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Challenges in Education Posed by the Fourth Industrial Revolution

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Abstract

This review article provides an overview of the challenges that the Fourth Industrial Revolution (4IR) may pose for education as reflected in scientific articles, white papers and other up-to-date publications. The approach taken here does not make distinctions among different educational levels but instead aims to highlight overarching challenges across the education sector as a whole, providing the opportunity to identify general or cross-cutting risks that may arise from the 4IR. The topic of digitization-one of the main pillars of the 4IR-seems highly controversial within the research studies examined, with disagreement regarding both possible harmful effects of digitizing classrooms and the fundamental benefits of multimedia. There seems to be a clear trend of many authors to recommend necessary adjustments that enable various stakeholders to adapt to the developments prompted by the 4IR. The main recommendations here are flexibility, personal responsibility, and self-reliance. Relatively few researchers-such as Yong Zhao-recommend active engagement in order to consciously influence or even delay the dynamics of the 4IR. Leaders in particular are called upon to make greater efforts to adapt, e.g. by implementing AI and AI-powered personalized learning into pedagogies and curricula, teacher support in using AI tools and developing ethical standards, fostering access and equity, data-driven decision making, future-ready skills development, partnerships with tech companies, continual adaptation and lifelong learning, and taking into account human aspects regarding the digitalization of education, such as the impact on people when they learn and work on computer screens or in virtual worlds.

Introduction

The purpose of this article-to present an overview of possible challenges and mitigations regarding the impact of the 4IR on the education sector-arises from the solid influence of the 4IR as described among others by Philbeck and Davis (2018). They state that the "4IR represents a series of significant shifts in the way that economic, political, and social value is being created, exchanged, and distributed. These shifts in value are intimately related to the emergence of new technologies

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that span the digital, physical, and biological worlds, and they are most powerful when they combine and reinforce one another". Hence, the value systems in which people live and work will change drastically. Perhaps the most important feature of 4IR is the optimization of production processes, including human resources. Publications by key figures in the 4IR arena may give the impression that the 4IR is not so much about creating a more humane work and living environment, but rather a more efficient one, viewing and treating people as human capital or human resources. Efficiency is a constantly recurring term in articles dealing with the 4IR. Humans must adapt to artificial intelligence, machine-to-machine communication (M2M), online learning, and virtual reality. The fusion of man and machine is already in the making, for example through brain implants. The classic man-machine dilemma is now taking on a new dynamic that questions people's self-image and their very existence, and not just from the military, such as the UK Ministry of Defense (2021), but also when it comes to civilian students and their education. According to Schwab (2016), one of the most prominent advocates of 4IR, "public-private research collaborations should increasingly be structured towards building knowledge and human capital", and a White Paper published by the World Economic Forum (2017), of which Schwab is the founder, states "As new approaches and new technologies emerge, funding and experiments are necessary for identifying the most effective models with potential to scale and create meaningful change in education. Education is one of the most obvious areas of private-public collaboration".

Like other industrial revolutions before, the 4IR doesn't come into existence without a certain amount of friction. A brief overview of previous industrial revolutions may help to classify the 4IR in its historical context:

1st IR (18th century): Machines using steam power

2nd IR (19th century): Electrically driven assembly lines and mass production

3rd IR (20th century): Digital revolution introducing computers

4th IR (21st century): Artificial intelligence, augmented reality, human-machine interfaces

