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APPLICATION OF 4IR FOR STEAM EDUCATION IN HIGHER EDUCATION AND IMPLICATIONS FOR DEVELOPING COUNTRIES: A SYSTEMATIC REVIEW

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Abstract

The Fourth Industrial Revolution (4IR) is driving a global shift towards digital technologies and the integration of Artificial Intelligence (AI), the Internet of Things (IoT), robotics and automation in all aspects of our lives and has brought about transformative changes in various sectors, including education. This systematic review explored the application of 4IR technologies and concepts in Science, Technology, Engineering, Arts, and Mathematics (STEAM) education within higher education institutions. STEAM education is key to equipping the African workforce with the necessary skills to participate in the 4IR. The review utilizes a systematic approach to identify relevant scholarly articles, conference papers, and reports published between 2014 and 2023. The search strategy encompassed Scopus and Web of Science databases complemented with grey literature. The inclusion criteria focus on studies that specifically address the use of 4IR technologies and concepts in higher education STEAM programs. The review includes an analysis of STEAM education initiatives, curricula, pedagogical approaches, teacher training and assessment practices in African countries. The findings highlight the current landscape of 4IR integration in STEAM education in higher institutions of learning, emphasizing the diverse range of technologies employed, such as artificial intelligence, the Internet of Things (IoT), robotics, and virtual reality. Overall, this systematic review contributes to the existing body of knowledge by providing a comprehensive analysis of the application of 4IR in STEAM education in higher education institutions, with the need for more engagements in Africa. The findings and recommendations can guide future research and policy initiatives to harness the potential of 4IR technologies for educational advancement and socio-economic development in developing countries.

Keywords
STEAM education, Fourth Industrial Revolution, Africa, Digital technologies, Pedagogical approaches

1. Introduction

The Fourth Industrial Revolution (4IR) is driving a global shift towards digital technologies and the integration of Artificial Intelligence (AI), Internet of Things (IoT), robotics and automation in all aspects of our lives. Africa is not exempt from this trend and must quickly adapt in order to keep up with the rest of the world. Science, Technology, Engineering, Arts and Mathematics (STEAM) education is key to equipping the African workforce with the necessary skills to participate in the 4IR. Higher educational (HE) institutions are responsible for human capital development for all nations, and this can be pursued through various modes, including traditional on-campus programs, online education, and hybrid models that combine both. HE plays a vital role in shaping individuals' intellectual abilities, fostering personal growth, contributing to societal progress, and driving economic development. It is important for HEs to continue to aim for improvements by leveraging 4IR possibilities to ensure quality workforce necessary for national developments. This is important considering the volatile future of work, and this brings about the need to structure education towards multi-skilling for optimal performance rather than providing a menu of predefined disciplines and degrees.

2. Literature Review

2.1 Higher education and development

Higher education refers to education provided by colleges, universities, and other institutions beyond the secondary school level. It typically involves post-secondary education and offers a more specialized and advanced curriculum compared to primary and secondary education. The concept of higher education encompasses undergraduate and graduate programs, leading to degrees such as bachelors, master's, and doctoral degrees. HE institutions are responsible for providing students with a broader and deeper understanding of various academic disciplines. They offer a range of courses and programs that allow students to pursue their interests and acquire specialized knowledge in specific fields such as sciences, humanities, social sciences, engineering, and business, among others. HE plays a crucial role in the development of individuals, societies, and nations (Arocena *et al*., 2013; Mei & Symaco, 2021). HE is a key driver of social and economic progress, offering numerous benefits that contribute to personal growth, innovation, and overall societal advancement (Zgaga, 2011). Some roles of higher education are Human Capital Development (Adedeji & Campbell, 2013; Eseyin *et al*., 2014; Kumari, 2018), research and innovation (Hatakenaka, 2007; Vessuri, 2008; Lakhotia, 2021), social mobility and inclusive development (Marginson, 2018; Cunninghame, 2017; Lin, 2020), as well as entrepreneurship and job creation required for closing the skills gap (Labi *et al*., 2014; Eze & Aroge, 2019; Nhleko & van der Westhuizen, 2022) among others. Educational institutions have contributed greatly to reshaping future technologies by being the test laboratories for innovations (Yusuf *et al*., 2020). As such, higher education plays a pivotal role in individual development, economic growth, and societal progress by equipping individuals with requisite knowledge, skills, and values necessary for personal success and contributes to innovation, social mobility, entrepreneurship, and global collaboration. Recent trends show a transition to service-based economies leading to working environments that require more collaboration rather than the performance of routine tasks and the university must continue to play the important role of closing the skills gap (Scott & Fisher, 2011; Labi *et al*., 2014). By investing adequately in higher education, societies can harness the transformative power of education to drive sustainable development. This investments should also take into cognizance the quality of faculty equipped with knowledge creation and authentic technology-driven assessment skills through which the extent to which learning is achieved is gauged (Carlow University, 2021; Atibuni *et al*., 2022). The training should also take into cognizance the use of IOTs required for accepting 4IR possibilities for teaching and learning and for creating smart education systems (Vinayachandra & Krishna Prasad, 2020; Gökçearslan *et al*., 2022). Considering that the need for universities to occupy the space of problem solving through research for societal relevance (Polushina *et al*., 2018; Moscardini *et al*, 2020), a new move in higher education is transdisciplinary knowledge construction fast gaining importance due to its ability for sustainably solving "wicked problems" (O'Neill *et al*., 2019; Oladele, 2022; Udovychenko *et al*., 2022). Higher institutions should also change from their traditional pedagogical approach to more technology integrated modes by leveraging 4IR technologies like most institutions were forced to during the COVID-19 Pandemis (Dhawan, 2020). This is particularly necessary for higher institutions in developing countries in catching up with the 4IR (Adhikari, 2020).

2.2 Science Technology Engineering, Arts and Mathematics Education (STEAM)

STEAM education is an educational approach that focuses on integrating the disciplines of science, technology, engineering, arts, and mathematics. It aims to provide students with a multidisciplinary and holistic learning experience that promotes critical thinking, problem-solving, creativity, and collaboration skills. STEAM education recognizes the interconnectedness of these fields and encourages students to explore the intersections between them. STEAM is an educational discipline that aims to spark an interest and lifelong love of the arts and sciences in children from an early age and are regarded as similar fields of study in that they all involve creative processes, and none uses just one method for inquiry and investigation. The need to teach relevant, in-demand skills was stressed as a precursor for preparing innovative students in an ever-evolving world, not only for the future of the students themselves but for the future of the country (Lathan, 2023). Some conceptual approaches to STEAM education are Inquiry-based learning which encourages students to ask questions, investigate, and discover answers through hands-on experiences. It emphasizes critical thinking, problem-solving, and creativity and fit for exploring real-world problems, project-based Learning involving students working on long-term projects that require them to use a variety of skills and knowledge across different subject areas and encourages collaboration, communication, and creativity, Integrated Learning which involves blending the content and skills from different subjects into a single lesson or activity and aids for a more holistic understanding of the world, design thinking which use human-centered problem-solving processes that emphasizes empathy, ideation, prototyping, and testing. Design thinking encourages students to think creatively, iterate on ideas, and develop solutions that meet the needs of their users. Overall, a conceptual approach to STEAM education should be student-centered, hands-on, and focused on solving real-world problems. It should also emphasize creativity, critical thinking, and collaboration, as these are essential skills for success in the 21st century (Yakman, 2008; Bauld, 2022). While STEAM education is an offshoot of STEM education, STEAM education includes an A for arts in the teaching–learning process having the purpose of improving the creativity of students among others (Singh, 2021; Aguilera Morales & Ortiz Revilla, 2021).

