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Addressing Skills Shortages through Low-Code/No-Code: Skill Profiles and Implementation Challenges

Paul Rozbitski
0009-0008-5413-0165
Technische Hochschule Mittelhessen (THM) – University of Applied Sciences
THM Business School
Giessen, Germany
Email: paul.rozbitski@w.thm.de

Christian Leyh
0000-0003-0535-0336
Technische Hochschule Mittelhessen (THM) – University of Applied Sciences
THM Business School
Giessen, Germany
Email: christian.leyh@w.thm.de

Ching-Ho Ip
Technische Hochschule Mittelhessen (THM) – University of Applied Sciences
THM Business School
Giessen, Germany
Email: ching-ho.ip@w.thm.de

***Abstract*—Low-code/no-code (LCNC) platforms promise low-barrier access to software development, increased efficiency, and programming with little to no code. This paper explores whether it is really possible to create software without writing code and with little programming knowledge. Using a systematic literature analysis, we lay a foundation for future research on the skills needed by citizen developers using LCNC tools in corporate and public-sector contexts. Our analysis of 58 articles identifies three key skill categories: hard skills, such as programming and working with APIs; soft skills, such as communication and collaboration; and domain-specific knowledge. However, challenges exist in the upskilling process. Additionally, generative AI (GenAI) shows potential to expand LCNC capabilities. Nevertheless, the intersection of LCNC and public-sector transformation remains underexplored, highlighting the need for deeper studies focused on sector-specific challenges, use cases, and long-term adoption.**

***Index Terms*—Low-Code, No-Code, Citizen Developer, Skills, Innovations, Digital Transformation.**

I. Introduction

INFORMATION and communication technology (ICT) has undergone rapid changes over the decades—particularly in the last ten to fifteen years—and has had a far-reaching impact on almost every aspect of daily life. These changes and the associated digitalization have caused not only companies but also public institutions, organizations, and private individuals to increasingly shift their activities to the digital world. Industrial and commercial companies are increasingly utilizing the potential of e-commerce to tap into new market opportunities; public authorities are turning to e-government to reduce the administrative workload; and social interactions are increasingly shifting to the digital world of social networks. Even a large proportion of global financial transactions would be almost inconceivable without the use of ICT [1] As a result, digitalization and digital transformation are far more than just buzzwords: they have become decisive strategic competitive factors. Digitalization is fundamentally changing the economy and society and shaping the way we live and work in unprecedented ways [1], [2].

For companies, digitalization opens up the opportunity to develop and establish new business models. In order to actualize these new business models as well as to remain competitive in global markets, the majority of companies must deal with the challenges of digitalization and digital transformation. Relatedly—and also revealed by the global crises of recent years—a critical characteristic of successful companies has been their ability to adapt quickly to external circumstances, respond to external factors, and become a learning organization that quickly adopts innovations, with a focus not only on efficiency but also on resilience. Digitalization can be a key enabler of innovations and competitiveness; organizations that do not push ahead with digitalization risk falling behind, because they may struggle to adapt to changing market conditions and external factors [3], [4].

Digitalization has been a central topic in the private sector for many years and is now often considered an integral part of business operations. At the same time, digitalization is also of great importance for public administrations, because administrations are often in contact with citizens, work with many people, and link infrastructure; therefore, the efficiency of administration has an impact on cities and municipalities [5]. Public administrations also face digitization challenges and pursue the goal of improving their own processes. Specifically, there is a fundamental need for e-government services among the German population, as the range of services on offer is too limited: according to the Bitkom survey examining people's preferences regarding administrative services, 79% of respondents consider Germany to be lagging behind regarding digitalization, and 78% would like to see significantly more investment in the digitalization of public administration. The use of artificial intelligence (AI) is particularly in demand: 61% are in favor of public authorities using AI [6]. Accordingly, given these aspects, the focus of research on digitalization should not only be on companies but also on public institutions with numerous stakeholders.

In addition to the organizational perspective on the benefits of digitalization, there are also macroeconomic and labor-market implications. Automation and the implementation of software systems can reshape the labor market, leading to job

losses and the creation of new job profiles. The difference between the demand and the supply of qualifications leads to a skill mismatch; it remains uncertain whether there will be enough new jobs for those who have lost their jobs, and whether they will be able to fill these positions. Those with medium qualifications are particularly at risk [7]. One thing is certain: there will be "losers of automation"—i.e., people who are unable to find a job in the long term or who are forced to take underpaid jobs in other regions [8].

The effects of skill mismatch are already evident in Germany, where small and medium-sized enterprises (SMEs) and public authorities are struggling to recruit qualified professionals despite the fact that the number of registered unemployed people far exceeds the number of vacancies [9], [10]. In 2023, German SMEs reported significant difficulties in filling information technology (IT) positions, with 149,000 roles remaining unfilled—almost twice the number of vacancies recorded five years earlier. According to a Bitkom study examining the shortage of IT professionals across all sectors, Germany could face a shortage of around 663,000 IT professionals by 2040 [11]. Therefore, organizations must take action to avoid the problems associated with a shortage of skilled employees. Introducing personnel development measures could help bridge the gap between the qualifications on offer and those in demand [7].

Innovative approaches such as citizen development (CD) and low-code/no-code (LCNC) are well suited to this purpose. People without in-depth IT knowledge could use LCNC platforms to automate processes and develop applications. Through CD, companies can reduce the workload of IT departments by enabling employees in other departments to develop their own solutions, thereby reducing their dependence on IT professionals [12], [13]. CD and LCNC can also help drive and promote digitalization by making use of existing employees.