Taking into account transhumanism, the 4IR may even be greater in scope than during the first three industrial revolutions. However, there are similarities, which is why it is worth taking a brief look at the situation during the 1IR. The transition from manual labor in crafts and agriculture to industrial production in the context of the 1IR was not at all enthusiastically received and accepted by all people. In fact, parts of the workers, who now suddenly had to adapt to the rhythm of machines in shift work, protested against this development and refused to give up their freedom to organize their work and their own work rhythm. Chomsky (2003) quotes one of those workers from the 1830s in the USA saying "When you sell your product, you retain your person. But when you sell your labor, you sell yourself". An analysis of the content of this statement both on a philosophical and personal level at the time is not the subject of this paper. The quote is remarkable at this point because it is of paramount importance for today's 4IR where there's again concerns that the virtual and transhumanist components of the 4IR in particular, carry with them a potential of alienation or estrangement from their human-oriented way of living and working. Scheidler (2020) writes in this regard: "In nineteenth-century Europe-as later in the Global South-people had to separate from their families and cultural roots to sell their physical labor in the anonymity of newly sprouted industrial cities. There was no security or protection against either illness or unemployment. The individual was degraded to being a mere object; a production factor; a replaceable cog in a monstrous economic machine. This uprooting has continued all across the planet ever since." This description refers to the 1IR. However, there is a common denominator which is the scope and gravity of macro-economic and social changes following technological developments, including education. O'Rourke, Rahman, and Taylor (2013) state "Technological change was unskilled-labor-biased during the early industrial revolution but is skill-biased today" and "In a setup with directed technological change, and fixed as well as variable costs of education, initial endowments dictate that the early industrial revolution be unskilled-labor-biased. Increasing basic knowledge then causes a growth takeoff, an income-led demand for fewer but more educated children, and a transition to skill-biased technological change in the long run." The connection between technological development and the corresponding level of education of students and employees becomes problematic when the maximum capabilities of the human brain-subjectively or objectively-are no longer sufficient to keep up. At this point, it seems sensible to also address the phenomenon of transhumanism as an integral part of the 4IR, because

far-reaching promoters such as Harari (2015) are already emphasizing the need for human augmentation such as brain implants, among other things, in order to avoid ending up as "economically useless people".

This literature review has been divided into the following topics:

- Transhumanism as part of the 4IR
- Impact on students
- Impact on educators
- Leadership Challenges

Methodology

Being a narrative literature review this research provides a broad overview of the subject, synthesizing findings qualitatively, offering insights based on the authors' interpretation, and following-in contrast to a systematic literature review-less rigidly structured methods for searching and selecting literature. It endeavors to systematically explore the pivotal elements of contemporary understandings regarding the impact of the 4IR on education, employing a narrative literature review methodology, the study synthesizes existing knowledge, elaborates on critical insights, and suggests future research directions. The methodology includes:

1. Comprehensive searches in multiple databases such as PubMed, Scopus, ABI, EBSCO, Springer, Sage, Google Scholar, Science Direct ea., focusing on specific languages and publication years to encompass relevant literature.

2. Utilization of various and varying strategic keywords to refine searches and locate pertinent studies.

3. Initial screening of abstracts to discard duplicates and verify relevance to the review question followed by full-text searches.

4. Analysis, integration and synthesis of significant findings from the literature into a coherent narrative that also reflects the researchers' interpretations. In this specific instance, it was imperative to adopt a consistent hermeneutic approach across all examined texts, given the highly political nature of the subject matter, which is often entangled with euphemisms, distortions, and even instances of misinformation.

Literature review

This literature review was conducted using scientific articles as well as books, and other primary sources such as whitepapers from organizations involved in shaping the 4IR and one publication that was published in cooperation by the British and German Ministries of Defence. The highly dynamic nature of the topic makes it necessary to qualitatively analyze and include not only academic publications but also information from various primary sources.

For reasons of clarity and conciseness, this study has deliberately not differentiated between various educational levels. This should be done in further studies, which could then also suggest concrete consequences for the curricula. The focus of this work is to identify general challenges that may arise from the 4IR for the education sector.

Transhumanism as part of the 4IR

The main idea of transhumanism is, among other things, to equip the human body and brain with enhancement technologies that increase physical and mental abilities and to create interfaces to computer networks. A rich source for getting an idea of the scope of 4IR and Transhumanism is the joint publication of the UK and German Ministries of Defence (2021).