2.3 The Fourth Industrial Revolution (4IR)

The Fourth Industrial Revolution (4IR) refers to the ongoing transformation of our society and economy through the integration of digital technologies, artificial intelligence, automation, robotics, and other emerging technologies. 4IR builds upon the foundation laid by the previous industrial revolutions, which were characterized by significant shifts in manufacturing and production processes. It is characterized by the fusion of physical, digital, and biological systems, which is reshaping various industries and sectors (Oladele *et al*, 2022). 4IR is marked by the rapid pace of technological advancements and their integration into various sectors including business, industry, healthcare, education, transportation, and governance has profound implications for the economy, society, and individuals (Alsulaimani & Islam, 2022). There is no gain-saying the fact that 4IR has the potential to significantly transform education and learning and reshape the future of work. However, it also raises concerns about job displacement, data privacy, cybersecurity, and ethical considerations surrounding the use of emerging technologies (Brown-Martin, 2017; Peckham, 2021; Jaafar, 2021). To navigate the challenges and maximize the benefits of the Fourth Industrial Revolution, stakeholders including governments, businesses, and individuals need to foster digital literacy, invest in education and skills development, establish appropriate regulatory frameworks, and promote ethical and responsible use of technology (Zervoudi, 2019). The Fourth Industrial Revolution has brought rapid advancement of technologies which has created a demand for a highly skilled workforce with expertise in science, technology, engineering, arts, and mathematics (World Economic Forum, 2017; Fox & Signé, 2021). STEAM education plays a crucial role in preparing students for the challenges and opportunities of the 4IR (Schwab, 2016). STEAM education is connected to the Fourth Industrial Revolution with respect to skill development as the 4IR demands a workforce equipped with advanced technical skills. As such, the 4IR is reshaping the job market, and many traditional roles are being automated and STEAM education holds the potential of equipping students with the knowledge and skills needed for the jobs of the future, ensuring they are prepared for the changing workforce landscape. This synergy is strong as STEAM education focuses on developing critical skills such as coding, programming, data analysis, and problem-solving, which are essential in the digital age. Also, the 4IR requires individuals who can think across disciplines and work collaboratively in diverse teams while encouraging students to integrate knowledge from various fields, fostering interdisciplinary thinking and promoting collaboration. The 4IR also emphasizes innovation and the ability to adapt to rapidly changing technologies and nurtures creativity, design thinking, and entrepreneurial skills, enabling students to become innovators and problem solvers. With the proliferation of emerging technologies, artificial intelligence, robotics, Internet of Things (IoT), and biotechnology have become mainstream in different sectors (Bajracharya *et al*., 2021). It becomes imperative for STEAM educators to familiarize students with these technologies, providing hands-on experience and enabling them to understand and harness their potential. STEAM education aligns with the goals and requirements of the Fourth Industrial Revolution by fostering the skills, knowledge, and mindset needed to thrive in an increasingly technology-driven world. It empowers students to become active participants in shaping the future and encourages lifelong learning to adapt to the evolving needs of the 4IR. To help the learner survive and thrive in a VUCA (volatility, uncertainty, complexity, ambiguity) environment, efforts should be put into 21st-century tailored instruction that engenders flexibility, adaptability, observation, empathy, creativity, innovation, openness to re-learn which are apparently metacognitive and fractal with the same basics at various levels of detail and knowledge (Reaves, 2019; Papadakis *et al*., 2022). This systematic review was carried out with the aim of getting a closer view on the application of 4IR for STEAM Education in higher education and implications for Africa. To address the mentioned research aim, this systematic review attempted to answer the research questions:

1. What are the 21st century skills for STEAM in Higher Education?
2. What are the areas of application of 4IR in Higher Education?
3. What is the regional responsiveness to STEAM Education and 4IR in Higher Education?

3. Research Method

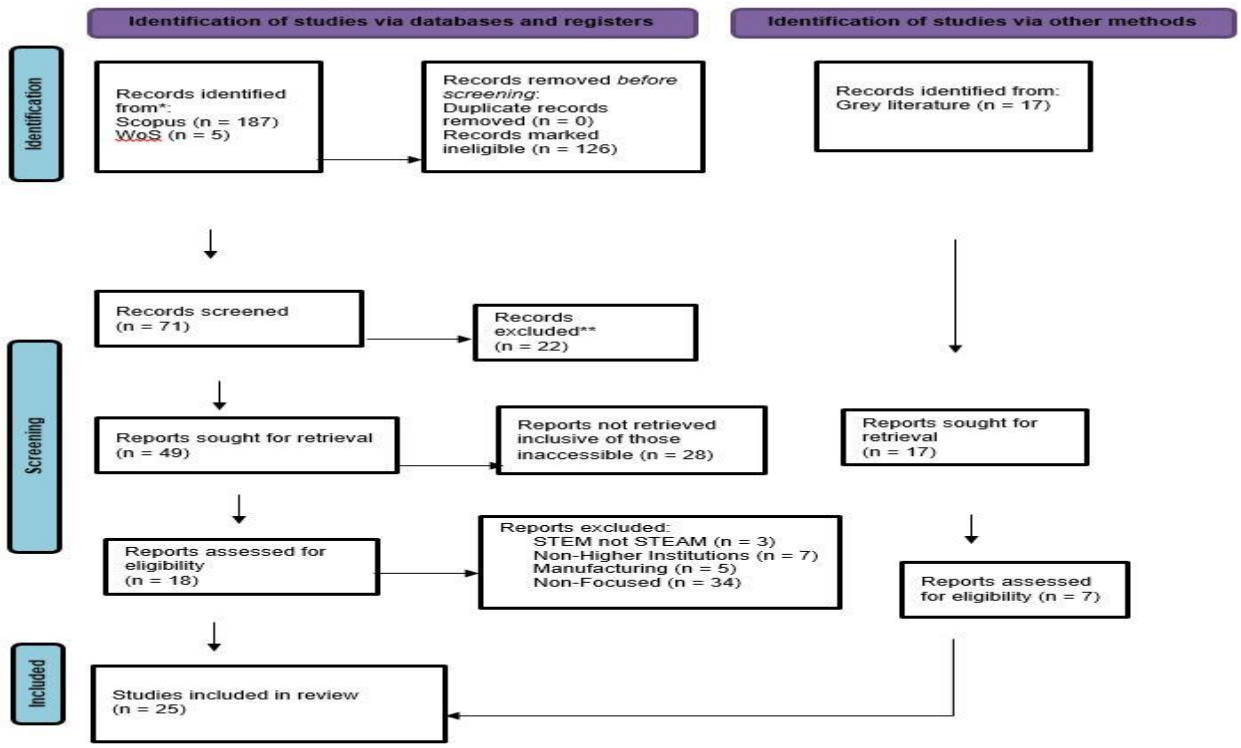

Figure 1: PRISMA 2020 statement (Page *et al*., 2020)

3.1 Identification

The identification process involves identifying articles through database searching as well as deduplication. There were two databases namely Web of Science (WoS) and Scopus chosen as both databases for information retrieval. This decision was premised on the perception of the two being the major and most wide-ranging sources of publication metadata as well as impact indicators (Pranckutė, 2021). The potential keywords related to the study was "STEAM Education AND The Fourth Industrial Revolution" to make sure an inclusive literature search. 187 articles including empirical, review and theoretical articles were identified from both databases with no duplicates. This retrieval was complemented with 17 articles from other sources including Grey Literature due to its emerging importance (Luzi, 2000; Pappas & Williams, 2011). A manual identification process was carried using the data from the three sources compiled into a CSV files to exclude the articles which were irrelevant to the STEAM education and 4IR between 2014 to April 2023 when the database was last visited. The choice of the query date was premised on the first mention of the 4IR by Schwab in 2016 and regarded as responsible for popularizing the concept (Cruz, 2019). This activity resulted in 187 articles with no duplicates and 126 articles which were marked as ineligible were then removed, resulting in 71 articles were eligible for the consecutive process.

