On The Role of Ethics in Engineering Education Towards Realizing Society 5.0.

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Abstract: The world is currently experiencing an exciting juxtaposition of Artificial Intelligence (AI) and humanity, leading to a global vision of Society 5.0. This is centered around a human-oriented society that integrates digital technology and physical spaces to solve complex social and environmental challenges. A hallmark attribute of Education 5.0 (E.D. 5.0) is the emergence of an AI-empowered Virtual Reality (VR) environment called a digital twin, which allows personalized content learning and immersive experiences. However, an unintended but existent consequence of this is the morphing of individual and collective societal ethics. In fact, user ethics and morality patterns are assessed and trained on by a digital twin to suggest content that the user is more likely to consume. Across universities and Higher Education Institutes (HEIs), this has necessitated an urgent curriculum revamp, especially at the undergraduate level. Thus, it becomes imperative to capture and comprehensively assess the exact impacts of AI on shaping ethics, which collectively shape mankind's direction towards Society 5.0. Based on strategically posed Research Questions (RQs) arising from a detailed literature review, an exhaustive bibliometric analysis was executed on the Scopus scientific database, with duplicates being removed via suitable Inclusion & Exclusion criteria, from 2018 (the start of the Fifth Industrial Revolution) to 2025 (present day). A trickle-down approach is presented in our analysis, and our co-citation network maps capture collective (big picture) trends before narrowing down to more specific roles of ethics in shaping engineering education, particularly across STEM (Science, Technology, Engineering, and Mathematics) fields. Analysis of data reveals a direct impact of ethics in shaping engineering education-assisted revamp of university curricula across HEIs, with the United States and the United Kingdom emerging as key players from the Global North, and India and China emerging as major players from the Global South. We observe a linear increase in publications on ethics, with the top contributing fields being Computer Science, Engineering, Materials Science, and Business, Management, and Accounting. As HEIs adapt to create curricula that build Industry 5.0 (I.D. 5.0) skillsets among enrolled students, understanding the pivotal role of ethics in an AI-based digital twin environment can help faculty and instructors design new /revamp existing courses with more mindfulness. By teaching content from a lens of inculcating E.D. 5.0 competencies and I.D. 5.0 skillsets, HEIs can produce university graduates who possess a strong ethical framework, while simultaneously being proficient at AI awareness/usage. The long-term vision of this work is truly transformative, and aims to produce a pedagogical blueprint towards the conscious teaching of ethics across universities and academic environments, in a manner that successfully encapsulates

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undergraduate/graduate student learning based on Bloom's taxonomy, in turn inspiring educators to design more Society 5.0-aligned content, in accordance with the tenets of Fink's taxonomy of significant learning.

Keywords: Artificial Intelligence (AI), Engineering Education, Higher Education Institute (HEI), Ethics, Society 5.0, Education 5.0 (E.D. 5.0).

Introduction: The Fifth Industrial Revolution is uniquely characterized by the rapid emergence of Artificial Intelligence (AI)[†] and Machine Learning (ML) to trigger the Education 5.0 (hereafter E.D. 5.0) and Industry 5.0 (I.D. 5.0) revolution. The direct impact of AI is the creation of unique, personalized learning environments at universities and Higher Education Institutes (HEIs). Since E.D. 5.0 is uniquely characterized by a learning experience that enables the conscious creation of ethics and ethical values in students, it is useful to assess the exact roles and implications of ethics in the engineering education landscape. The perfect integration of E.D. 5.0 – I.D. 5.0 leads to the creation of a technically competent global workforce, which leads to the creation of a society that is super smart and utilizes digital technologies effectively to integrate cyberspace and the physical world. This leads to the creation of a humanity-centric system that can solve some pernicious and persistent social problems like ageing populations (especially for some countries in the Orient like Japan and South Korea, as well as European nations like Germany, Finland, Spain, Portugal, and Greece), environmental and sustainability issues, and individual and collective well-being. Such a society is called Society 5.0 [7,13] (a concept first proposed by Japan). Efforts have been recorded to map E.D. 4.0 to I.D. 4.0 [2], as well as investigating the set of factors responsible for the shift from E.D. 4.0 to E.D. 5.0 across universities [4]. Simultaneously, recent initiatives have focused on mapping the E.D. 5.0 to I.D. 5.0 landscape in the context of a chemical engineering course at the undergraduate level [11], as well as revamping capstones and process design [10] courses to ensure they adhere to the requirements of I.D. 5.0. As I.D. 5.0 skillsets continuously evolve; it becomes imperative to map the set of causal factors that are directing the global transformation from E.D. 4.0 to E.D. 5.0 [4,15]. An assessment of the online learning experience for students, especially at the undergraduate level, reveals that the AI-based virtual learning environment has both pros and cons. A key outcome of E.D. 5.0 is the creation of an AI-empowered Virtual Reality environment called a digital twin, which can learn from user behavior/pattern, and consequently, can suggest curated academic (or otherwise) content. So, while students can consume information on much shorter time scales, with content curated to their needs, a big con of the process is the reduced attention span observed in Gen Z, Gen Alpha, and future generations.

Recent pedagogical initiatives have aimed at bringing E.D. 5.0 into the classroom, like approaches to realize Fluid Mechanics 5.0 [1] or capturing the shift in student perception towards a more positive perspective on the historically ill-reputed Oil & Gas (O&G) industry, after students were made aware of recent greener initiatives implemented by the industry [3]. In fact, as of early 2026, it is obvious that worldwide geopolitical and geoeconomic supply/demand currents are heavily

[†] A table of all symbols and abbreviations used in this manuscript are available in **Appendix B**.

impacted by oil (e.g., countries like Venezuela, Iran, Russia, Saudi Arabia, United Arab Emirates, etc.) and rare earths (e.g., China, Greenland, Brazil, India, Australia, etc.), among other valuable commodities. Battery ageing can also be taught using AI-assisted personalized learning, coupled with Effective Prompt Engineering (EPE) [12]. It has recently also been shown that there is currently an AI implementation gap between the Global North and the Global South [6], which further exacerbates if India and China, the two Global South economic powerhouses, are removed from the analysis. Incorporation of E.D. 5.0 and I.D. 5.0 shows promising initiatives within the lens of engineering education, to realize Society 5.0 [5]. E.D. 5.0, when incorporated correctly, shows tremendous promise towards attaining Society 5.0 [8] targets globally, and this is best incorporated via curriculum revamp within the higher education landscape [9,14]. Therefore, to summarize, the broad corpus of pedagogical and curriculum-revamp related literature pertaining to E.D. 5.0 and I.D. 5.0 has identified pedagogical strategies to revamp curricula and has voiced its concerns on how to incorporate ethics comprehensively, but almost no quantitative or semi-empirical methods are reported in the literature on how to implement them. This work posits a nascent framework towards realizing that target, and to that effect, a set of Research Questions is proposed in the following section to capture this phenomenon and obtain direct, quantitative insights that may be directly utilized towards bridging the E.D. 5.0 – I.D. 5.0 implementation gap.

Methods: To analyze our proposed hypotheses, a set of Research Questions (hereafter referred to as RQs) was formulated, as summarized in **Table 1**. The method of analysis chosen for our work is bibliometric analysis, since it assumes no prior assumptions from the user's end. The search is restricted to the last decade (2015 – 2025), which coincides with the advent and rise of AI in E.D. 5.0, and has overseen the development of global Large Language Models (LLMs)-based search engines such as ChatGPT, Copilot, Gemini AI, and DeepSeek. As will be observed, despite the search being performed over the last decade, we do not find any articles matching our RQs before 2018 (with most results starting from 2020). This indicates that this research field is completely new, and therefore, there are immense future opportunities to study and publish in this area of engineering education. The search, conducted on the Scopus database, was restricted to Social Sciences, Computer Science, Business, Engineering, Economics, Environmental Science, Energy, Decision Sciences, Mathematics, Medicine, Physics, Chemistry, Biochemistry, Materials, Earth Sciences, and Chemical Engineering (i.e., primarily STEM fields). Only published articles were considered (articles in press were ignored), and the content was limited to articles, conference proceedings, reviews, books, and book chapters. For each RQ, co-citation networks were generated on VOS viewer; temporal and subject/country-specific trends were obtained using MS-Excel, as summarized in **Appendix A**. A total of 5 RQs are analyzed, each building on the previous one, making the search criteria successively more rigorous. In the next section, we summarize our results for each RQ and explain our observations and data from a combined academic, economic, and geopolitical perspective.

Results & Discussion: We now present the results and findings of each of our RQs and analyze the broader context of our results. The data presents an undeniable shift towards Society 5.0, as

AI/ML-assisted DSAI-led innovations pave the way towards bridging the AI-implementation gap, and uniting the E.D. 5.0-I.D. 5.0 architectural framework.

Table 1: Summary of search criteria implemented on Scopus for our proposed RQs.