Given the current developments and the opportunities that LCNC can provide for companies and governmental institutions, this paper focuses on two research questions (RQs) that address the tension between the usage of LCNC and the necessary employee skills and competencies:

RQ1: What competencies are discussed in the literature in the context of LCNC platforms?

RQ2: What is the state of research on LCNC platforms in the public sector, and what skill profiles and implementation challenges are discussed in this context?

To answer these research questions, our paper proceeds as follows. After the introduction, a short theoretical background related to LCNC platforms is provided; this includes information about the typical users of these platforms, as well as their advantages and disadvantages. Thereafter, in Section 3, we describe our methodology (namely systematic literature review) to make our analysis reproducible. Section 4 presents the results of the literature review, highlighting the most discussed topics. In Section 5, we discuss the results of our analysis from different perspectives. Finally, the paper concludes with a summary and an outlook regarding potential further research steps.

II. Theoretical Background

A. Citizen Developers

Employees in specialist departments have in-depth domain knowledge and are familiar with the workflows in their respective areas. However, due to a lack of formal programming education and skills, they are often unable to develop digital solutions on their own. At the same time, IT departments that could take on such tasks are often overloaded [13], which leads to a backlog of innovation-related activities due to a focus on operational tasks [14].

In this context, the term citizen developers is employed to denote individuals who lack extensive expertise in IT yet employ platforms to automate processes and develop applications. These people are guided by platforms, which are toolboxes containing the necessary tools for creating customized applications.

B. Low-Code/No-Code Platforms

LCNC platforms are visual development environments that enable users to build software applications and automate workflows with little to no coding experience. The platforms provide users with a graphical user interface (GUI), where they can choose from available elements—such as buttons or application programming interface (API) calls—which can be visually combined through drag-and-drop into ready-to-use software [12].

While NC platforms require no programming knowledge, LC platforms require a little programming knowledge to make applications more flexible. With LC, existing modules can be extended with the user's own code [15].

Another important feature of LCNC platforms is that they not only provide support for visual programming and handle the entire application lifecycle, but they also typically provide integrated tools for the deployment process. They also can enable collaboration between software developers in terms of distributed work [16].

Transferring selected development work to citizen developers reduces the need for expensive IT expertise [17]. CD relieves the strain on scarce IT capacity, as implementations can be distributed across more resources. In particular, this reduces technical dependencies on IT departments; as a result, professional developers can focus on more strategic and value-adding tasks [18].

LCNC platforms combine declarative programming and model-driven development with visual interfaces, making software development more user-friendly and efficient [18]. These advantages have led to their high adoption among non-technical users looking to leverage their strengths. However, professional developers are skeptical about using LCNC platforms, which they consider to be inferior to traditional programming tools [19], [20].

C. Advantages and Challenges of LCNC Platforms

The advantages of LCNC platforms are well documented in the literature. One particularly interesting feature of such platforms is that they have a very low barrier to entry for non-programmers. This has led to the democratization of software development, whereby more people can develop, which in turn enables companies to benefit from new, fast prototypes and innovations [21], [19]. Furthermore, according to expert assessments, LCNC application development can in some cases be at least twice as fast as traditional code-based development [17]. Response times to customer feature requests are also reduced due to faster implementation and shorter delivery times and cycles. Such platforms also emphasize the high agility of development processes. Overall, using LCNC platforms can lead to increased efficiency and productivity, thus saving costs [17], [18], [12]. Additionally, technical training and CD initiatives form a key part of LCNC platforms: targeted training and education programs introduce employees to basic and advanced digital skills, thereby helping companies to boost the digital literacy of their entire workforce [18].

On the other hand, the literature also highlights some challenges associated with LCNC platforms. These include difficult-to-estimate licensing costs, which nevertheless can be justified by faster development processes and potential resource savings related to expensive IT specialists [17], [22]. A bigger challenge is vendor lock-in, which has been highlighted by several authors. Users are tied to the platform manufacturers of their chosen platform, making it difficult to transfer solutions to another platform and thus reducing flexibility [17], [18], [22]. Therefore, it is important to choose the right LCNC platform; otherwise, the investment costs will be too high. Companies experience the difficulty of choosing the right LCNC platform from dozens of providers. To this end, a systematic approach can be adopted to address this challenge [22].

The last aspect that is often discussed is the quality dimension. To start, there are always concerns about data protection and IT security. Although certain security standards can be met or even enhanced by LCNC platforms, a significant number of citizen developers lack the necessary knowledge to ensure secure development. Additionally, these platforms can be hard to debug, because the underlying code is typically generated by the platform's developers and is not directly accessible to users, making it difficult to identify and maintain issues [17]. Opinions on data protection vary: some see advantages, while others warn of risks, particularly when citizen developers create applications [20].

D. Institutionalization and the Rise of LCNC

According to reports by Gartner and Forrester, the market for LCNC is growing year on year. These market research companies predict that this market will continue to grow as a result of the ongoing digital transformation, which is accelerating the demand for software while at the same time leading to skill shortages in the IT sector. As outlined above, as new digital products and services emerge and new markets are developed, the demand for digital skills rises. In an effort to reduce costs and increase efficiency while meeting the growing demand for software, organizations are increasingly institutionalizing LC solutions within their IT departments [23], [24]. This means that LC solutions are used by IT companies to develop and deliver professional software solutions for their customers. This results in the acceleration of the distribution of LCNC. Therefore, the LCNC market will continue to grow and reach a volume of $50 billion by 2028. The fact that larger providers of LCNC platforms are being bought by corporations such as Siemens also indicates the relevance of this topic [25].