It describes specifically which technical applications are being pursued and it also sets out how ethical concerns are to be managed. They state, "The ethical and moral implications of human augmentation are profound" and then ask, "Does human augmentation go against nature and undermine people's dignity by robbing them of the ability to live a 'natural', 'authentic' life?" This question indeed is at the heart of the issue while the answer given does not correspond to what one would expect in a democratic society of self-determined citizens. They write "The imperative to use human augmentation may ultimately not be dictated by any explicit ethical argument, but by national interest." Furthermore, the authors claim that moral perceptions

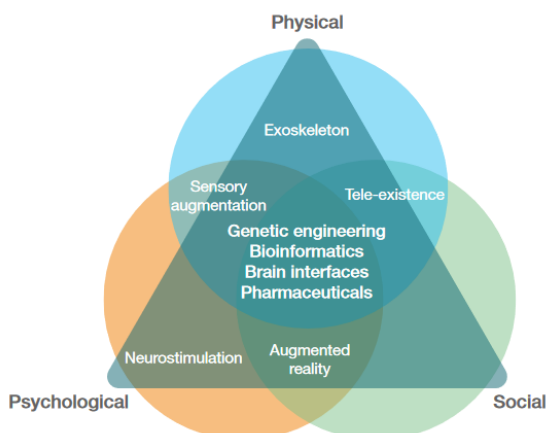

Figure 1 Augmentation technologies for the human platform (UK Ministry of Defense, 2021)

of the people could be changed by new guidelines from the government, though they also say that they are not willing to wait for that to happen: “Defence, however, cannot wait for ethics to change before engaging with human augmentation”. Exo-skeletons, genetic engineering, brain interfaces were mentioned.

Some of those features are already in the making. For example, Elon Musk's company Neuralink has already implanted its brain interface in humans. The merging of man and machine thus seems to be in full swing. Suitably, many young people have a rather positive image of Marvel-like, transhumanistic augmented superheroes, and this inclination seems remarkably well in line with the dynamics and requirements of the 4IR.

The willingness to put ethics aside for the benefit of a super-human can also be found in similar form in Yuval Noah Harari, a best-selling author and famous promoter of transhumanism, who sees people as hackable animals and not as spiritual beings with a desirable balance of heart and mind. Harari (2014) writes “As far as we can tell, from a purely scientific viewpoint, human life has absolutely no meaning. Humans are the outcome of blind evolutionary processes that operate without goal or purpose.” Since no rule of good scientific practice requires an atheistic or materialistic view of humanity and since spirituality has never been scientifically falsified, Mr. Harari is definitively mistaken. Nevertheless, his views are being perceived by a large audience which makes him a key influencer. This quote illustrates the difficulty of correctly interpreting and understanding some primary sources on the subject of 4IR. This is because all related topics are highly political, opinionated and emotionally charged. We have therefore continuously pursued a hermeneutic approach in all the texts we have worked on, which has hopefully enabled us to sort out most of the euphemisms, distortions and misinformation.

Moreover, the technological environment for applying brain enhancing implants is already there e.g. in the form of devices produced by Elon Musk’s company Neuralink. Hence, if such applications are recognized as a competitive advantage for students, they might become acceptable for parents of minors as well as students in higher education. In the context of Marvel superheroes, helicopter parents and economic expectations, technical enhancements to students' brains could not only become an attractive option but may even lead to competitive pressures with academic and professional disadvantages if resisted.

Impact on students

Horoszkiewicz (2022) summarizes some of the latest research of Prof. Dr. Manfred Spitzer regarding Digital Dementia, a term coined by Spitzer. He writes: “Dementia, in Spitzer's terms is not just memory loss resulting from the overuse of new digital technologies, but more importantly, a diminished ability to think and make critical judgements. Innovative digital technologies evoke different emotions not only among younger generations. It should be noted that their excessive use can lead to the development of addiction. Many scientific publications on the phenomena described in this thesis point to the negative consequences of digital technologies on human cognitive and emotional functioning. However, it is worth emphasizing that in the current reality, it will be difficult for us to escape from it.” He also provides a description of the state of knowledge and some definitions and explanations for rather new terms, e.g. for ‘Digital Zombie’, ‘Phubbing’, ‘FOMO’, and ‘Digitrosis’.