RQ	Scopus Search Prompt
RQ_1	Ethics AND Society 5.0
RQ_2	Ethics AND Society 5.0 AND engineering education
RQ_3	Ethics AND Society 5.0 AND pedagogical innovation OR pedagogy
RQ_4	Ethics AND Society 5.0 AND pedagogical innovation OR pedagogy AND universities OR Higher Education Institutes
RQ_5	Ethics AND Society 5.0 AND engineering education AND universities OR Higher Education Institutes

RQ_1: The first generalized search was intended to capture and assess the exact impacts of ethics on Society 5.0. 4537 articles met our search criteria, and the resulting co-citation network map arising from the analysis is shown in **Figure 1**. The most prominent keywords are Artificial Intelligence (AI), Society 5.0, sustainability, sustainable development, I.D. 4.0, I.D. 5.0, ethical technology, ethics, innovation, digitization, decision making, Machine Learning (ML), marketing, commerce, education, higher education, marketing and investments. These keywords are particularly relevant, since they capture a picture of a dynamic, global AI-shaped ethics landscape that is shaping global sentiment, perception, and predisposition towards Society 5.0. Ethics appears to bridge the gap towards the attainment of Society 5.0 via the multiple pathways of business, innovation, teaching/research at universities and Higher Education Institutes (HEIs), commerce, technological advancements, and sustainability-led initiatives. Fields best matching our search are the Social Sciences (18%, 837 articles), Computer Science (18%, 822 articles), Business, Management and Accounting (14%, 652 articles), Engineering (11%, 480 articles), and Economics, Econometrics and Finance (9%, 408 articles). Countries leading these changes are India (11%, 350 articles), Indonesia (8%, 248 articles), the United States (5%, 149 articles), the United Kingdom (4%, 136 articles), and Malaysia (4%, 131 articles). Note that three nations in our top five list are members of the Global South, and within this country bloc, India emerges as the key powerhouse driving these changes. Publication trends also show a cubic increase with time (a third-order polynomial best fits the bibliometric data), a claim supported by a strong regression coefficient ($R^2 = 0.986$). This demonstrates that ethics as a construct is rapidly shaping AI and ML-led advances, in turn creating the skeleton and the infrastructure towards creating a Society 5.0 conscious society. These results are summarized in **Figure 2**.

RQ_2: Refining the search further, we now focus our attention on the impacts of ethics on Society 5.0, within the context of engineering education. The search led to 667 articles meeting our search criteria, and the co-citation network map in **Figure 3** shows that the keywords are most centered on engineering education, AI, I.D. 5.0, I.D. 4.0, ethical technology, e-learning, teaching, curricula, higher education, industrial revolutions, and sustainability. The top-performing fields in this aspect are the Social Sciences (23%, 153 articles), Computer Science (22%, 144 articles), Engineering (13%, 88 articles), Business, Management and Accounting (11%, 75 articles), and Economics, Econometrics and Finance (9%, 57 articles). The top performing nations for this RQ are India (11%, 51 articles), Indonesia (8%, 37 articles), China (4%, 21 articles), the United States (4%, 21 articles), and the United Kingdom (4%, 20 articles). Note that the top three performing nations are all members of the Global South bloc. Within the Global South, India leads the initiatives on ethics as a framework to achieve the Society 5.0 vision. This is interesting to note, since India is culturally a country where ethics is integrated into the very fabric of its cultural existence (it shapes the philosophy, literature, arts, and social dynamics of the country). From the Global North, the United States and the United Kingdom lead such initiatives. However, despite having more infrastructural and technical resources, these nations fall short of their Global South counterparts. Temporal publication trends show a cubic growth trend, with a strong regression coefficient ($R^2 = 0.984$). These results, summarized in **Figure 4**, comprehensively capture these trends. We expect future research in this area to keep on growing with time.

RQ_3: Within the discipline of engineering education, such transformations are typically executed via pedagogical innovation/reforms. To this effect, our next RQ further refines the previous one, with the additional filter of pedagogical innovation/pedagogy now being further added to the search. 510 articles met our search criteria, and **Figure 5** presents the co-citation map arising out of this. Major keywords are centered around AI, teaching, integration, engineering education, economics, higher education, sustainable development, computer-aided instruction, innovation, sustainability, sustainable development goals, sustainable practices, Society 5.0, problem solving, learning, e-learning, and digital transformation. These keywords reveal that pedagogical innovation appears to be assimilated via pathways such as sustainability/sustainable development to teach and impart the values of ethics across societies. Fields most relevant to our search are the Social Sciences (32%, 167 articles), Computer Science (19%, 97 articles), Business, Management and Accounting (11%, 56 articles), Economics, Econometrics and Finance (8%, 42 articles) and Engineering (7%, 36 articles). The order of these fields reveals that STEM-based fields are only starting to lead and execute transformational initiatives that will employ ethics as a learning and teaching framework to create students who will join the I.D. 5.0 landscape in future years, to realize Society 5.0. Countries leading these changes are Indonesia (13%, 46 articles), followed by India (7%, 25 articles), the United States (5%, 19 articles), Malaysia (4%, 15 articles), and the United Kingdom (4%, 15 articles). Again, it is the Global South that leads, although this time, Indonesia emerges as a clear frontrunner. Economies in the Global North could take note of countries like India, Indonesia, and Malaysia, and utilize their pedagogical systems to learn from and implement

similar measures across their own nations. With a strong regression coefficient ($R^2 = 0.969$), as shown in **Figure 6**, publication trends continue to show a cubic increase. We envision future research to grow in this area, as ethics becomes an important driver of socially conscious and emotionally aware societies.

RQ_4: Since the landscape where ethics is integrated for students is primarily at the undergraduate level at universities and Higher Education Institutions (HEIs), this RQ is a further refinement on the previous one, with the additional filter of universities/HEIs being added to the search criteria. The co-citation network presented in **Figure 7** centers around the keywords of AI, engineering education, sustainable development, sustainable practices, ecological footprint, circular economy, social sustainability, ML, education computing, computer-aided instruction, higher education, ethics, learning experiences, learning experiences, AR, learning, technology, real-world, integration, I.D. 4.0, and generative AI. These reveal that AI-centric e-learning environments are the primary platform via which the principles of ethics are taught to students at HEIs. The fields most relevant to our search are the Social Sciences (32%, 159 articles), Computer Science (19%, 93 articles), Business, Management and Accounting (11%, 55 articles), Economics, Econometrics and Finance (8%, 40 articles), and Engineering (7%, 35 articles). Again, nations that lead these initiatives are Indonesia (11%, 40 articles), India (7%, 24 articles), the United States (5%, 19 articles), Malaysia (4%, 15 articles), and the United Kingdom (4%, 15 articles). The consistent trend we observe is that the Global South leads these initiatives more than its Global North counterparts. This is important to note, since Global South economies (especially Indonesia and India) can achieve this, despite lower resources. Again, as shown in **Figure 8**, a cubic growth trend is observed for publications in this aspect, supported by a strong coefficient ($R^2 = 0.965$).

RQ_5: Our last search focused on a refinement of RQ_2, with the additional filter of analyzing how these initiatives are implemented within the context of universities/Higher Education Initiatives (HEIs). 610 articles met our search criteria, and the resulting co-citation network map arising from the analysis is shown in **Figure 9**. The most prominent keywords are centered around AI, teaching, engineering education, personalized learning, learning experiences, behavioral research, higher education, I.D. 5.0, decision making, sustainable development, gamification, curricula, decision making, metaverse, IoT, educational robots, AR, VR, cyber-physical systems, educational robots, active learning, and ethical issues. These keywords are particularly relevant, since they capture a picture of a dynamic, global AI-shaped ethics landscape that is shaping global sentiment, perception, and predisposition towards Society 5.0. Ethics appears to bridge the gap towards the attainment of Society 5.0 via the multiple pathways of business, innovation, teaching/research at universities and Higher Education Institutes (HEIs), commerce, technological advancements, and sustainability-led initiatives. Fields best matching our search are the Social Sciences (23%, 139 articles), Computer Science (21%, 128 articles), Engineering (13%, 79 articles), Business, Management and Accounting (12%, 72 articles), and Economics, Econometrics and Finance (9%, 55 articles). Countries leading these changes are India (11%, 48 articles), Indonesia (7%, 30

articles), China (5%, 21 articles), the United States (5%, 21 articles), and the United Kingdom (4%, 20 articles). Note that the top three nations in our list are members of the Global South, and within this country bloc, India and China again emerge as the two key powerhouses driving these changes. Publication trends, as presented in **Figure 10,** clearly reveal (again) a cubic growth curve in published articles, supplemented by a strong regression coefficient ($R^2 = 0.98$).