Given the growing importance of LCNC platforms, especially regarding organizational usage, it is important to understand which providers are currently available on the market.

E. Overview of LCNC Vendors

To classify technology providers, especially in markets that are rapidly changing and growing, Gartner has developed a methodology for categorizing IT providers into four distinct categories. The measurement of various factors—such as geographical strategy, marketing strategy, business model, and innovative strength—contribute to the assessment of "completeness of vision." Other criteria—such as customer experience, product or service quality, responsiveness to market changes, and operational performance—are used to measure the "ability to execute" [26]. By combining these two dimensions, Gartner categorizes vendors into four groups: "Leaders," "Challengers," "Visionaries," and "Niche Players."

- Leaders are highly competitive, have a strong market presence, possess a clear vision, demonstrate strong ability to execute, and are well positioned for the future. According to the Gartner report on LCNC from 2024, the following vendors are classified as Leaders: Mendix, OutSystems, Microsoft, Appian, ServiceNow, and Pegasystems.
- Challengers can also execute well today and may even dominate large market segments, but they do not have a clear vision of where the market is heading or they fail to respond to emerging trends. Challenger LCNC vendors include Oracle, Salesforce, and Zoho.
- Visionaries are companies with a clear vision of the future and an understanding of market trends, but they are not yet executing well or their products' features are not stable enough. The following vendors are classified as Visionaries: SAP and Retool.
- Niche players, such as Creatio and Newgen, focus successfully on a small part of the market or a specific geographical region. They may be a suitable choice for particular use cases or industries, but they do not yet match the breadth nor innovation of the other categories.

III. Methodology – Systematic Literature Review

Our literature review follows the approach of Webster and Watson [27]. The details of our methodology and the individual steps can be found in Fig. 1. The review consists of three main steps: literature search, topic identification, and analysis. In the first step, keywords and operators are used to identify the relevant literature. The second step involves identifying relevant topics. The final step consists of a detailed analysis of the literature and central topics. We selected relevant databases, defined the inclusion and exclusion criteria, documented the search process, and ultimately stored the identified literature in the Zotero literature management program

A. Phase 1 – Literature Search

We considered various databases and selected the following as sources: IEEE Xplore, ACM DL, and Springer Link. For titles, we used the search terms "low-code" and "no-code" along with additional keywords, such as "digital transformation" and "citizen developer," to achieve more precise results. Since the search functions in the individual databases are structured differently, we adapted the search fields depending on the database: in IEEE, we searched across all metadata; in ACM, within all abstracts; and in Springer Link, using the "with all the words" function.

The first phase of the literature search, which entailed a broad search, was carried out in November 2024. The time frame was set for 2019–2024 to ensure that the research was up to date. Sources with a high degree of relevance to the topic requirements were selected.

During the screening process, titles were first analyzed for their relevance. This was followed by in-depth reviews and summaries. Only German- and English-language sources were considered. Papers such as workshop documents, short articles, and articles without full-text access were excluded from the evaluation. After Zotero removed the duplicates, we were left with 151 articles, which provide a solid foundation for further research in the field of LCNC. However, in order to gain a better overview of certain topics, we narrowed the sample even further for our analysis.

The second step of the literature search involved conducting a targeted search guided by the research questions, particularly with regard to competencies (RQ1) and challenges in the public sector (RQ2). This step occurred in March 2025. The remaining articles were screened once more; in addition, further relevant articles were searched using backward and forward searches in accordance with the method described by [27]. We analyzed the papers until no new concepts emerged. In total, the steps in phase 1 led to the identification of 58 relevant papers that were analyzed in detail in the subsequent phases of our literature review. A complete list of these 58 papers is available upon request from the authors.