Sandu and Nistor (2020) are investigating the extent to which claimed undesirable side effects of the digitalization of classrooms can actually be proven in reality. Under the umbrella term 'digital dementia', they are disputing the existence of a causal relationship between the multitasking use of multimedia technology and the decline of cognitive skills. They conclude: “The literature presents studies for and against the existence of this phenomenon, however a study on a significant group of 1,000 people seems to highlight a series of cognitive impairment phenomena, similar in terms of symptoms with classic dementia.” Also, the virtualization of social space, which refers to moving various activities into a virtual environment, altering traditional social interactions, is being discussed. This process, explored by several cited articles, includes transferring communication to virtual platforms and achieving a state of virtual ubiquity. Notably, this shift creates a broader, non-physical interaction space, challenging traditional notions of human experience that emphasize physical closeness. This expansion into a 'noetic' dimension prompts a reevaluation of fundamental concepts like normality and the human condition, especially as physical presence becomes less central.

Butler (2019) refers to findings from neurology and comes to a very critical conclusion regarding the suitability of the excessive use of multimedia in schools. He states that the current use of digital technology in education, both in classrooms and at home, lacks

substantial scientific backing and evidence-based practice. Numerous studies from cognitive psychology, neuroscience, and education highlight its negative effects on cognition, learning, and behavior. Key issues include: screen time disrupting sleep and learning, leading to obesity and vision problems; computer use in classrooms hindering learning for all students; traditional learning with books and paper being more effective than e-books; note-taking by hand proving superior to typing for learning outcomes; and the use of smartphones, iPads, and laptops causing distraction and limiting focusing, stressful multitasking, and potential addiction. Despite some noteworthy successes, there is still little proof that digital or educational technologies enhance teaching or learning. Butler's paper urges a cautious approach to integrating digital technology in education and calls for basic digital technology education in curricula. It concludes with practical suggestions and a proposed shift in pedagogical emphasis regarding digital technology.

Preiss (2014) argues from a psychiatric point of view, agreeing with some issues regarding Digital Dementia but also claiming that when it comes to computer-based memory training, "Spitzer omits the results of other studies that deal with cognitive rehabilitation" and "Dozens of studies with Cogmed program predominantly confirm the effectiveness of working memory training." He concludes by stating "Spitzer rightfully warns against the superficiality caused by the excessive exposure to digital media. However, he ignores the possibilities that could bring the proper use and appropriate application of digital media."

Selwyn (2019) offers critical perspectives on the use of technology in education, including AI, and its implications for teachers and learners. He provides a picture of the current state of AI in education, dispelling myths and highlighting the actual capabilities of AI technologies in educational settings. He delves into how AI and robots might affect various aspects of education, including teaching methods, student engagement, and the role of teachers, which probably will be replaced by AI systems in the very near future. Selwyn discusses ethical and social implications of using AI in education and raises concerns about privacy, data security, and the potential for AI to perpetuate biases and inequalities. Central to the discussion is whether AI and robots could or should replace human teachers. Selwyn argues for a balanced view, acknowledging the potential of AI to assist in educational tasks while emphasizing the irreplaceable value of human interaction and empathy in teaching. He looks at potential future scenarios of AI in education, both optimistic and cautious, and advocates for a thoughtful and informed approach to integrating AI into education, urging educators, policymakers, and technologists to consider the broader implications of these technologies on teaching and learning. The book is a call to approach AI in education with a mix of enthusiasm and a healthy dose of skepticism, emphasizing the need to prioritize human values and educational principles.

McLeod and Graber (2018) provide a practical framework for using technology, including AI, to enhance student learning. Their rather technology-friendly guide is designed to help educators integrate technology effectively into their classrooms for more meaningful and deeper learning experiences. The book focuses on the '4 Shifts Protocol', a framework developed by the authors to assist teachers and school leaders in rethinking their pedagogical approaches and strategies for designing classroom activities and environments. Another key element of the book includes a shift in teaching from traditional methods to more innovative practices that promote critical thinking, creativity, and problem-solving skills. The authors include various examples and scenarios that illustrate how educators can apply the 4 Shifts Protocol in different subjects and grade levels. McLeod and Graber consistently focus on how technology integration and pedagogical shifts can lead to improved student learning outcomes, preparing students for the demands of the modern world.