3.2 Screening and Inclusion

The screening process was done to the 71 remaining articles according to their titles, abstracts, and keywords related to STEAM Education and 4IR. The outcome of the screening process revealed 22 articles which were irrelevant to this study and were excluded. On the other hand, 49 articles were sought for retrieval of which 25 articles were included for review. The articles were subjected to the word cloud function to have an overview of the inclusions as shown in Figure 2.

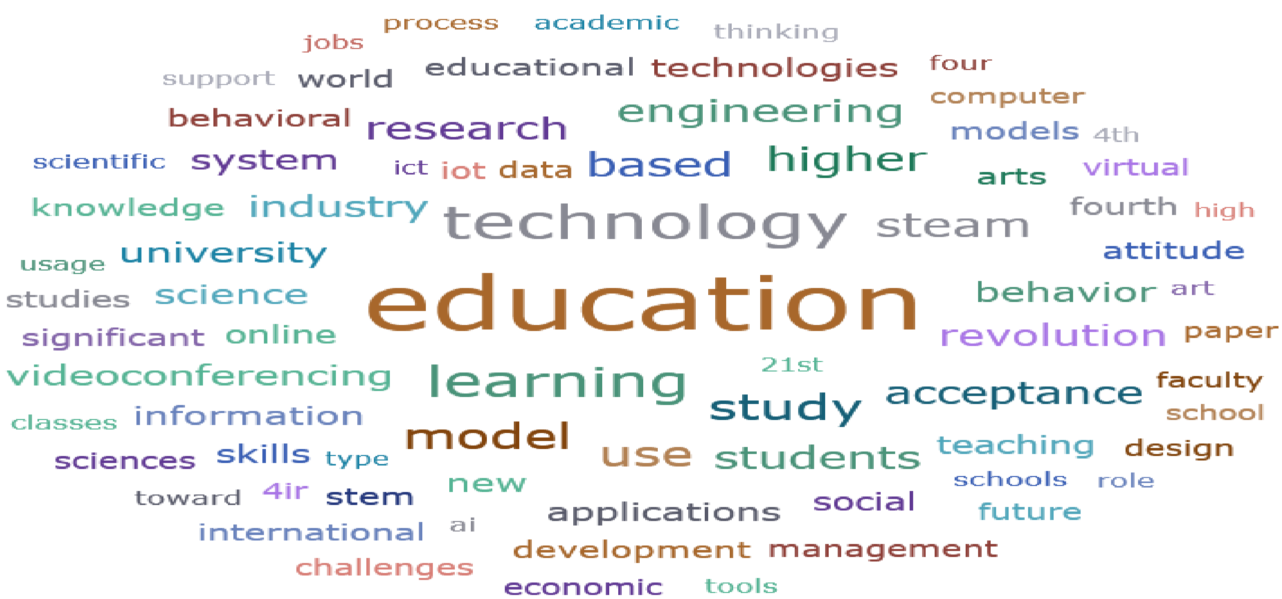

Figure 2: Word Cloud based on Reviewed Documents (Atlas ti Reports)

4. Data analysis procedure

The Analysis was carried out qualitatively using Atlasti 23. In the first stage, all documents were subjected to AI coding also known as In Vivo coding to ensure a broad overview of matters arising in the included documents. At the second stage, A Priori coding was performed based on the research questions to closely examine 21st century skills for STEAM Education, areas of application of 4IR in Higher Education and the regional responsiveness to STEAM Education and 4IR in Higher Education. Following this activity, the codes were subjected to networking tool analysis and discussed with appropriate literature.

5. Results and Discussion

5.1 RQ1: What are the 21st century skills for 4IR in Higher Education?

In response to the first research question, skills-related generated AI codes were screened and created using the network tool as shown in Figure 3.