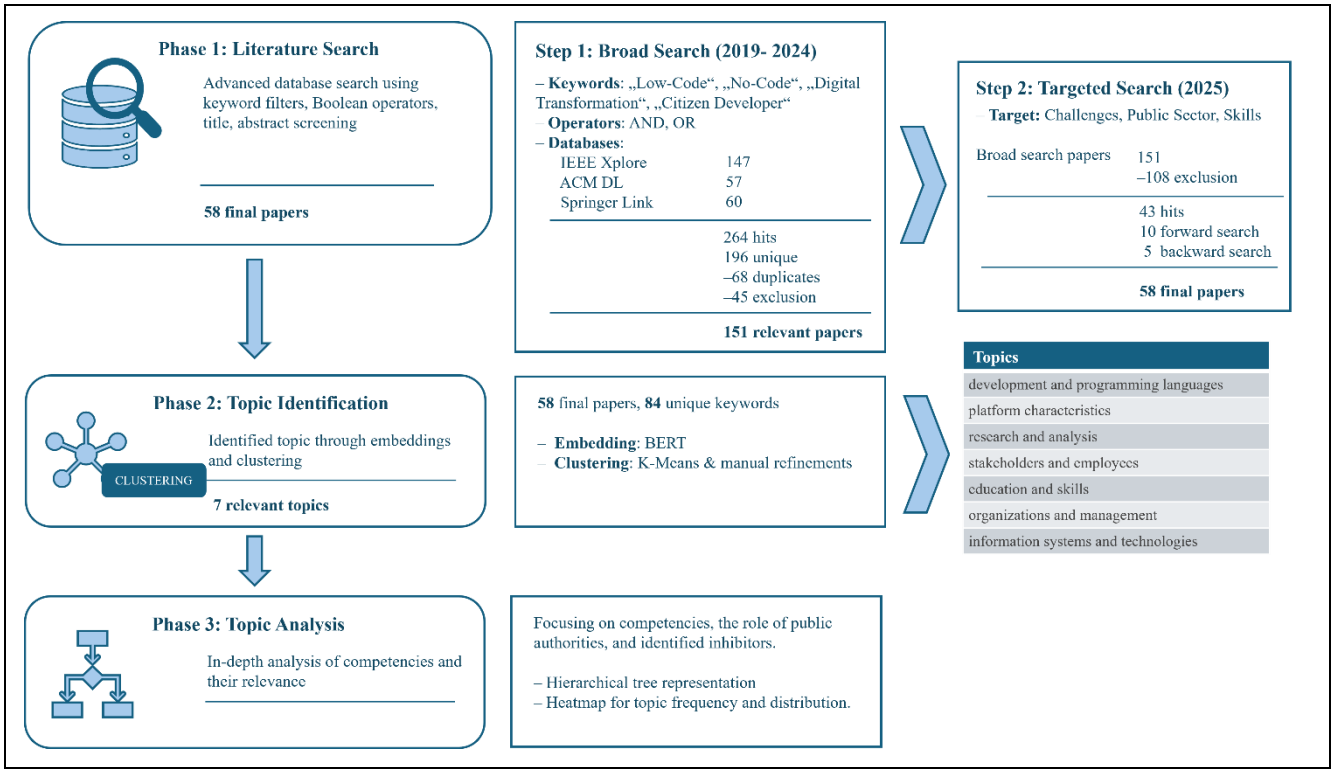

Fig. 1. Overview of the Three Steps of the Methodological Approach

B. Phase 2 – Topic Identification

During the screening of titles and abstracts, suitable keywords from the databases, as well as keywords identified manually, were entered for each article to enable subsequent classification. Recurring keywords were identified and organized by topic. However, these keywords had different levels of abstraction, which made further analysis difficult; therefore, an attempt was made to make the levels of abstraction more similar by combining some keywords into generic terms. As there were 84 keywords, an automatic clustering method was initially employed, which was then supplemented by our own review.

Python and the KNIME Analytics Platform were utilized for the data analysis, especially to analyze keywords, clusters, and frequencies, as well as to create tables. Additionally, we incorporated D3.js into our workflows for the purpose of displaying the tree structure of keywords. We also used the Seaborn Python data visualization library to create a heatmap. Token-level embeddings were created using the Bidirectional Encoder Representations from Transformers (BERT) bert-base-uncased model to evaluate the semantic similarity of keywords. BERT is a state-of-the-art language representation model that captures the contextual meaning of terms based on how they are used in natural language; although the model is frequently used to analyze entire sentences, it can also be used to understand specific keywords. As BERT does not require labeled data, it allows us to apply unsupervised clustering without the need for manual annotations. The classical k-means clustering algorithm was then applied, with varying numbers of clusters, to identify coherent term groups [28]. The analysis produced the best results with seven clusters, which were then manually checked and optimized.

C. Phase 3 – Topic Analysis

In order to gain more detailed insights into thematic trends, an analysis was conducted to determine which articles covered which topics. This made it possible to identify both gaps in content and potential trends. A heat map (see Fig. 2) was used for this purpose, with individual articles shown on the x-axis and the thematic clusters shown on the y-axis. The heat map depicts which topics dominate the literature and which are underrepresented. Each cell contains a number indicating how many aspects of a particular cluster are covered in the respective article. This facilitates the identification of thematic foci and research gaps at a glance.

Another tool used to represent the clusters is a hierarchical tree structure. This is particularly well suited for visualizing subordinate concepts and highlighting thematic connections, dependencies, and analysis paths. The tree displays the main topics at the top level, the subcategories at the second level, and the individual keywords (including the number of times they are mentioned in the analyzed papers) at the bottom level.

Finally, a concept-centered method based on Webster and Watson [27] was used to systematically synthesize the authors' findings and positions on specific, relevant concepts.

IV. Results

This section presents the results of the keyword and thematic analyses, which were based on a concept matrix comprising 58 articles on LCNC platforms. First, each article was assigned to relevant keywords, and then the keywords were grouped into overarching thematic clusters. In total, 84 unique keywords were extracted, with 518 mentions across all papers. Several keywords with the same meaning but different spellings were standardized.

The results of the literature review are presented in three visual formats: a heatmap, two tables, and a hierarchical tree diagram. The heatmap (see Fig. 2) illustrates the seven main thematic clusters and their distributions across the selected articles; the x-axis shows the unique article numbers in ascending order (i.e., from article 1 to article 58) and the y-axis shows the clusters, or subject areas, sorted by how often they were mentioned in articles. The frequency with which each cluster was mentioned is indicated by a number in the cell at the intersection of the cluster and paper number. Table I contains these clusters, the numbers of articles in which these topics were mentioned, the corresponding keywords, and the number of times each keyword appears in the papers. Table II shows the most and least frequently used keywords. The hierarchical tree diagram (see Fig. 3) groups keywords into thematic clusters based on their contextual relationships; each level has its own color to aid in distinguishing between them. In Fig. 3, we have chosen to omit certain individual clusters—i.e., platform characteristics, research analysis, and development and programming languages—so that the illustration fits into our article; however, the full illustration is available upon request.