Conclusions: The current work serves to provide an unbiased perspective on how ethics as a social construct is currently paving the way across the global academic landscape to usher in the Society 5.0 vision. Our bibliometric analysis does not start with any a priori assumptions, and therefore, our results are applicable universally. Our RQs demonstrate a strong integration of ethics and Society 5.0, and it appears that the Global South economies (primarily Indonesia, India, Malaysia, and China) lead these initiatives more than their Global North counterparts (led by the United States and the United Kingdom). Publication trends show a cubic increase in research interest in this field, evidenced by a growing number of publications. Our results prove that there is a direct cause-and-effect relationship between the incorporation of ethics and ethical frameworks into the university/HEI curriculum, as it directly impacts the realization of E.D. 5.0 competencies among university students. Post graduation, these students are perceived as valuable by industry, as they possess I.D. 5.0 skillsets. Eventually, they form part of a more aware workplace, eventually working their way towards realizing the Society 5.0 vision. A distinct difference we observe is that the Global South nations produce a higher volume of publications and lead initiatives more than their Global North counterparts and retain this leadership position despite possessing notably scarcer infrastructural and techno-economic resources. Thus, the Global North can tremendously benefit by observing and implementing similar initiatives like their Global South counterparts. Likewise, the incorporation of AI-led teaching/learning environments facilitates the creation of a digital twin, which may be strategically harnessed by students to enable personalized content learning and immersive experiences. In fact, future works may also employ digital twins to train users on ethics and morality patterns, based on analyzing user consumption trends. The proposed pedagogical blueprint to realize Society 5.0 is to have a clear goal (university graduates trained succinctly in E.D. 5.0 and having AI awareness/usage experience), an established methodology (via thoughtful and strategic curriculum revamps executed by faculty and educators across HEIs), a clear framework (to encapsulate cohesive student learning, such as Bloom's and Fink's taxonomy of significant learning) and conscious AI integration (via digital twins). Our proposed pathway serves to consciously create future generations of graduates who can successfully integrate E.D. 5.0 and I.D. 5.0 together, to realize the Society 5.0 global vision. Most notably, existing literature focuses on the ethical problems of utilizing AI in higher education (e.g., algorithmic bias, data privacy), but most of these concerns remain purely theoretical (without any empirical grounding). This paper directly addresses this lacuna by analyzing real-world global publication trends, laying the foundations for a concrete, evidence-based assessment (for the first time).

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Appendix A: Bibliometric analysis and trends obtained for the posed RQs.

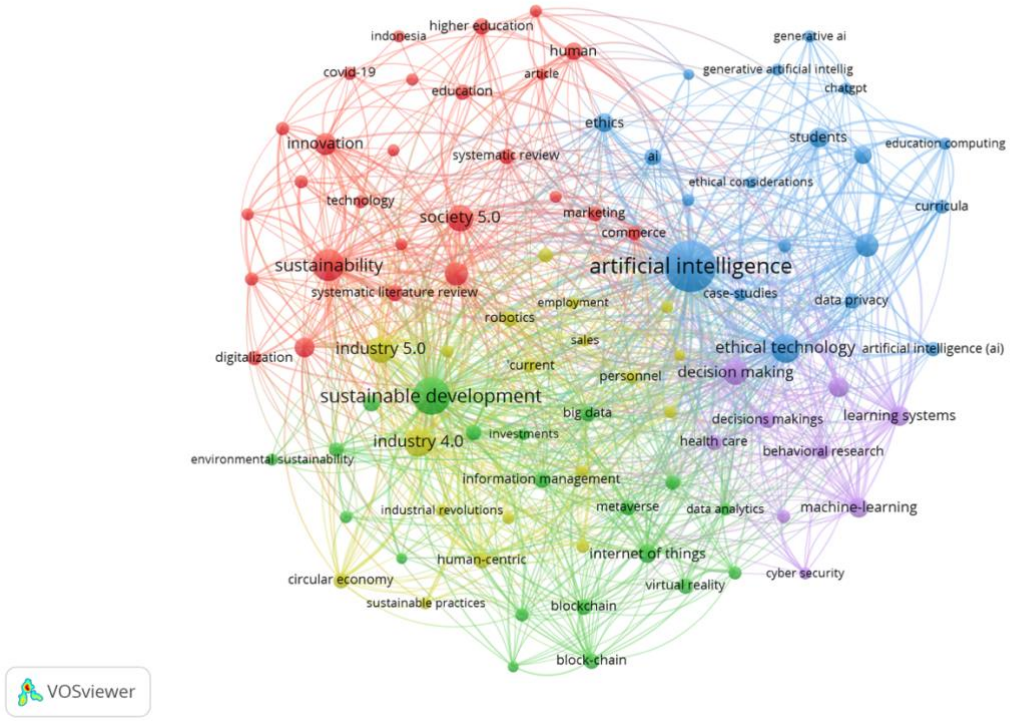
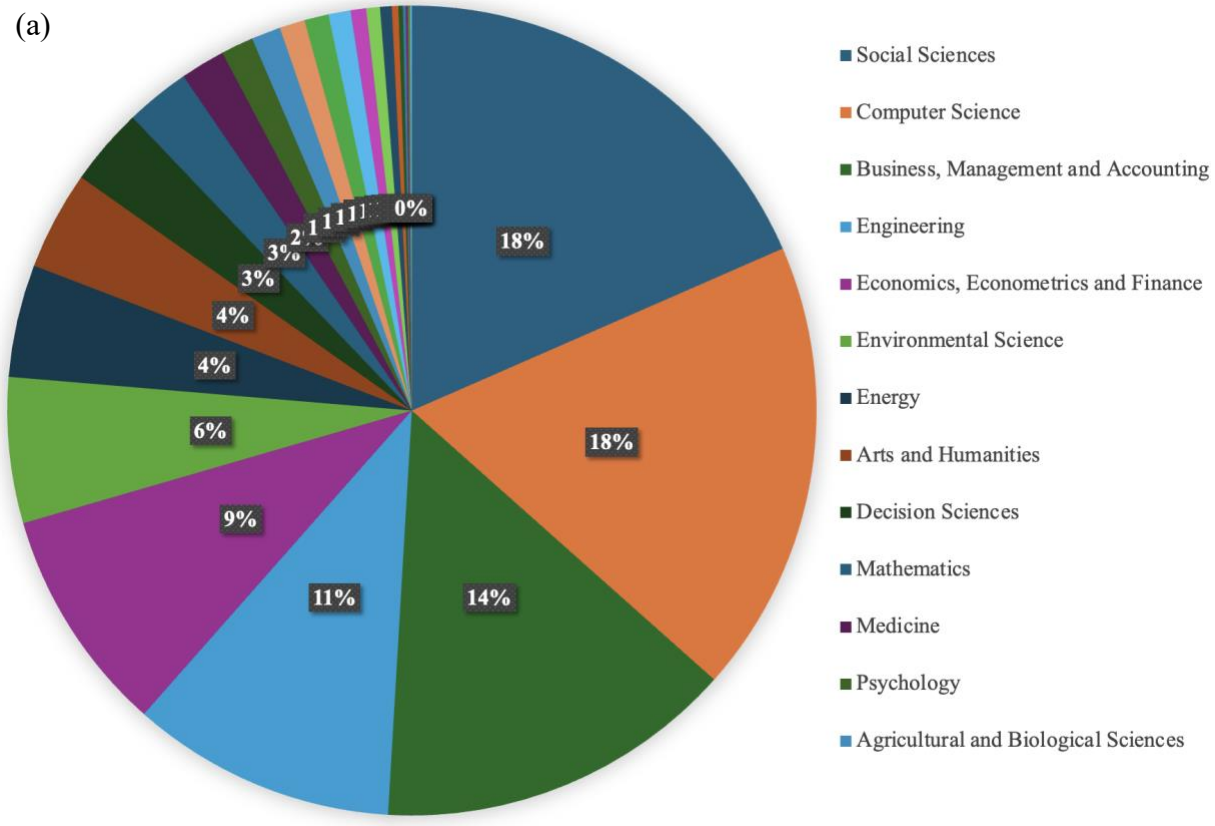


Figure 1: The co-citation network generated for RQ_1.