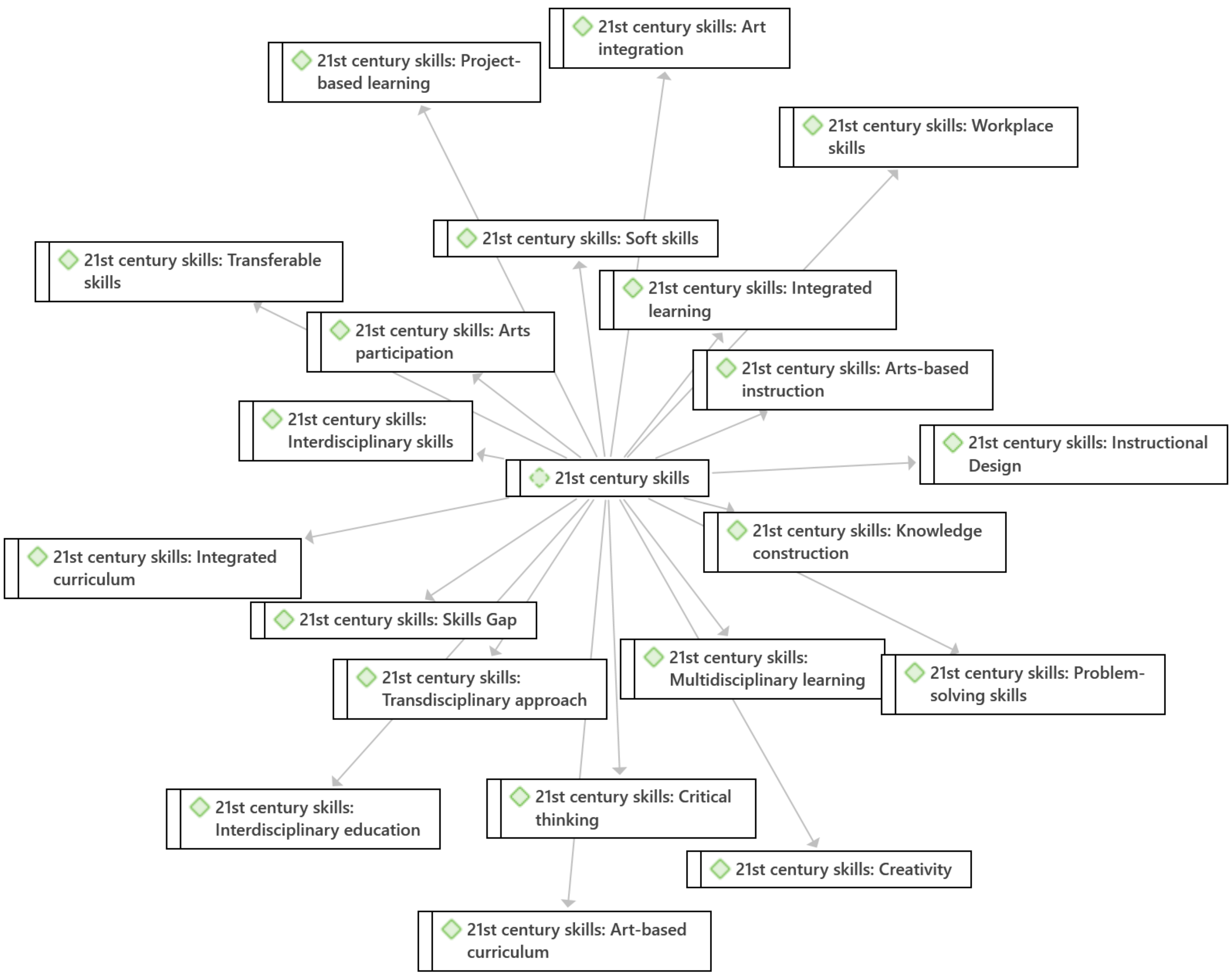

Figure 3: 21st Century Skills

Figure 3 display a network of 21st century skills relevant for 4IR in Higher Education such as creativity, Arts-based/integrated curriculum and instructional designs, critical thinking, inter, multi and trans-disciplinarily, problem solving, skills gapping, skills transferability, problem-based learning and workplace skills. In the context of the Fourth Industrial Revolution (4IR), higher education institutions need to equip students with a set of skills that are relevant to the rapidly evolving technological landscape. These skills play a crucial role in preparing students for the demands of the 4IR. This is eminent as the future of work and the future of education are closely connected and if the fourth industrial revolution evolves as expected, a significant change was projected for the very nature of work and careers. Therefore, students in higher education should be prepared to be functionally part of an enlightened society while optimising life (Reaves, 2019). To achieve the desired level of functionality, HE training requires the ability to effectively navigate, evaluate, and create digital content. This includes proficiency in using digital tools, understanding online security and privacy, and having a critical mindset when consuming digital information (Dube, 2018; Fox & Jones, 2018). Also, the ability to analyze problems, break them down into smaller components, and solve them using algorithmic and logical thinking also known as computational thinking will also be a great asset in these VUCA times (Papadakis *et al*., 2022). While this skill is particularly relevant for STEM education, integrating creativity improve students' outcomes and ultimately industrial relevance (Singh, 2021; Aguilera Morales & Ortiz Revilla, 2021). Furthermore, the capacity to think critically, analyze information, and develop innovative solutions to complex problems enables individuals to adapt to new challenges and make informed decisions in the face of uncertainty (Waller *et al*., 2019; Taguma *et al*., 2020). The skill of creativity also speaks to the ability to generate novel ideas, think outside the box, and apply creative approaches to problem-solving. In the 4IR, where new technologies are re-modeling the educational rapidly, the capacity to innovate is crucial (Yusuf *et al*., 2020; Rodnyansky *et al*., 2020). The Inter, multi and trans-disciplinary approach to teaching and learning also requires coeffective communication and a high level of collaboration (O'Neill *et al*., 2019; Udovychenko *et al*., 2022). Effective communication skills, both written and verbal, as well as the ability to work collaboratively in diverse teams are now in high demand as they are relevant for 21st Century workplace that are becoming more virtual with the proliferation of the internet which is a major pillar of the 4IR (Cascio & Montealegre, 2016). In the 4IR era, individuals need to continue to improve in communicating complex ideas, while effectively leveraging virtual collaboration tools. The 4IR is characterized by constant change and if not carefully handled may further widen the already created skills gap. As such, higher education training should equip individuals to be adaptable and resilient in order to thrive (Scott & Fisher, 2011). This necessitates the capacity to embrace change, be open to learning new skills, and adapt to evolving technologies and work environments. Lifelong Learning is the mindset and skills necessary for continuous learning and professional development. This is apt as the 4IR requires individuals to keep up with rapidly evolving technologies and embrace lifelong learning to remain relevant in their careers (Brown-Martin, 2017). Similarly, the need for arts integrated curriculum is on the rise as the societal changes from the 4IR will require higher education to develop greater capacity for ethical and intercultural understanding, placing a premium on liberal arts-type education with modifications to adapt to the particular issues raised by 4IR technologies and their disruptions to society (Penprase, 2018). The importance of these skills may vary depending on specific disciplines and career paths. However, integrating these 21st-century skills into higher education curricula can help prepare students for the challenges and opportunities of the Fourth Industrial Revolution.

5.2 RQ2: What are the areas of application of 4IR in Higher Education?

To answer this research question, the documents were coded for application to 4IR and analysed using the network tool as shown in Figure 4.