A. Topic Coverage across Articles

As shown in Fig. 2 and in Table I, the seven thematic clusters are:

- #1 information systems and technologies,
- #2 development and programming languages,
- #3 education and skills,
- #4 platform characteristics,
- #5 organizations and management,
- #6 stakeholders and employees, and
- #7 research and analysis.

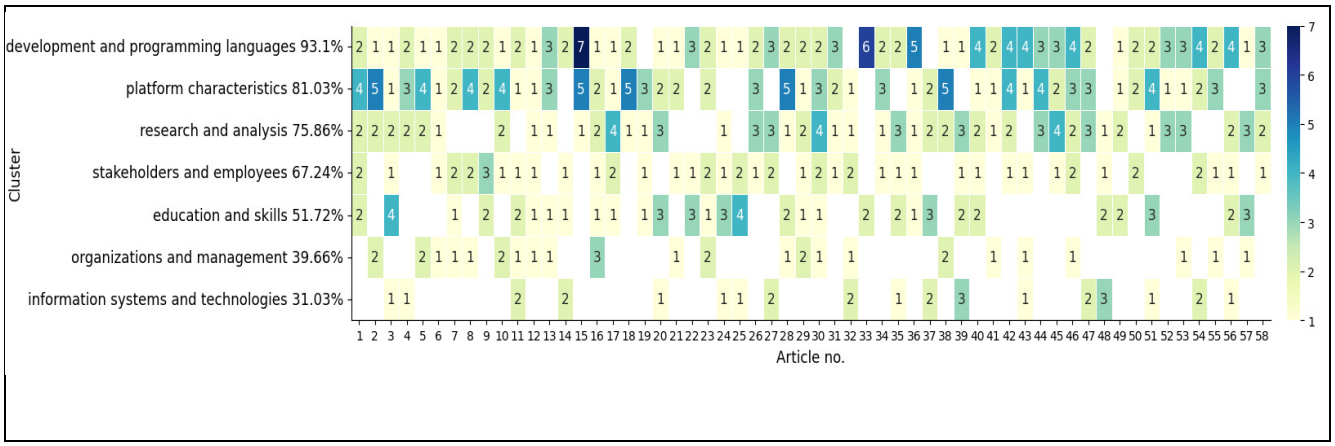

Fig. 2. Heatmap of Topic Coverage Across Articles

TABLE I.
TOPICS, ASSOCIATED KEYWORDS, AND FREQUENCY OF OCCURRENCE

No.	Cluster	Article Count	Keywords with Occurrences Count
#1	information systems and technologies	18	information systems (9), artificial intelligence (7), integration (5), data handling (4), IoT (2), connectors (1), machine learning (1)
#2	development and programming languages	54	low-code (51), software development (20), no-code (16), rapid application development (6), model-driven engineering (6), traditional development (5), programming languages (4), prototyping (3), domain-specific language (3), testing (2), devops (2), generators (1), mobile applications (1), digital process automation (1), paradigm (1), visual programming (1), automation (1), design to code (1)
#3	education and skills	29	skills (21), education (12), skills shortage (12), re- and upskilling (5), learning (5), experiential learning (1), authentic learning (1)
#4	platform characteristics	47	challenges (30), platform (21), drivers (19), fundamentals (9), forecast (8), adoption (7), security (5), recommendations (4), quality (4), inhibitors (3), classification (3), taxonomy (2), features (2), architecture (1), technical roles (1)
#5	organizations and management	24	companies (10), organization (4), governance (3), management (2), job crafting (2), work system (2), resource demand theory (1), business unit development (1), project management (1), agile methodology (1), socio-technical theory (1), decision making (1), manufacturing (1), public administrations (1), paradox theory (1), product line (1)
#6	stakeholders and employees	39	democratization (21), citizen developer (18), innovations (7), employees (3), employee-driven innovation (2), stakeholders (1), job roles (1)
#7	research and analysis	44	conceptional (36), use case (22), survey (8), experiment (6), interviews (4), analysis (2), research (2), group discussion (2), metamodeling (2), task analysis (1), empirical study (1), expert interviews (1), hackathon (1), model (1)

A notable finding is that *development and programming languages* (cluster #2) dominates, with a frequency of 93.1%, followed by *platform characteristics* (cluster #4) with 81.03%. Cluster #7, *research and analysis,* shows which articles explicitly mention the type of method or research approach used (75.86%). The clusters *education and skills* (#3, 51.72%), *organizations and management* (#5, 39.66%), and *information systems and technologies* (#1, 31.3%) are significantly less represented.

Table I illustrates the distribution of the 58 articles across the seven theme clusters; for each cluster, the table shows the number of articles in which each topic is addressed. The corresponding keywords are listed in descending order of frequency (provided in parentheses). The number of keywords per topic vary: across all topics, *development and programming languages* (#2) contain the highest number of unique keywords (18), while *education and skills* (#3), *information systems and technologies* (#1), and *stakeholders and employees* (#6) include only 7 keywords.

As shown in Table I, *development and programming languages* (#2) is the most frequently addressed cluster, with 54 mentions across the articles. The most frequently mentioned keywords in this cluster are “low-code” (51), “software development” (20), and “no-code” (16). This cluster and its keywords are followed by *platform characteristics* (#4, 47 articles); the most frequent keywords here are “challenges” (30), “platform” (21), and “drivers” (19). The third most represented cluster is *research and analysis* (#7), with 44 mentions across the articles. The most frequent keywords in this cluster are “conceptual” (36), “use case” (22), and “survey” (8). The least addressed clusters are *organizations and management* (#5, 24 articles) and *information systems and technologies* (#1, 18 articles).