(a)



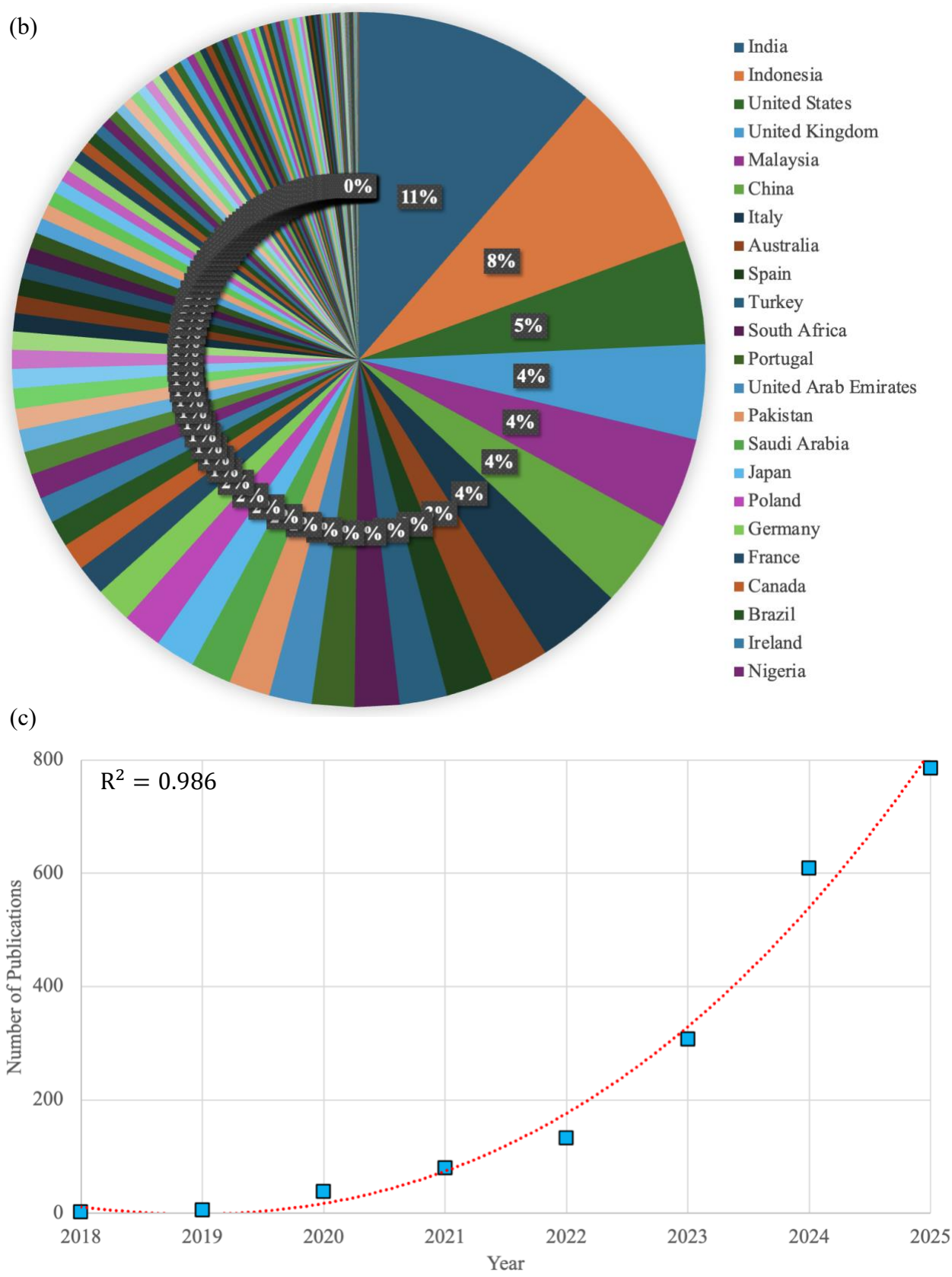


Figure 2: RQ_1 trends by (a) discipline, (b) countries, and (c) publication trends over the last decade.

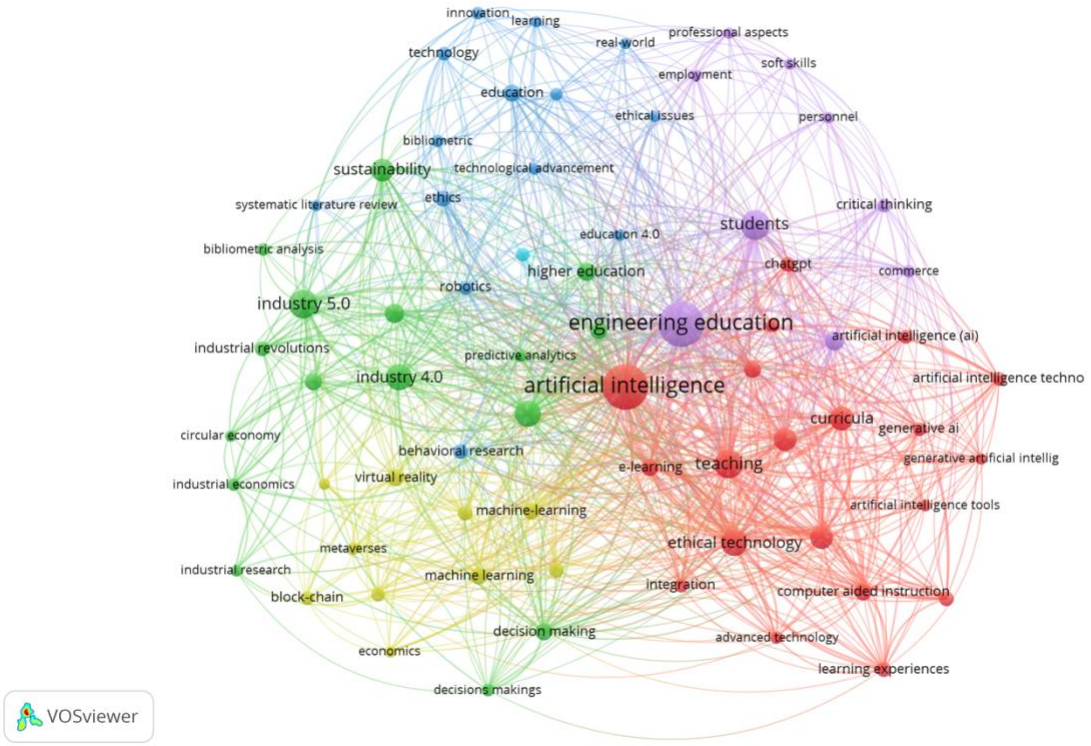
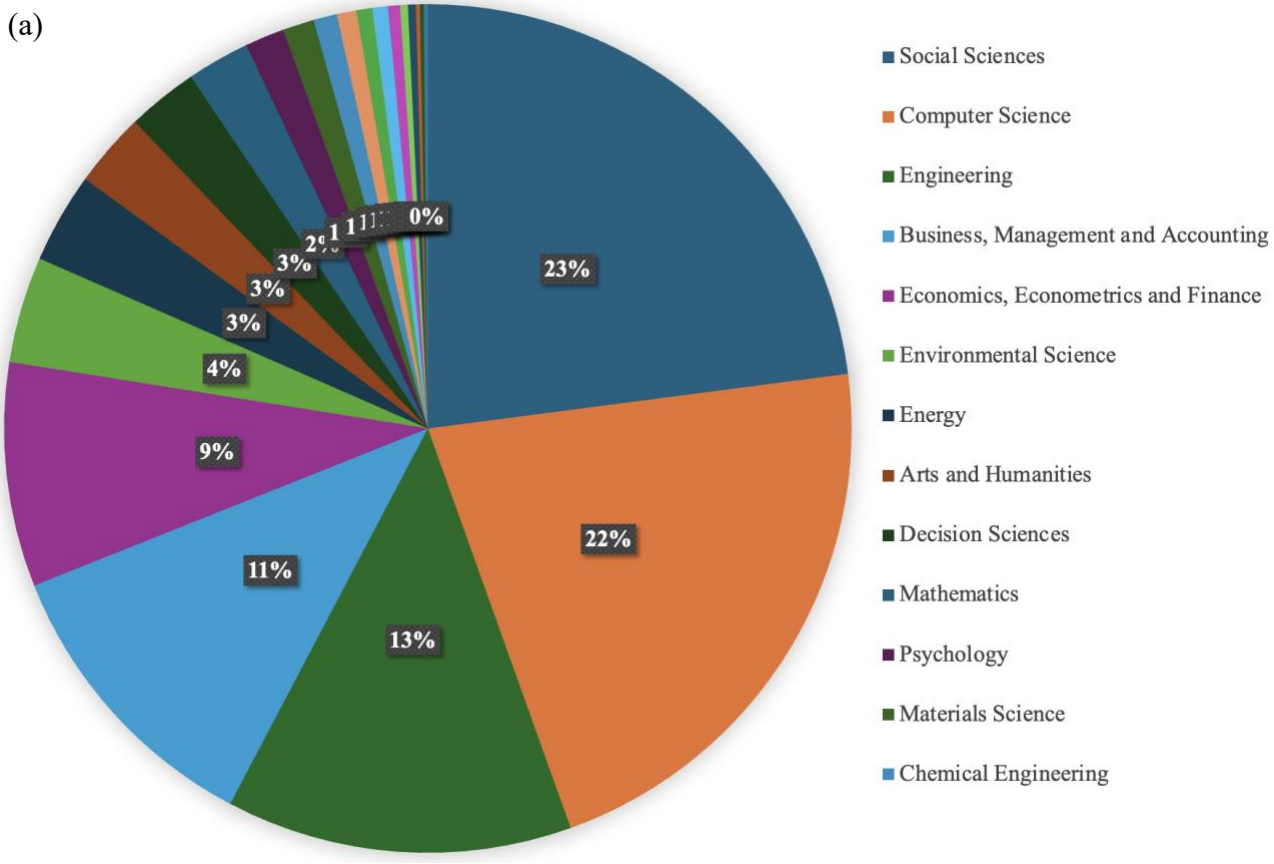


Figure 3: The co-citation network generated for RQ_2.

