the education reform project of Yunnan Normal University, titled "Emerging Engineering Education Oriented Engineering Ethics Awareness Education Digital Transformation".

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