Fig. 3 provides an overview of our classification structure through a hierarchical tree representation of topics and keywords. The seven thematic clusters form the basic components for either keywords or subcategories, as certain keywords are connected to more specific subtopics. For example, *education and skills* (#3) has been divided into the "skill demand" subcategory—with the keywords "skills", "skill shortage", and "re- and upskilling"—and the subcategory "learning approaches"—with the keywords "experimental learning", "learning" and "authentic learning"—as well as the keyword "education". The cluster *platform characteristics* (#4) relates to fundamental platform properties, such as "architecture" and "features", and comprises the subcategory "categorization" with the keywords "classification" and "taxonomy". Other clusters have a similar structure of branches, subcategories, and keywords.

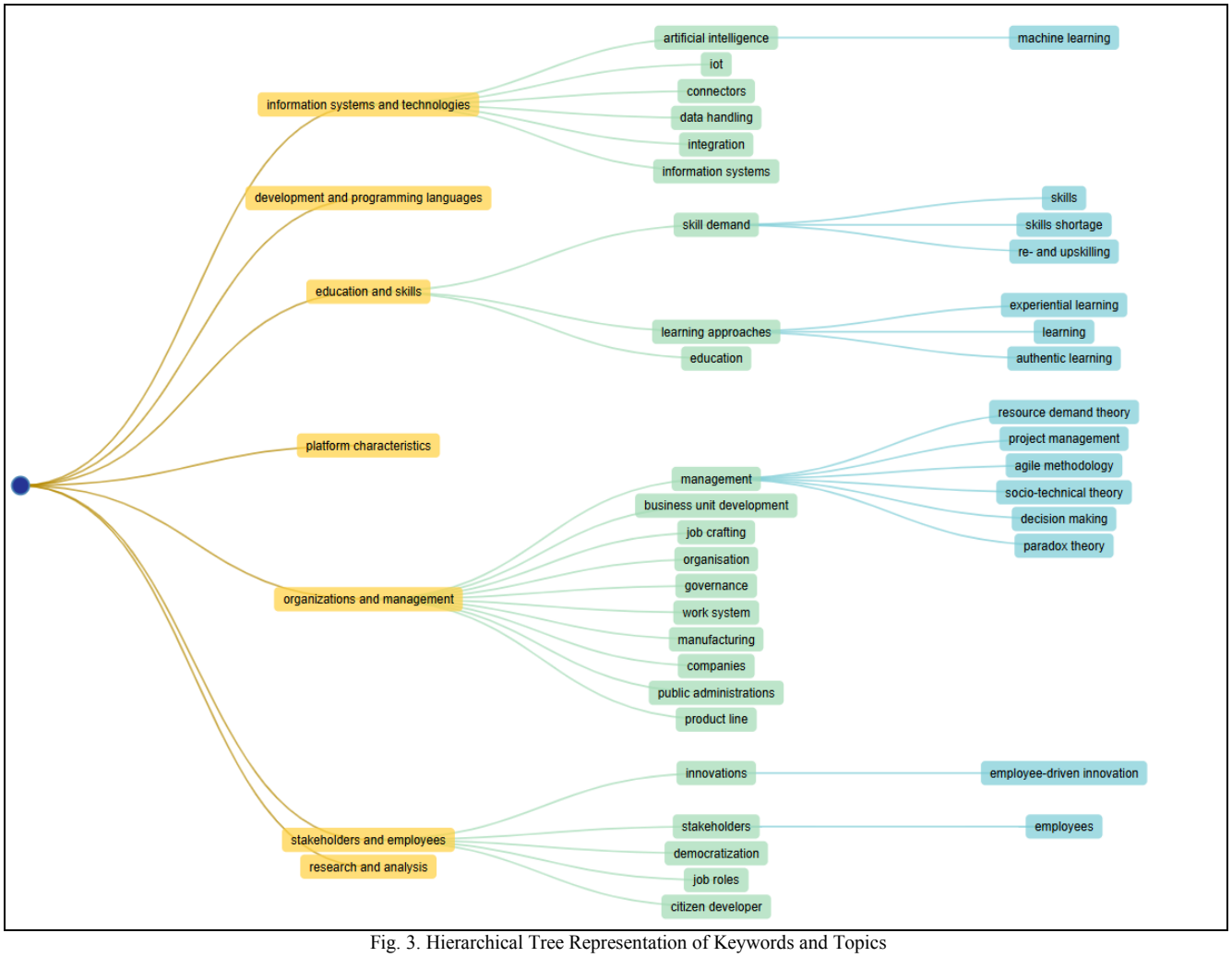

Fig. 3. Hierarchical Tree Representation of Keywords and Topics

B. Keywords' Frequency

A keyword analysis was conducted to better elucidate the thematic focus of the selected literature. An overview of the 15 most- and least-frequently occurring keywords found in the selected publications is shown in Table II. Notably, approximately 35.7% of all keywords were mentioned only once.