Shukla (2020) asks whether academia was prepared for the 4IR and whether social changes that the 4IR initiates-degradation of human relationships, digital devices taking over social interaction in the real world-would disrupt the ability of children to separate from their parents, and raise other obstacles to adulthood, decline in children and adolescents conducting knowledge-gathering activities such as reading, developing regions with use of one of the world languages tend to have a lower percentage of local Internet content. This last point addresses a possible cultural degradation that, while important to society as a whole, also affects the education sector. If the preservation and promotion of different local cultures is seen as desirable, and digitalization can lead to cultural erosion, then perhaps educational institutions should take countermeasures and adapt their curricula accordingly. Furthermore, the author states that the Internet could act as a vehicle for cultural uprooting and pursues the question "How do we educate

our children for a future whose main characteristic is ambiguous change?" McDiarmid and Zhao (2023) also directly addressed stakeholders in the education sector: "The uncertainties and possible existential disasters of the future require a broad coalition of families, students, educators, business leaders, and policymakers to rethink education."

Eleyyan (2021) presents variations in science teachers' perceptions about the implications of IR 4.0 on education. He states that block-chain, cloud computing, and cybersecurity will be used more and in broader ways in the future in order to improve learning opportunities and increase options for students' activities. Then again, he refers to the fact that the teaching-learning processes will place less value and with a lower extent of student-teacher interactions. He also predicts AI driven robots and algorithms acting as teacher avatars and replacing humans even in educational jobs. According to the study the following measures are suggested: implementing significant transformations in instructional programs, curricula, learning environment, liquid instructional skills, and new teachers-students' roles to deal with IR 4.0 technologies and products.

Inequality would still be a concern for digital based education since more than 4 billion people are still offline without access to the internet according to a study by McKinsey (2014). Although digital based education can be more affordable compared to other education options, education institutions need to consider the best ways to reach underserved populations where education can serve as a strong empowerment and change tool. Risks concerning privacy and online security are other challenges facing education. Collaboration, integration and aligning security processes are key words for scaling education efforts and bringing sustainability. For some researchers, this is the time to ask whether the global education community will only react to how the business world is shaping the Fourth Industrial Revolution or if they will be among the key players for the sake of the mental, emotional and physical health of students (Mezied, 2016). Mezied also points out that cooperation and mutual help are essential components of education, and that these elements-not only but also-should take place in the real world. Such abilities to act self-reliantly with a view to the needs of the environment are urgently needed. The several changes happening in environmental, social, economic, technological and geopolitical spheres of our society result in new risks, challenges and opportunities for human development.

Reaves (2019) suggests that traditional education with set disciplines and degrees may be inappropriate for students facing an ever-changing future job market. To equip learners for a VUCA (volatile, uncertain, complex, and ambiguous) world, educational programs should emphasize 21st-century skills such as adaptability, empathy, creativity, and the ability to learn continuously. These broad, metacognitive skills prompt a reevaluation of online education strategies. Key issues include the effective online teaching of these skills, identifying crucial knowledge from the vast online resources, and utilizing digital platforms for practical application and mentorship. Addressing these challenges is crucial for fostering growth at individual, community, and global levels.

Kamsuwan (2021) contributes to possible ways to deal with effects related to digitalization respectively online learning. He explores how community-based research projects can boost student motivation by linking classroom learning to real-world challenges. Students begin by identifying local issues, which helps enrich the community's cultural assets. Implementing innovative solutions in these real settings not only increases motivation but also alleviates stress compared to traditional online learning. For instance, civil environmental engineering students enhance their learning by applying urban planning concepts from their coursework to actual community surveys, thereby invigorating online discussions and fieldwork problem-solving. This method proves especially effective in revitalizing online education with more dynamic and creative experiences.