(a)



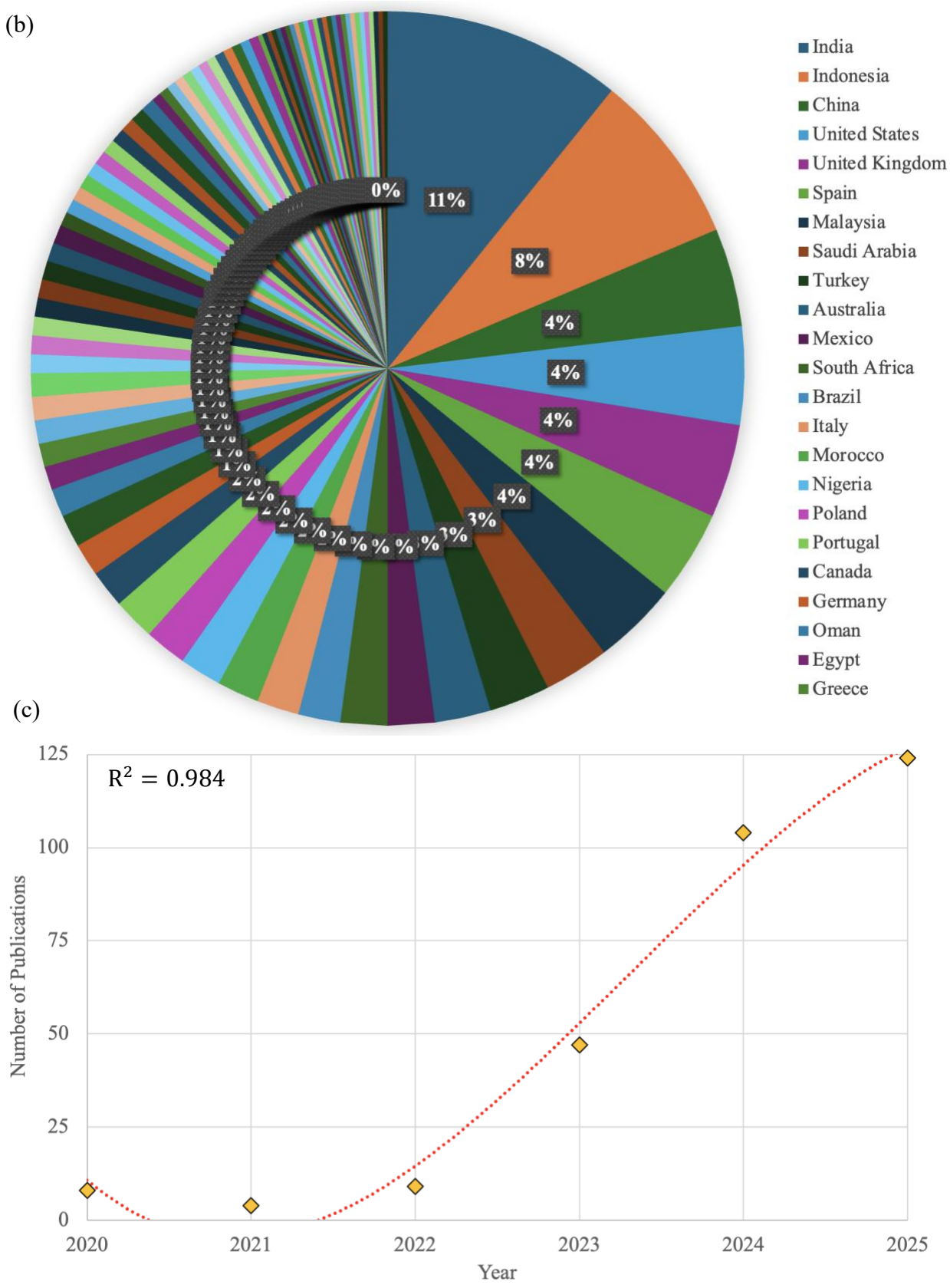


Figure 4: RQ_2 trends by (a) discipline, (b) countries, and (c) publication trends over the last decade.

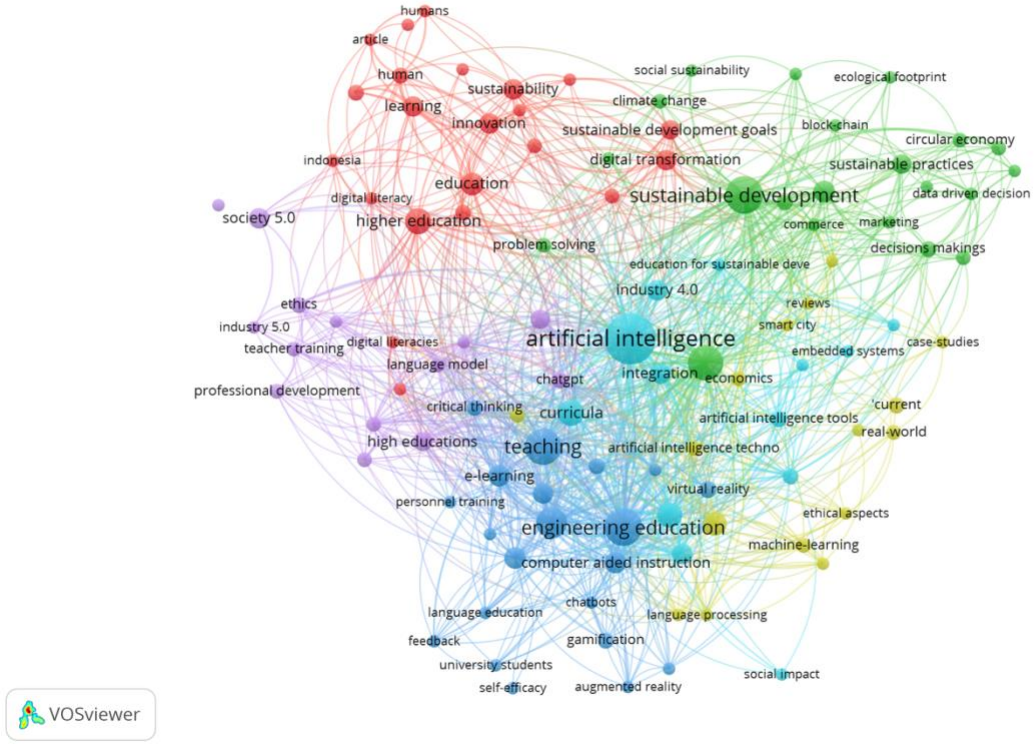
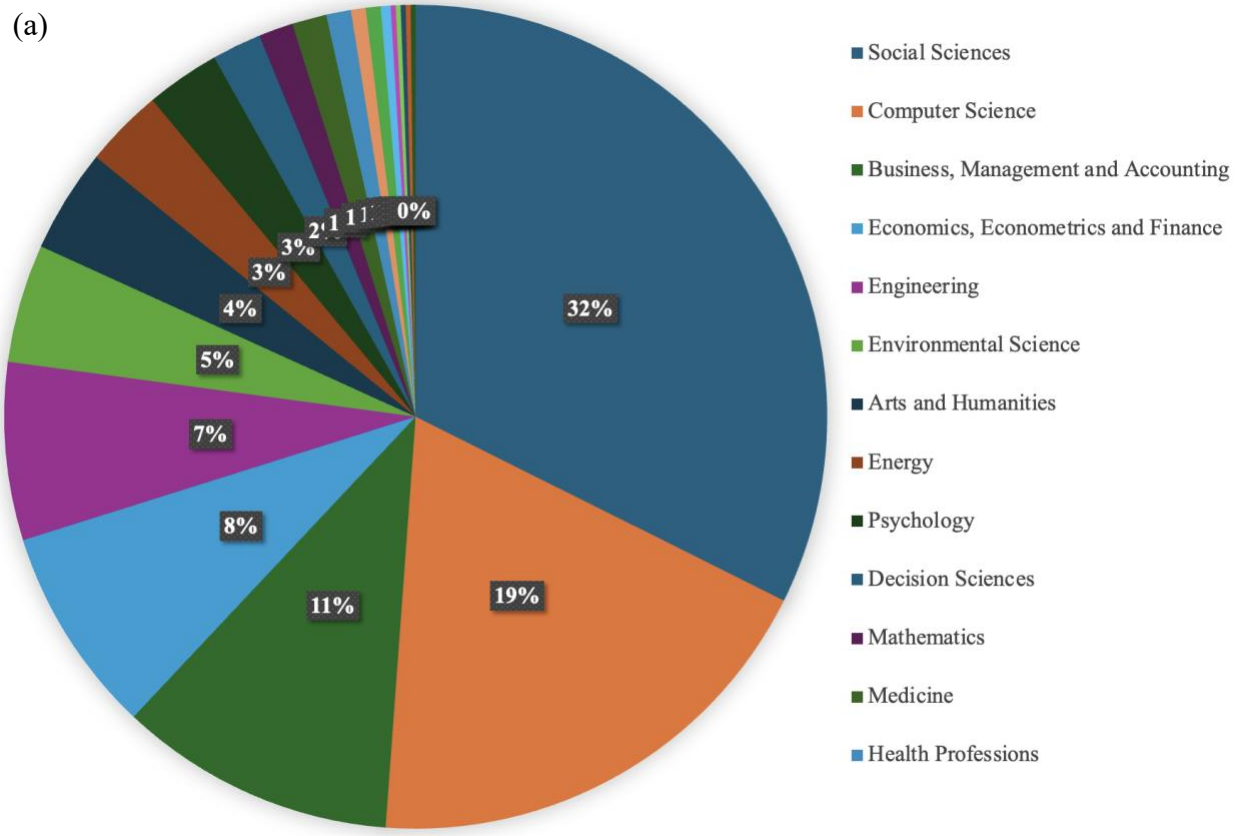