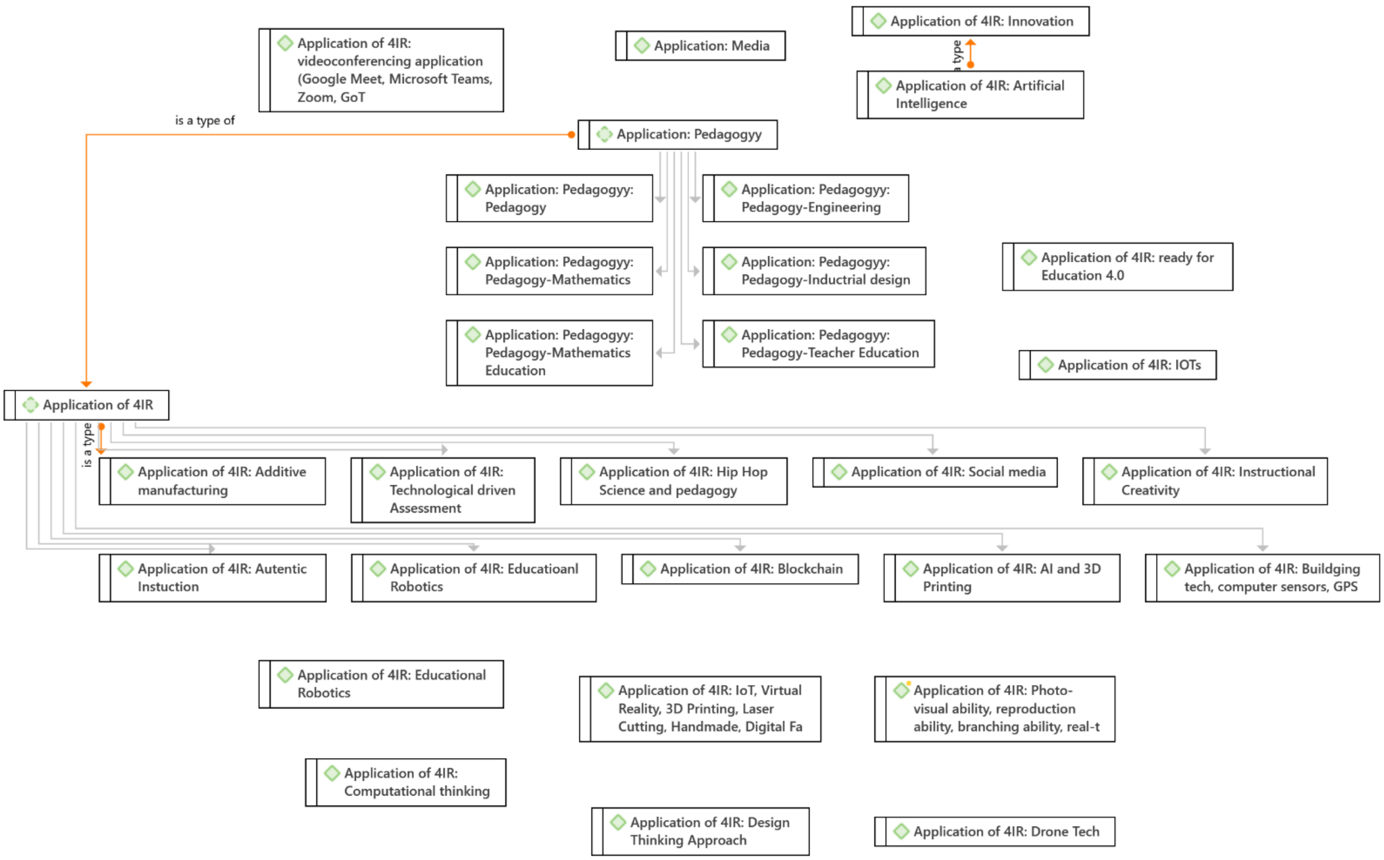

Figure 4: Application of 4IR to STEAM Education

The pillars of 4IR described by Erboz (2017) include Autonomous Robots, Simulation, Horizontal and Vertical System Integration, Internet of Things (IoT), Cloud technologies, Additive Manufacturing (3D Printing), Augmented Reality and Cyber Security. As shown in Figure 5, there is a positive relationship and STEAM Education and 4IR with the highlighted application areas of Pedagogy in the predominant fields of Engineering, Industrial design, Robotics and sparingly, for Teacher Education. The review reveals some of the 4IR-driven instructional approaches such as authentic instruction, instructional creativity computational thinking, design thinking, technological driven assessment. This show that instruction paradigm which has been dominated by teacher-centred instructional strategies is changing with a shift to the learning paradigm which would require higher institutions to engage faculty who are equipped with interactive teaching skills. This was described by Atibuni *et al*. (2022) as "teachers who are 'meddlers in the middle', who create puzzling situations and work alongside students to construct knowledge". The authors stressed the plausibility of shifting from the instruction paradigm to the learning paradigm in order to prepare teachers to meet the needs of 21st century learners within the 4IR. The Fourth Industrial Revolution brings forth a range of advanced technologies that hold immense potential for transforming pedagogy. From AI and machine learning to VR/AR, IoT, robotics, and data analytics, these technologies offer innovative approaches to teaching and learning. By harnessing the power of 4IR, educators can create personalized, engaging, and effective learning experiences that cater to the diverse needs of students. As these advancements are embraced in the educational sector, it is crucial to ensure equitable access to technology while maintaining a human-centric approach, where teachers play a vital role in guiding and supporting students in their learning journeys. AI and 3D Printing. The use of video conferencing application (Google Meet, Microsoft Teams, Zoom) for deploying teaching which was triggered by the COVID-19 Pandemic has helped in the transformation of the education sector towards industry 4.0 and a key driver for the digital transformation of the education sector. This transformation creates an opportunity to ensure that universities become innovative and creative hubs at the same time being able to scale up access to educational resources as space is no longer a challenge while leveraging the asynchronous and synchronous learning modes (Kayembe & Nel, 2019; Mhlanga, 2020). In an educational context, IoT devices can facilitate smart classrooms and campuses (Al-Taai *et al*., 2023; Ayanwale & Oladele, 2021). For instance, sensor-equipped classrooms can monitor environmental conditions such as temperature, humidity, and lighting, optimizing the learning environment for student comfort and productivity. IoT devices can also track students' attendance, movement patterns, and interactions, enabling educators to gain insights into individual learning behaviors and tailor instruction accordingly. Gökçearslan *et al*. (2022) stressed that the acceptance of IoT technologies in education by pre-service teachers will affect their intention to use these technologies in the future. In educational sectors, many institutions are exploring advanced digital infrastructure applications to improve the learning and teaching abilities of the difficult subjects of STEAM subjects. IoT devices in the classroom or in laboratory activities can enhance the learning process with innovative ideas to increase student motivation in much faster and effective ways (Ayanwale & Oladele, 2021; Bajracharya *et al*. 2021). Smart education systems make efficient use of IT technology that takes advantage of IoT and cloud computing technologies to track and act on multiple educational system components (Vinayachandra & Krishna Prasad, 2020). Prospects with immense potential for education is the combining IoTs with AI for AI-powered chatbots, virtual assistants, and intelligent tutoring systems which can provide personalized guidance, answer student queries, and offer real-time feedback to further enhancing the learning experience (Slepankova, 2021; Okonkwo & Ade-Ibijola, 2021; Oladele *et al*., 2021). Another prospect is on the area of wearable devices, such as smartwatches or fitness trackers, integrated with IoTs can monitor student health and well-being. This data can help educators identify patterns, adjust teaching strategies, and promote a healthier and more productive learning environment (Dinh-Le *et al*., 2019; Passos *et al*., 2021. Automating every entity of the education system and the elements involved in it can enrich and improve, as well as change, the knowledge ecosystem's end-to-end learning lifecycle (Ayanwale & Oladele, 2021). Educational institutions have to continually adopt 4IR technologies being an important factors for improving learning outcomes for STEAM Education.

5.3 RQ 3: What is the regional responsiveness to STEAM Education and 4IR in Higher Education?

To ascertain the level of regional responsiveness to STEAM Education and 4IR, the country level involvements in research in these fields were screened and to understand the geographical context of their discussions as shown in Figure 6.