Interestingly, the keyword "skills" first appeared in 2021, after which it has continuously increased (2021=2, 2022=5, 2023=6, 2024=10, 2025 (January–May)=3). Notably, the related term "re- and upskilling" did not appear until 2022. "Low-code" was mentioned significantly more often than "no-code", with 51 mentions compared to 16. Frequently discussed topics included challenges related to LCNC, platform characteristics, software development drivers, and information systems—keywords with strong technical focus. The keywords "citizen development" (18), "democratization (21)", and "skills" (21) also appeared frequently, as did "education" and "skills shortage" (both with 21 mentions).

In contrast, non-technical aspects were rarely mentioned. For example, terms like "agile methodology" and "project management" appeared only once; notably, "public administration" and "manufacturing" were also mentioned only once each.

TABLE II.
MOST AND LEAST FREQUENTLY USED KEYWORDS IN THE ANALYZED LITERATURE

Most frequently occurring keywords		Least frequently occurring keywords	
Keyword	**Frequency**	**Keyword**	**Frequency**
low-code	51	project management	1
conceptual	36	agile methodology	1
challenges	30	socio-technical theory	1
use case	22	decision-making	1
skills	21	manufacturing	1
platform	21	public administration	1
democratization	21	paradox theory	1
software development	20	product plan	1
drivers	19	stakeholders	1
citizen development	18	job roles	1
no-code	16	task analysis	1
education	12	empirical study	1
skills shortage	12	expert interviews	1
companies	10	hackathon	1
information systems	9	model	1

V. DISCUSSION

A. Overview of General Findings

An important observation concerning the results was that the two most frequent clusters were technical. The strong concentration of keywords in these clusters indicates that most of the literature focuses on the technical foundations of LCNC platforms. This finding aligns with previous literature reviews in this context, which also found that the majority of papers concentrate on the technical aspects of LCNC platforms [20]. Less prevalent terms—particularly regarding skills, organizational context, and emerging technologies—highlight areas that may be underexplored, suggesting potential directions for further research.

The cluster research and analysis show that conceptual approaches and use cases are particularly common. This indicates that current research is primarily focused on developing fundamental ideas and describing specific applications. More empirical investigations would be useful for obtaining a more comprehensive picture: while many works present practical examples (i.e., use cases), systematic studies that quantify these experiences are much rarer.

Most articles include keywords from multiple clusters, reflecting the interdisciplinary nature of LCNC research. On average, each article contributes to 4.4 clusters, indicating that LCNC platforms are examined from multiple perspectives simultaneously.

B. Competencies, Skills, Education (RQ1)

The skills topic has gained noticeable momentum in recent years, reflecting the growing relevance of competency-related aspects in the context of LCNC platforms.

In general, the skills and competencies of citizen developers can be classified into two areas: hard skills and soft skills [29]. Elshan et al. [30] add a third dimension of business or domain expertise (which we combine with soft skills in the article).

Many training programs are aimed at professional developers. In contrast, citizen developers would benefit more from "knowledge nuggets" [29], which address specific knowledge deficiencies without overwhelming citizen developers. Knowledge nuggets are small, focused learning units that fill specific topic or skill gaps in a concise and accessible format. Citizen developers certainly require technical competencies, but only those relevant to their specific fields of application, and these can be conveyed in the form of courses, presentations, and short videos. It is important to ensure that these materials are tailored to citizen developers. Currently, most offerings still focus on professional software developers, and they unfortunately rarely meet the needs of citizen developers, who need concrete, relevant, bite-sized pieces of knowledge for their development [22]. Accordingly, proper didactic concepts should be taken into account [29].

Although LCNC minimizes entry barriers to software development, employees still need some technical skills to work with LCNC efficiently. The most commonly identified hard skill is basic programming knowledge [30], [29]: authors emphasize proficiency in LCNC, data management and analytics, familiarity with integration technologies and APIs, general IT knowledge, an understanding of technical requirements, knowledge of business processes (domain), and design knowledge.

As mentioned by Bernsteiner et al. [29], individuals with strong technical skills often still fail in LCNC projects due to the lack of soft skills. One of the key responsibilities of citizen developers is coordinating and communicating with the various stakeholders involved in the process. Therefore, interpersonal skills and the ability to communicate between multiple stakeholders are crucial for citizen developers. To this end, reskilling and upskilling initiatives should not focus only on technical aspects, but also on soft skills. Another four important soft skills were also emphasized: problem-solving, communication and collaboration, adaptability and flexibility, and initiative and self-motivation. In contrast to professional developers, citizen developers benefit especially from skills like team understanding, user comprehension, and creativity, as well as business skills including domain expertise, an understanding of business processes, and project management [30].

In response to RQ1:

The literature identifies three main areas of competence for citizen developers: *hard skills*, such as IT knowledge, programming (e.g., basic programming skills), and working with integrations and API; *soft skills*, such as communication and collaboration; and *domain-specific business knowledge*. Technical, communication, and domain-specific skills are equally important for implementing CD. Difficulties arise with the learning process: it is not particularly limited, but citizen developers should be taught differently than IT professionals. To this end, learning processes based on targeted knowledge nuggets can help close gaps relevant to their work context.

C. Governmental Authorities (RQ2)

The keyword distribution shows that the dominant discourse is centered around technical foundations, skills, and the broad application of LCNC platforms in the private sector, even though the search was not limited to this domain.