Figure 5: The co-citation network generated for RQ3.

(a)



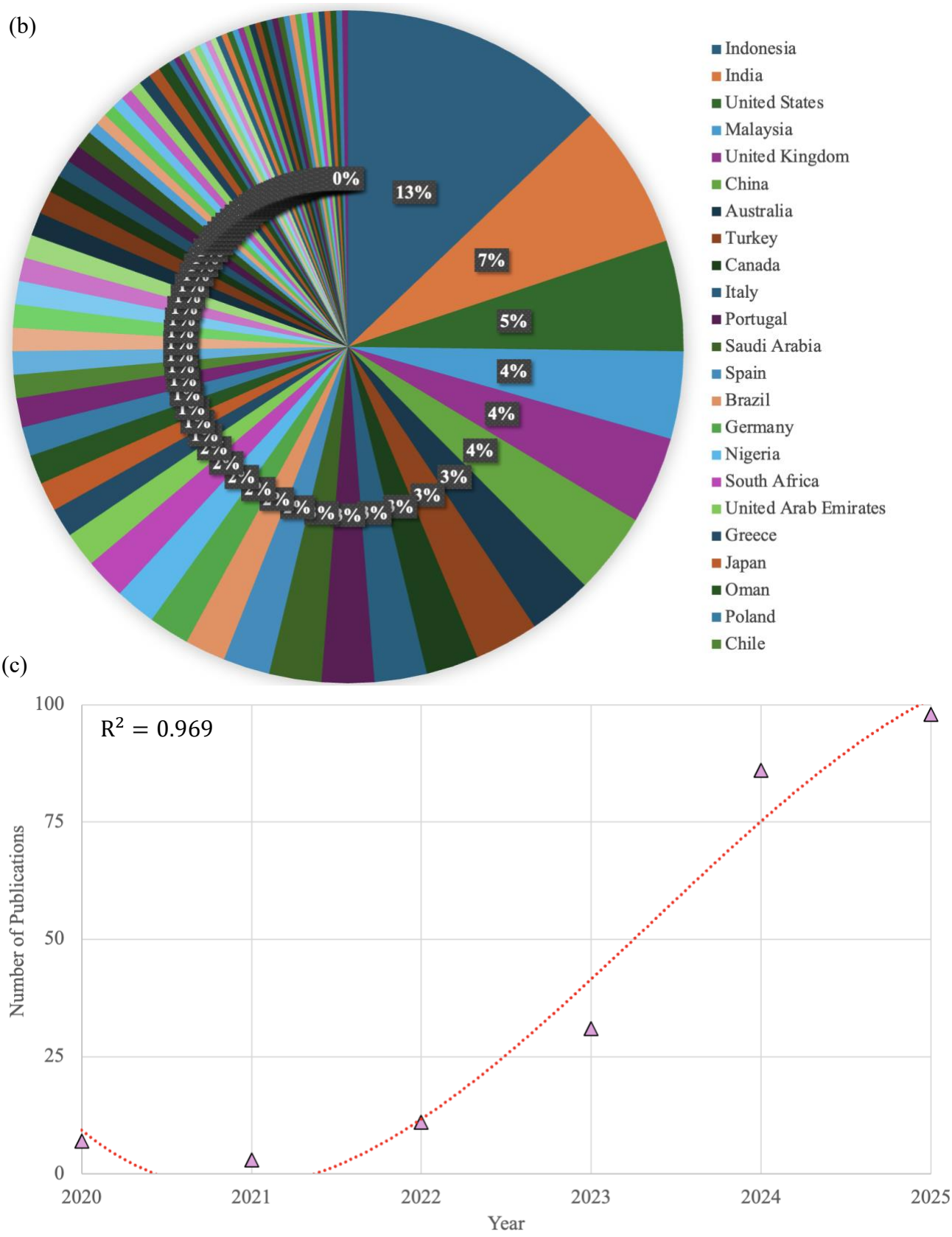


Figure 6: RQ_3 trends by (a) discipline, (b) countries, and (c) publication trends over the last decade.

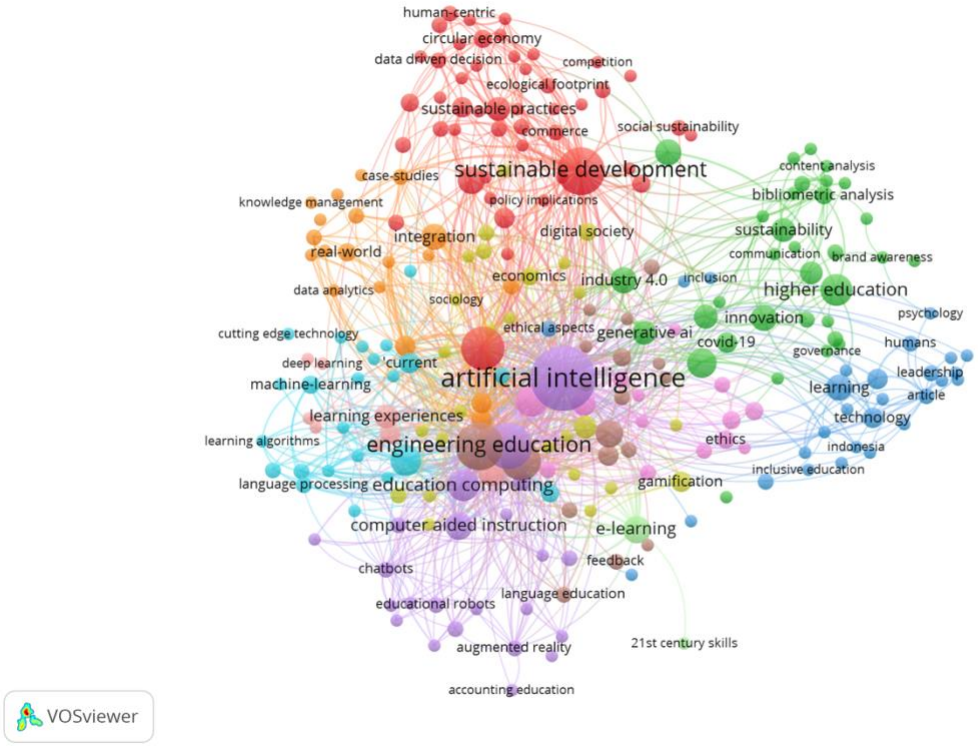
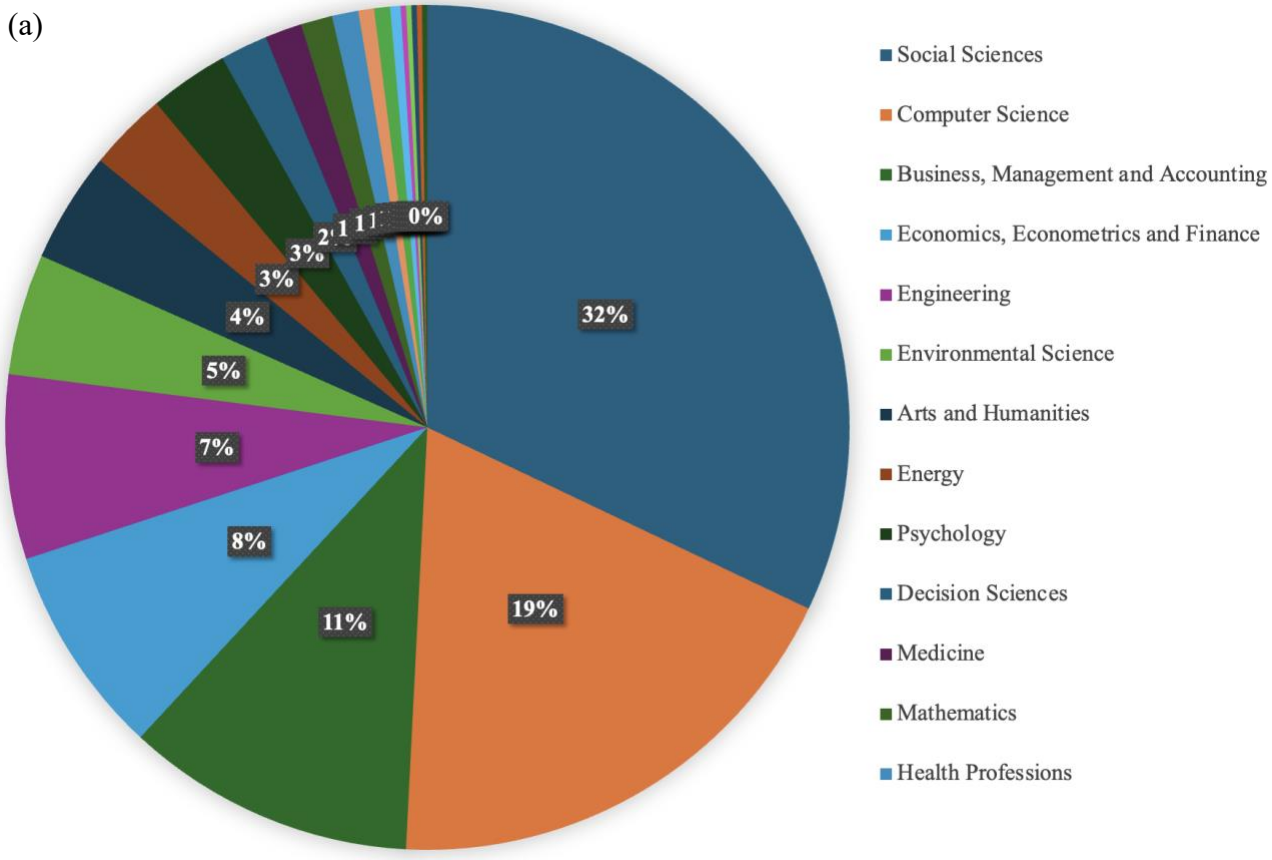