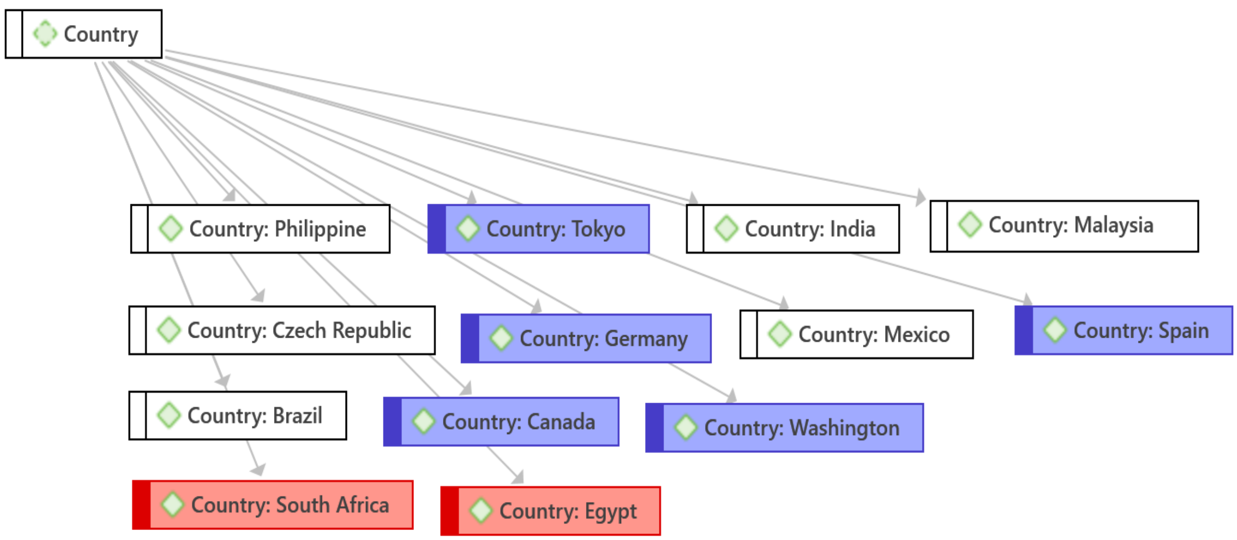

Figure 5: Countries level Research Involvements in STEAM Education and 4IR

As shown in Figure 5, most of the countries where the manuscripts were the published research were carried out mostly in developing countries (WorldData.info, 2023); with researches emerging from only two African countries (red boxes). The study carried out in Philippine explored assessment practices of the sampled higher education Philippine STEAM educators and result showed that assessment was career or industry readiness-tailored while mounting the needed assessment systems by leveraging 4IR tenants and engagement in collective and reflective assessment processes. Technology-driven assessment practices were reported to offer quick and compelling insights when used to identify knowledge gaps in formative assessments with instant feedback required for consolidation of learning (Carlow University, 2021). One of the studies carried out in Malaysia investigated required reliance on e-learning and robotics education with reference to the school closure necessitated by the pandemic. This is quite necessary considering the drawbacks suffered in the face of school closure experienced in the education sector with developing countries being the most hit. The COVID-19 Pandemic jolted many institutions to remote learning and learning through the process as there were little or no preparatory periods (Dhawan, 2020). Considering that the previous three Industrial Revolutions have bypassed the LDCs, the (4IR) offers several opportunities for them to leapfrog along their development trajectory, provided correct measures are taken to prepare them as well as to mitigate potential risks (Adhikari, 2020). With the 4IR now well underway, many developing countries have a golden opportunity to make huge progress over the coming years. However, if the world's least developed countries (LDCs) want to take full advantage of the 4IR they will need to start laying foundations to get involved sooner rather than later as technology and STEAM education are two major areas where LDCs could benefit from the 4IR (Black, 2019). The engagement of developing countries in the Fourth Industrial Revolution (4IR) is a topic of great significance and potential. While developed countries have been at the forefront of technological advancements, there is increasing recognition of the importance of including developing nations in the 4IR to ensure inclusive and sustainable growth worldwide (Ndung'u & Signé, 2020; Udovychenko *et al*., 2022). Another reviewed study carried out in India investigated the key factors influencing educational institutions' (knowledge providers) and learners' (knowledge recipients) intentions to use blockchain technology as one of the foundational 4IR technologies with multi-sectoral application. Closing the digital divide is necessary with technology adoption to leverage the 4IR which has the potential to drive efficiency, productivity, and innovation across various sectors, including healthcare, agriculture, manufacturing, and education and especially in populous countries. Yet another study carried out in Czech Republic focused on analysing the labour market situation from employers perspective and their expectations of university graduates in the context of 4IR. This study is apt as there is an urgent need to strengthen the capabilities and skills of the workforce vital for developing countries to harness the benefits of the 4IR (Fox & Signé, 2021). Some of the reviewed studies were on pedagogic involvements with higher education students such as service-learning using drone technology with the real context application in Engineering Education (Malaysia), technology-enhanced industrial design education and Design Thinking Approach to students STEAM project (South Africa), Computational Thinking in Mathematics Education (Malaysia) and Active Learning in Engineering Education for fostering digital literacy (Mexico). Appropriate pedagogy will continue to play a crucial role in STEAM education, as it directly impacts the effectiveness of teaching and learning experiences in these disciplines. The relevance of the right pedagogical approach for STEAM education cannot be over-emphasised as STEAM subjects require active participation and engagement from students. The right pedagogy encourages hands-on, inquiry-based learning experiences that promote critical thinking, problem-solving, and creativity. It shifts the focus from passive listening to active exploration, experimentation, and collaboration, allowing students to develop a deep understanding of concepts and their practical applications. Considering that STEAM education emphasizes the integration of multiple disciplines to solve real-world problems, effective pedagogy facilitates the exploration of connections between science, technology, engineering, arts, and mathematics, enabling students to see the interconnectedness of these subjects while encouraging students to think holistically, promoting interdisciplinary thinking and problem-solving skills that are valuable in the modern world being a skill required in VUCA times (Bauld, 2022). Also, applying the appropriate pedagogy for STEAM Education provides authentic and meaningful contexts for learning and enhances students' motivation and engagement. STEAM education should connect classroom learning to real-world problems, applications, and examples to help students see the relevance of what they are learning and understand how it can be applied in practical situations (Bauld, 2022). Authentic contextualization helps students develop a deeper appreciation for the subjects and fosters a sense of purpose and curiosity which is a prerequisite for creativity and Innovation being at the heart of STEAM Education (Aguilera Morales & Ortiz Revilla, 2021). Another study aimed at understanding how the production of knowledge policies is implemented in a public Mexican university. This study is apt for educational institutional administration requiring collaboration from industry stakeholders to provide training programs, vocational education, and upskilling opportunities to equip individuals with the necessary digital literacy and technical expertise. Also, developing innovation ecosystems by supporting entrepreneurship in higher institutions of learning through research and development (Lakhotia, 2021; Labi *et al*., 2014), and technology startups is inevitable for meaningful development while promoting indigenous technological solutions that address specific socio-economic challenges (Moscardini *et al*, 2020). Developing countries should also develop forward-looking policies and regulations that encourage innovation, protect intellectual property rights, and ensure ethical and responsible use of technologies through collaboration between governments, industry, academia, and civil society is essential to establish effective frameworks being a sure path for transdisciplinary engagement for problem-solving.

6. Conclusion

This systematic literature review has critically reviewed papers related to teachers' technology acceptance in the COVID-19 pandemic to identify literature on STEAM Education and 4IR and 25 articles which met the search criteria were identified with the adherence to the preferred reporting items for systematic review recommendations and meta-analyses PRISMA protocol to review published studies in Scopus, WoS databases supported with grey literature. The findings show that learning of STEAM is now widely touted as an urgent requirement to future-proof current and future generations. Relevant to the 4IR are the knowledge about privacy and data protection, the role of social media in information circulation, understanding cyberattacks, bots and hacking, and how algorithms and automation are changing the future of work in various sectors. These should inform the curricular design for higher education. Also, digital literacy is that next step which gives students the adaptive abilities they need to participate fully in the global digital society. Digital literacy guarantees that students will benefit from the digital economy and derive new opportunities for employment, innovation, creative expression, and social inclusion required for 21st Century relevance. Furthermore, education and lifelong learning will be of vital importance to equip present and future generations to not only be a productive part of this new world but also to meet the societal challenges presented by the 4IR, and the existential challenges presented by climate change and population growth. The engagement of developing countries in the Fourth Industrial Revolution and STEAM Education requires concerted efforts from multiple stakeholders. By addressing infrastructure gaps, fostering innovation, and investing in human capital, developing nations can position themselves to leverage the transformative potential of the 4IR and promote sustainable development.

7. Limitations of the Study

The findings of this study shall be interpreted with caution and several limitations should be borne in mind. First and foremost, considering the comprehensiveness of the database content, this systematic review adopted Scopus and WoS databases supplemented with grey literature to identify the articles related to the research focus from 2014 to April, 2023. There might be more relevant articles available in other databases as the years unfold which could inform the direction on future research.