Of the articles on LCNC platforms, only one addresses the public sector directly: Gialitakis et al. [31]. This study highlights the potential for the broader use of LCNC tools in the digitalization of bodies of government authority, and it suggests wider application to demonstrate its feasibility. In that article, the researchers analyzed the characteristics of several low-code development platforms available on the market, and they pointed to well-known technical challenges that are not specific to the public sector. They limited their focus to vendor lock-in, lack of interoperability with other systems, lack of flexibility in custom logic or integrations, and security concerns. Subsequently, a system that supports business process model and notation (BPMN) was selected, and a five-step approach was conceptualized. The proposed methodology—spanning BPMN modeling to database design, user interface creation, optional scripting in procedural language/structured query language (PL/SQL), and the integration of process models into the application—was devised for use in both business and governmental contexts, with the objective of facilitating the implementation of applications for workflow-based processes. To demonstrate the practical application of the concept, the authors implemented a case study: following consultation with the Greek government, the researchers selected a public service process (specifically, the reimbursement of travel expenses) for digitization, which they subsequently undertook. The researchers demonstrated that the implementation of such an application was not only feasible with LCDP but also that the digital process now took one to three days, in comparison to twenty days for the in-person process.

The objective of the present study was to demonstrate the feasibility of implementing public service processes in low-code development platforms, with the goal of highlighting the potential for developing process-driven applications in this domain. This approach has been demonstrated to reduce the need for extensive coding methods and is accessible to individuals without formal computer science degrees. Consequently, this approach has the potential to facilitate digital transformation in public administrations by streamlining developer cycles, minimizing costs, and leveraging citizen-centric design to obtain feedback from users. This, in turn, could result in more effective public services.

Nevertheless, despite the clear advantages of this approach, it is important to acknowledge its limitations. It is clear that many real-world processes involve a high level of complexity, largely due to the participation of numerous organizations. This complexity creates challenges with process modeling. A further issue that must be addressed is the synchronization of models and tables in databases. The process of database synchronization is a prerequisite for implementing model changes; however, this procedure is not without its complications.

Overall, governmental authorities remain less represented in the literature. Further studies are necessary to identify sector-specific barriers, skill requirements, and implementation strategies in public administrations.

In response to RQ2:

Research on governmental administrations is limited; only one article was identified. The main challenges were not explicitly mentioned—only the standard limitations of LCNC platforms, such as issues with interoperability, flexibility, and vendor lock-in. Competency profiles were also not identified. Further research is needed in this area.

D. Future of LCNC Platforms

The low coverage of the cluster information systems and technologies (#1) may be due to the inclusion of newer emergent topics in the LCNC context, such as AI, machine learning (ML), and the internet of things (IoT). AI has recently gained attention in the context of LCNC platforms and tools, as the integration of AI into LCNC could potentially expand the latter's usage and help overcome issues such as lack of flexibility, inadequate documentation, and technical constraints, thereby leading to synergies [32], [33].

Generative AI (GAI) can support the work of citizen developers in LCNC platforms, and automating certain tasks may compensate for missing technical skills [34]. This is seen as a way to address the technical limitations and skills gaps that LCNC alone cannot overcome.

It is also notable that "low-code" is mentioned far more often than "no-code." This may be because the use of NC platforms is more limited compared to that of LC platforms [30]. However, recent conceptual work suggests that this distinction may blur in the future: for example, [35] suggests a conceptual model which integrates large language models (LLMs) into LC tools, bringing them closer to true NC solutions.

LCNC is also occasionally discussed in the educational sector, particularly in connection with modern learning methods. It is interesting to note that within the skills cluster, LCNC is occasionally discussed in the context of modern learning methods: students can learn how AI works and how to deal with data in practice, guided through the ML workflow [36].

Implication:

Emerging technologies such as AI, ML, and IoT were underrepresented in the context of LCNC and CD research. Studies are currently being conducted in the area of merging GAI with LCNC to support and simplify CD. There are also practical applications in education, where AI supports both teaching and student learning in IT. These are promising areas for future research.

VI. Conclusion and Limitations

This study presents a systematic literature review of the current research on LCNC platforms, with a particular focus on skills and governmental authorities. The analysis reveals that the examined literature primarily addresses technical aspects, while organizational and educational dimensions are less frequently examined, although the topic of skills has gained greater visibility in recent years. This study indicates that the competencies required for citizen developers are generally categorized, but challenges remain in adapting training methods to the specific needs of citizen developers.

The use of LCNC tools in the context of governmental administration is seldom discussed, and sector-specific barriers are insufficiently explored. The integration of GAI into LCNC platforms may help reduce technical barriers and support the empowerment of citizen developers. Nonetheless, further (empirical) research is necessary to validate these concepts. Future research could focus on the use of LCNC platforms in government settings and the development of upskilling strategies for employees.

We are aware that this study has several limitations, which should be considered when interpreting the results. For example, we did not identify all relevant papers published in journals and conference proceedings, because we made our selection from specific databases. Other journals and conference proceedings not included in the databases we examined might also contain relevant articles, and expanding the analysis to include additional databases could have produced different results and a different number of hits. A literature review cannot provide a comprehensive overview of a topic, particularly when the focus is limited to three databases, and so this may not have provided sufficient coverage of the topic. Therefore, a broader search using more databases, and particularly interdisciplinary ones, could highlight further limitations of our research and findings. Additionally, the focus on LCNC in the context of digital transformation may have led to some bias. Another limiting factor is that although a technically-driven clustering approach was used, assigning topics to clusters is still somewhat subjective, as some aspects may overlap between categories depending on the context. Additional clustering based on abstracts or keywords could improve the analysis further and reduce bias. Last but not least, we are aware that the study has temporal limitations, as the relevance and accuracy of the findings may change over time due to the quick speed of development in this field.

VII. References

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