Figure 7: The co-citation network generated for RQ4.

(a)



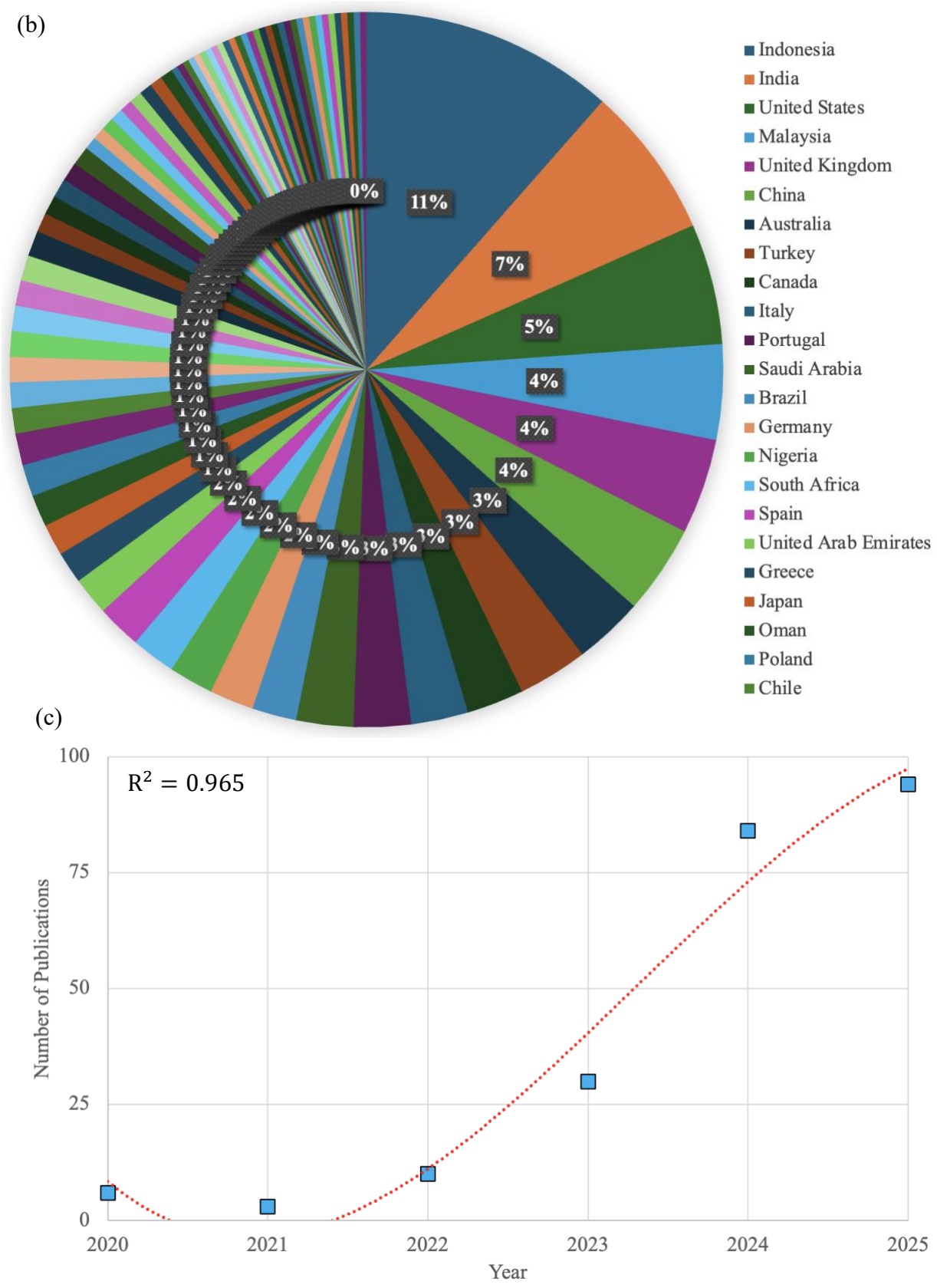


Figure 8: RQ_4 trends by (a) discipline, (b) countries, and (c) publication trends over the last decade.