References

Adedeji, O., & Campbell, O. (2013). The role of higher education in human capital development. https://doi.org/10.2139/ssrn.2380878

Adhikari, R. (2020). Fourth industrial revolution: From least developed countries to knowledge societies. *Corridors of knowledge for peace and development*, 41-66. https://www.jstor.org/stable/pdf/resrep24374.13.pdf?refreqid=excelsior%3A98a953298bc44b1da66afdf2a53591f4&ab_segments=&origin=&initiator=&acceptTC=1

Aguilera Morales, D., & Ortiz Revilla, J. (2021). STEM vs. STEAM Education and Student Creativity: A Systematic Literature Review. *Education Sciences, 111*(7) 331; https://doi.org/10.3390/educsci11070331

Alsulaimani, B., & Islam, A. (2022). Impact of 4ir technology and its impact on the current deployment. https://doi.org/10.48550/arXiv.2209.01791

Al-Taai, S. H. H., Kanber, H. A., & al-Dulaimi, W. A. M. (2023). The Importance of Using the Internet of Things in Education. International Journal of Emerging Technologies in Learning (Online), 18(1), 19. https://doi.org/10.3991/ijet.v18i01.35999

Arocena, R., Göransson, B., & Sutz, J. (2013). Universities and higher education in development. https://idl-bnc-idrc.dspacedirect.org/bitstream/handle/10625/51576/IDL-51576.pdf?sequence=1&isAllowed=y

Atibuni, D. Z., Manyiraho, D., & Nabitula, A. N. (2022). A Fourth Industrial Revolution Paradigm Shift in Teacher Education?.

International Journal of African Higher Education, 9(2), 1-21. https://doi.org/10.6017/ijahe.v9i2.15365

Ayanwale, M. A., & Oladele, J. I. (2021). Path modeling of online learning indicators and learners' satisfaction during COVID-19 pandemic. International Journal of Innovation, Creativity and Change, 15(10), 521-541. https://www.ijicc.net/index.php/ijicc-editions/2021/226-vol-15-iss-10

Bajracharya, B., Gondi, V., & Hua, D. (2021). IoT Education Using Learning Kits of IoT Devices. *Information Systems Education Journal*, *19*(6), 40-44. https://files.eric.ed.gov/fulltext/EJ1329491.pdf

Bauld, A. (2022). What is STEAM Education? XQ Super Schools, January 13. https://xqsuperschool.org/rethinktogether/what-is-steam-education/

Black, M. (2019). How can developing countries take advantage of the fourth industrial revolution? https://www.geospatialworld.net/blogs/how-can-developing-countries-take-advantage-of-the-fourth-industrial-revolution/

Brown-Martin, G. (2017). Education and the fourth industrial revolution. Report for Groupe Media TFO. https://cdn.lgseta.co.za/resources/research_and_reports/4IR%20Resources/Education%20and%20the%204IR_Graham%20Brown-Martin_2017.pdf

Carlow University (2021). How Technology-Based Assessments Aid Student Learning. https://blog.carlow.edu/2021/11/01/how-technology-based-assessments-aid-student-learning-in-the-classroom/

Cascio, W. F., & Montealegre, R. (2016). How technology is changing work and organizations. *Annual review of organizational psychology and organizational behavior*, *3*, 349-375. https://doi.org/10.1146/annurev-orgpsych-041015-062352

Cruz, E.S. (2019). Fourth Industrial Revolution. PressReader, February 21. https://www.pressreader.com/philippines/the-philippine-star/20190221/281651076383455

Cunninghame, I. (2017). The role of higher education in facilitating social mobility. *International Studies in Widening Participation*, 4(1), 74-85.

Dhawan, S. (2020). Online learning: A panacea in the time of COVID-19 crisis. *Journal of educational technology systems*, *49*(1), 5-22. https://doi.org/10.1177/004723952093401

Dinh-Le, C., Chuang, R., Chokshi, S., & Mann, D. (2019). Wearable health technology and electronic health record integration: scoping review and future directions. JMIR mHealth and uHealth, 7(9), e12861. https://doi.org/10.2196/12861

Dube, A. (2018). Improving your Students' Navigation of Online Sources of Knowledge. 8th Annual Summit on

Educational Technology Strategies. https://doi.org/10.13140/RG.2.2.29029.50405

Erboz, G. (2017). How to define industry 4.0: main pillars of industry 4.0. Managerial trends in the development of enterprises in globalization era, 761, 767.

Eseyin, E. O., Uchendu, E. E., & Bright, I. B. (2014). Higher education as a tool for human capital development in Nigeria. *International Journal of Education and Research,* *2*(6), 591-600. https://www.ijern.com/journal/June-2014/49.pdf

Eze, F. & Aroge, P. A. (2019). Impact of Entrepreneurship Education on Job Creation Ability of Bingham University Students. *Journal of Accounting, Finance and Development (JAFID),* 77-88. http://35.188.205.12:8080/xmlui/bitstream/handle/123456789/461/5.pdf?sequence=1&isAllowed=y

Fox, C., & Jones, R. (2018). Navigating the Digital Shift 2019: Equitable Opportunities for All Learners. State Educational Technology Directors Association. https://files.eric.ed.gov/fulltext/ED599408.pdf

Hatakenaka, S. (2007). The Role of Higher Education Institutions in Innovation and Economic Development. *International Higher Education,* (47). https://doi.org/10.6017/ihe.2007.47.7961 21/07/2021

Jaafar, N. F. B. (2021). Ethical issues in the 4th Industrial Revolution. https://colleges.segi.edu.my/kualalumpur/ethical-issues-in-the-4th-industrial-revolution/

Kayembe, C., & Nel, D. (2019). Challenges and opportunities for education in the Fourth Industrial Revolution. *African Journal of Public Affairs,* *11*(3), 79-94. https://hdl.handle.net/10520/EJC-19605d342e

Kumari, N. (2018). The Role of Higher Education in Human Capital Formation in India. *International Journal of Creative Research Thoughts (IJCRT),* *6*(2), 38-52. https://ijcrt.org/papers/IJCRT1812003.pdf

Labi, A., Richmond, R., & Kenny, M. (2014). Closing the skills gap: Companies and colleges collaborating for change. Economist Intelligence Unit. https://www.luminafoundation.org/files/publications/Closing_the_skills_gap.pdf.

Lakhotia, S.C. (2021). Research and Innovation in Universities Why and How These Should be Promoted. *In Quality Mandate for Higher Education Institutions in India*. New Delhi.

Lathan, J. (2023). Why STEAM is so Important to 21st Century Education. University of San Diego. https://onlinedegrees.sandiego.edu/steam-education-in-schools/

Lin, M. L. (2020). Educational Upward Mobility. Practices of Social Changes-Research on Social Mobility and Educational

Inequality. *Int'l J. Soc. Sci. Stud.*, 8, 25. https://doi.org/10.11114/ijsss.v8i3.4789

Luzi, D. (2000). Trends and evolution in the development of grey literature: a review. *International Journal on Grey Literature, 1*(3), 106-117. https://doi.org/10.1108/14666180010345537

Marginson, S. (2018). Higher education, economic inequality and social mobility: Implications for emerging East Asia. *International Journal of Educational Development*, 63, 4-11. https://doi.org/10.1016/j.ijedudev.2017.03.002

Mei, W., & Symaco, L. P. (2021). Higher education for development: The role of University Towns in China. *SAGE Open*, *11*(3), 21582440211046586. https://doi.org/10.1177/21582440211046586

Mhlanga, D. (2020). Industry 4.0: The challenges associated with the digital transformation of education in South Africa. *The impacts of digital transformation*, 13, 51.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & Prisma Group. (2010). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *International journal of surgery, 8*(5), 336-341.