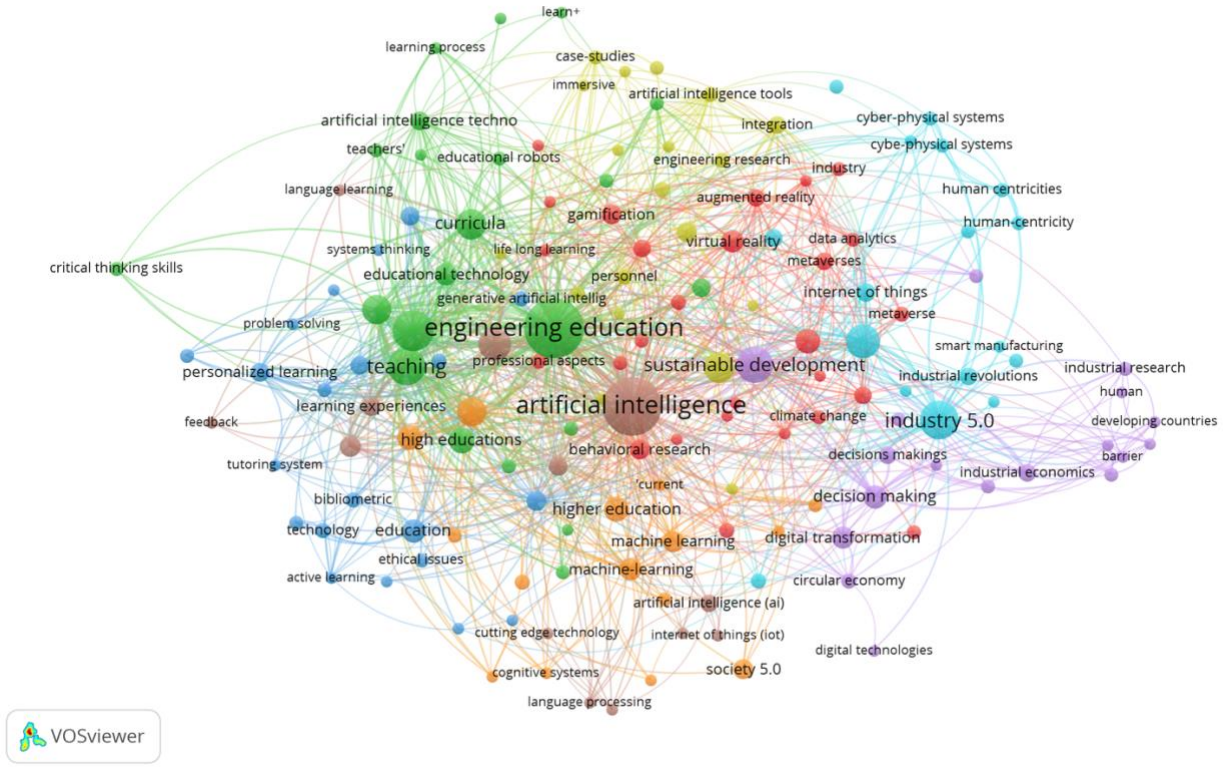
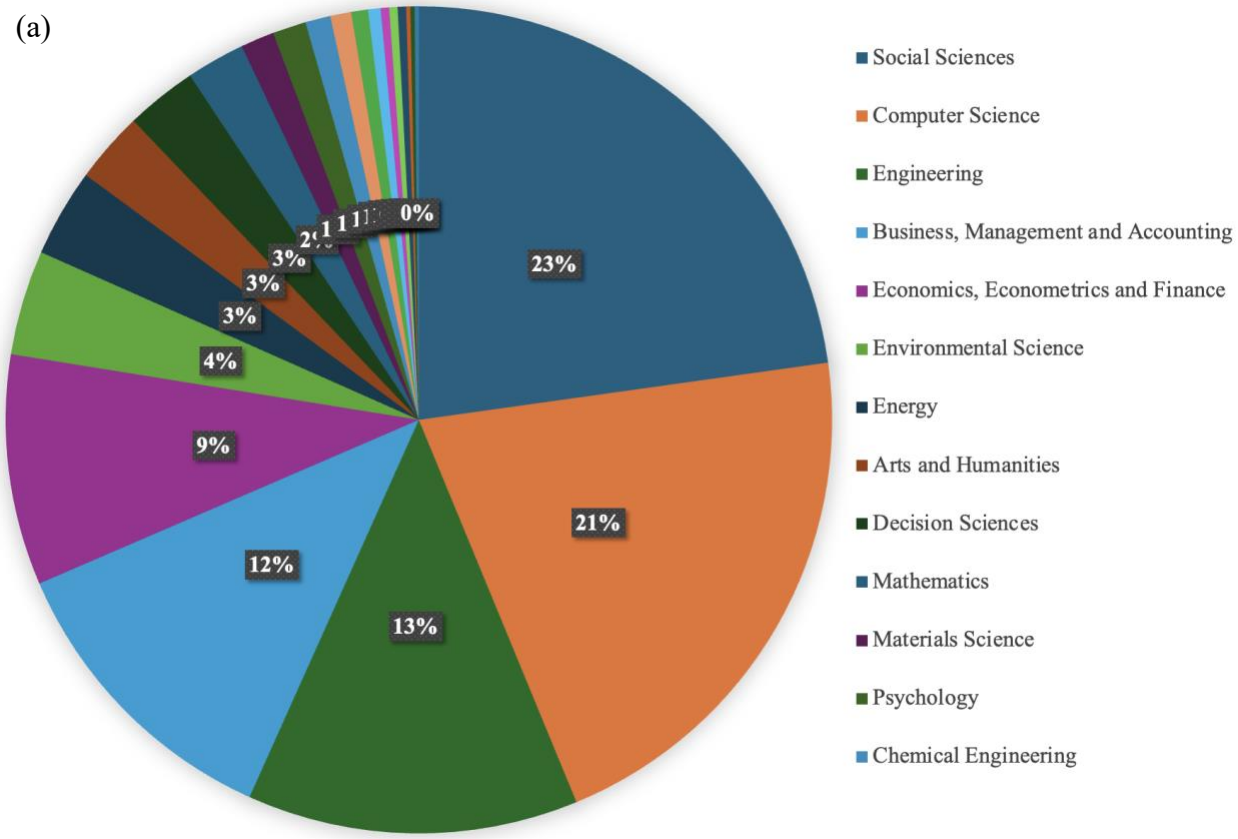


Figure 9: The co-citation network generated for RQ_5.

(a)



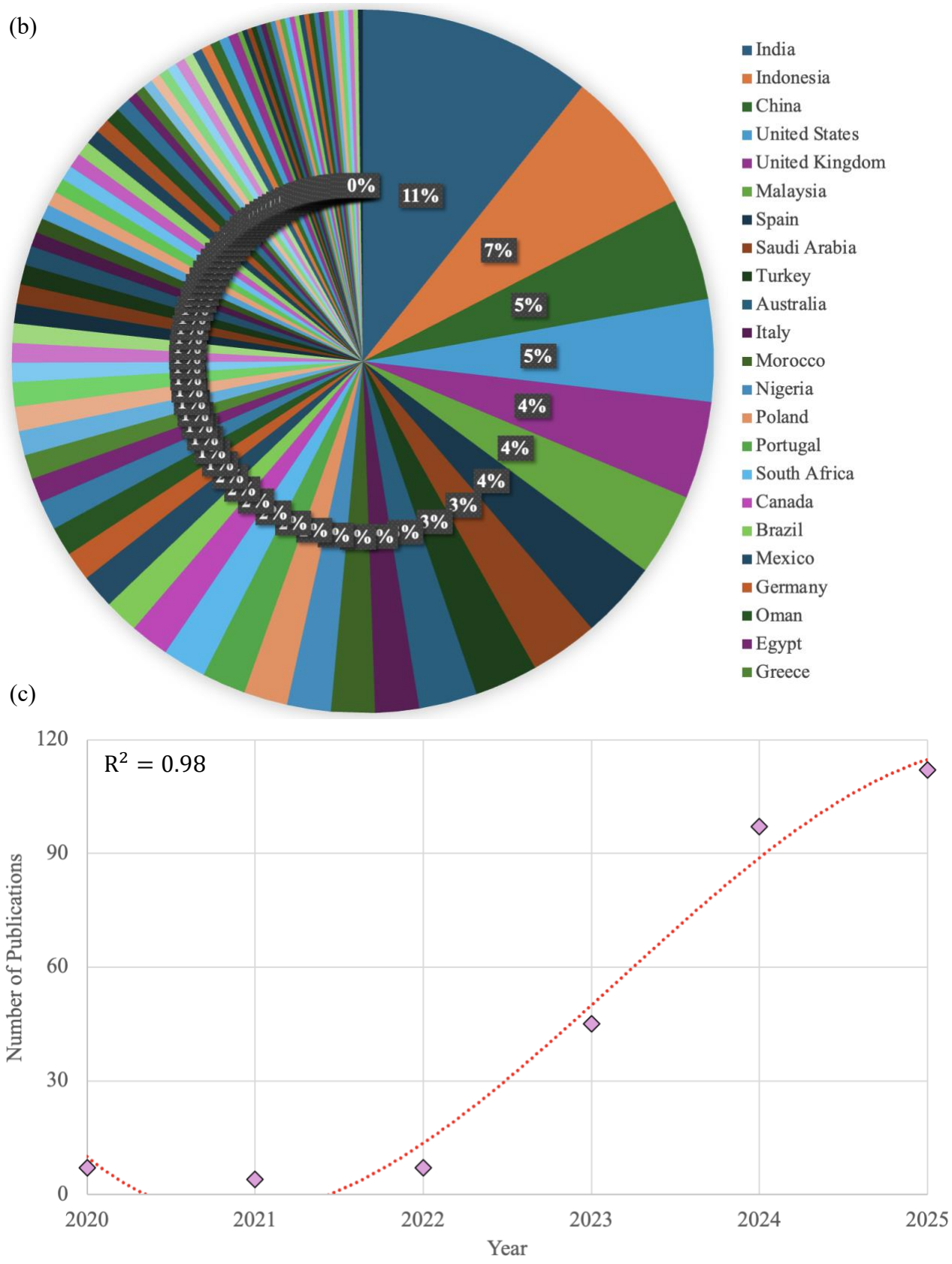


Figure 10: RQ_5 trends by (a) discipline, (b) countries, and (c) publication trends over the last decade.

Appendix B: Table of acronyms and symbols used in this work.

Acronym	Description	Acronym	Description
E.D. 5.0	Education 5.0	VR	Virtual Reality
I.D. 5.0	Industry 5.0	AR	Augmented Reality
HEI	Higher Education Institutes	RQ	Research Question
ML	Machine Learning	R^2	Regression Coefficient
IoT	Internet of Things	VR	Virtual Reality
EPE	Effective Prompt Engineering	STEM	Science, Technology, Engineering and Mathematics