Moscardini, A. O., Strachan, R., & Vlasova, T. (2020). The role of universities in modern society. *Studies in Higher Education, 47*(4), 812-830. https://doi.org/10.1080/03075079.2020.1807493

Ndung'u, N., & Signé, L. (2020). The Fourth Industrial Revolution and digitization will transform Africa into a global powerhouse. Foresight Africa Report, 5(1), 1-177. https://www.brookings.edu/wp-content/uploads/2020/01/ForesightAfrica2020_Chapter5_20200110.pdf

Nhleko, Y., & van der Westhuizen, T. (2022). The role of higher education institutions in introducing entrepreneurship education to meet the demands of industry 4.0. *Academy of Entrepreneurship Journal, 28*(1), 1-23. https://www.abacademies.org/articles/The-role-of-higher-education-institutions-in-introducing-entrepreneurship-education-to-meet-the-1528-2686-28-1-116.pdf

Okonkwo, C. W., & Ade-Ibijola, A. (2021). Chatbots applications in education: A systematic review. *Computers and Education: Artificial Intelligence*, *2*, 100033. https://doi.org/10.1016/j.caeai.2021.100033

Oladele, J. I. (2022). Feature Data Generation for Computer Adaptive Testing: A Novel method for Transdisciplinary Psychometrics Improvements using Post-hoc Simulation Approach. *Transdisciplinary Journal of Engineering & Science, 13,* 159-171. https://doi.org/10.22545/2022/00188.

Oladele, J. I., Ndlovu, M. & Ayanwale, M. A. (2022). Implementing Assessment as

Learning with Computer Adaptive Learning for Enhancing STEM Education in Africa: A Fourth Industrial Revolution Possibility. In B. Chirinda, K. Luneta and A. Uworwabayeho (Eds.), *The fourth Industrial Revolution (4IR) and Mathematics Education in Africa.* Springer. https://doi.org/10.1007/978-3-031-13927-7_8

O'Neill, M., Adams, M. P., Bandelt, M. J., Chester, S. A., Cai, W., & Nadimpalli, S. P. (2019). Cohort Learning: Supporting Transdisciplinary Communication and Problem-Solving Skills in Graduate STEM Researchers. International Journal of Teaching and Learning in Higher Education, 31(1), 166-175. https://files.eric.ed.gov/fulltext/EJ1206958.pdf

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., ... & Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. International journal of surgery, 88, 105906. https://doi.org/10.1136/bmj.n71

Papadakis, S., Kalogiannakis, M., & Gözüm, A. I. C. (2022). STEM, STEAM, computational thinking, and coding: Evidence-based research and practice in children's development. Frontiers in Psychology, 13.

Pappas, C., & Williams, I. (2011). Grey literature: its emerging importance. *Journal of Hospital Librarianship, 11*(3), 228-234. https://doi.org/10.1080/15323269.2011.587100

Passos, J., Lopes, S. I., Clemente, F. M., Moreira, P. M., Rico-González, M., Bezerra, P., & Rodrigues, L. P. (2021). Wearables and Internet of Things (IoT) technologies for fitness assessment: a systematic review. Sensors, 21(16), 5418. https://doi.org/10.3390/s21165418

Peckham, J. B. (2021). The ethical implications of 4IR. *Journal of Ethics in Entrepreneurship and Technology, 1*(1), 30-42. https://doi.org/10.1108/JEET-04-2021-0016

Penprase, B. E. (2018). The fourth industrial revolution and higher education. Higher education in the era of the fourth industrial revolution, 10(1), 978-981. https://doi.org/10.1007/978-981-13-0194-0_9

Polushina, L. N., Kleshchina, N. N., Sinitsyna, I. A., merzlikina, N. I., & Shlenskaya, N. M. (2018). The role of higher education in saving societies in challenging circumstances. *Revista ESPACIOS, 39*(49).

Pranckutė, R. (2021). Web of Science (WoS) and Scopus: The titans of bibliographic information in today's academic world. *Publications, 9*(1), 12. https://doi.org/10.3390/publications9010012

Reaves, J. (2019). 21st-century skills and the fourth Industrial Revolution: A critical future role for online education. *International Journal on Innovations in Online Education, 3*(1).

https://onlineinnovationsjournal.com/download/4f6fa2666b8cd098.pdf

Rodnyansky, D. V., Abramov, R. A., & Bulgakova, V. N. (2020, November). Educational Technologies of the Fourth Industrial Revolution in the Context of the Covid-19 Pandemic. *In Research Technologies of Pandemic Coronavirus Impact (RTCOV 2020) (pp. 7-11). Atlantis Press.* https://doi.org/10.2991/assehr.k.201105.002

Schwab, K. (2016). The fourth industrial revolution. World Economic Forum.

Scott, I., & Fisher, G. (2011). The role of higher education in closing the skills gap in South Africa.

Singh, M. (2021). Acquisition of 21st century skills through STEAM education. *Academia Letters, 2*, 712. https://doi.org/10.20935/AL712

Slepankova, M. (2021). Possibilities of Artificial Intelligence in Education: An Assessment of the role of AI chatbots as a communication medium in higher education. http://www.diva-portal.org/smash/get/diva2:1617720/FULLTEXT01.pdf

Swartz, M. K. (2011). The PRISMA Statement: A Guideline for Systematic Reviews and Meta-Analyses. *Journal of Pediatric Health Care, 25*(1):1-2 https://doi.org/10.1016/j.pedhc.2010.09.006

Taguma, M., Gabriel, F., Meow Hwee, L. I. M., & Expert, O. E. C. D. (2020). Future of Education and Skills 2030: Curriculum Analysis. *Organisation for Economic Co-operation and Development (OECD).* https://www.oecd.org/education/2030/Preparing-humanity-for-change-and-artificial-intelligence.pdf

Udovychenko, L., Pyatnitska-Pozdnyakova, I., Skliar, I., Pavliv, A., & Fonariuk, O. (2022). A transdisciplinary approach to teaching and building a higher education system. Revista Eduweb, 16(3), 91-105. https://doi.org/10.46502/issn.1856-7576/2022.16.03.7

Vessuri, H. (2008). The role of research in higher education: Implications and challenges for an active future contribution to human and social development. https://upcommons.upc.edu/bitstream/handle/2099/8119/vessuri.pdf

Vinayachandra, & Krishna Prasad, K. (2020). Application of IoT in the Development of Intelligent Education System – A Thematic Literature Review. *International Journal of Management, Technology, and Social Sciences, 5*(1), 124-146. http://doi.org/10.5281/zenodo.3775850

Waller, R. E., Lemoine, P. A., Mense, E. G., Garretson, C. J., & Richardson, M. D. (2019). Global higher education in a VUCA world: Concerns and projections. *Journal of Education and Development, 3*(2), 73. https://doi.org/10.20849/jed.v3i2.613

World Economic Forum. (2017). Accelerating workforce reskilling for the fourth industrial revolution: An agenda for leaders to shape the future of education, gender and work. Geneva, Switzerland: World Economic Forum. https://www3.weforum.org/docs/WEF_EGW_White_Paper_Reskilling.pdf

WorldData.info (2023). Developing Countries. https://www.worlddata.info/developing-countries.php

Yakman, G. (2008). STEAM education: An overview of creating a model of integrative education.

Yusuf, B., Walters, L. M., & Sailin, S. N. (2020). Restructuring Educational Institutions for Growth in the Fourth Industrial Revolution (4IR): A Systematic Review. *Int. J. Emerg. Technol. Learn.*, *15*(3), 93-109. https://doi.org/10.3991/ijet.v15i03.11849

Zervoudi, E. K. (2020). Fourth industrial revolution: opportunities, challenges, and proposed policies. *Industrial Robotics-New Paradigms.* 10.5772/intechopen.90412

Zgaga, P. (2011). The Role of Higher Education in the National Development.