Impact on educators

As described, the 4IR is profoundly influencing the role of teachers, requiring significant adjustments in educational approaches and teacher competencies. Teachers are now expected to not only deliver knowledge but also facilitate students' ability to adapt to rapidly changing technologies and job markets. According to the World Economic Forum (2023) 81% of educational institutions are planning to implement new technologies like AI within the next 5 years. This shift emphasizes the need for teachers to integrate new digital tools and educational technologies into their teaching practices effectively. Waldia, Sonawane, Mali, and Jadhav (2023) elaborates on that issue and suggests a strategy called microlearning, a self-directed bite-size learning approach which might help some teachers to learn, digest and retain new content easier than lengthy further training. The

necessity for continuous professional development to keep pace with technological advancements seems to be one of the key impacts of 4IR on teachers. This includes being comfortable with and capable of integrating technological tools in the classroom to enhance learning experiences. Moreover, the rapid obsolescence of knowledge due to technological advancements challenges teachers to focus not just on content delivery but on fostering critical thinking, problem-solving, and adaptability among students. Furthermore, educators are tasked with preparing students for a job market where many roles may be automated, and new careers will require advanced digital and interpersonal skills. This situation demands that teachers help students learn how to learn, unlearn, and relearn throughout their lives to remain versatile and employable in a dynamic work environment.

Job security is an existentially important issue for teachers. It may seem plausible that AI driven avatars can and will replace some teachers sooner or later. However, views on this topic vary widely. Shen and Zhang (2024) state that the "introduction and installation of artificial intelligence technology as represented by industrial robots in Chinese enterprises has increased the number of jobs". While they focus on employment in the industrial sector in China, they are very optimistic overall, including with regard to other areas like education. They state that: " the intelligent development of enterprises will come to replace their initial programmed tasks and produce more complex new tasks, and human workers in nonprogrammed positions, such as technology and knowledge, will have more comparative advantages". Far less optimistic is a report by Briggs and Kodnani (2023) that estimates that 27% of jobs in the educational sector could be replaced by AI. This figure is almost exactly in line with an estimate by McKinsey (2022), which states that "only 25 percent of the sector's work is automatable".

However, many researchers point out that digitalization will not only lead to job losses but will also create new jobs-both within and outside the education sector.

Leadership challenges

Seldon, Abidoye, and Metcalf (2020) discusses how AI is transforming education and calls for a significant rethink of the education system to adapt to this new era. He highlights the need for visionary leaders who can foresee the potential and risks of AI in education which involves understanding not only the technological aspects but also the pedagogical implications. He describes the ambivalent relationship between AI and education in the following words: "AI in education has been the Cinderella of the AI story, largely ignored in the literature and by governments, companies and educational institutions worldwide. This needs to change rapidly: AI should be the fairy-tale princess or the Prince Charming in education." Seldon then discusses some important points about the transformative impact of AI such as a necessary adaptation to change for educational leaders in order to cope with the rapidly evolving technological landscape. Seldon argues that leaders must be proactive in integrating AI and other technological advancements into educational systems. Leaders are encouraged to consider the ethical implications of using AI, such as data privacy, bias in AI algorithms, and the impact on students' well-being. Seldon points out that effective leadership in the age of AI requires collaboration with technologists, educators, policymakers, and students. Open communication is essential to address concerns and share best practices. He suggests that leaders should invest in their own professional development and that of their staff to understand and effectively utilize AI technologies in educational settings and argues for a rethinking of curriculum design to incorporate skills that are relevant in an AI-dominated future, such as critical thinking, creativity, and digital literacy. Student-centered learning requires a shift towards more personalized learning experiences, facilitated by AI. Leaders in education are encouraged to foster environments where technology supports individual learning paths.

Zhao (2014) describes authoritarian aspects in the education sector: "A survival strategy the Chinese people developed to cope with thousands of years of authoritarian rule has been glorified as China's secret to educational success. The belief that the Chinese attach high values to education is widespread in the United States." but the USA doesn't come off any better: "Under the spell of authoritarianism, 50 million American children are being taught a de facto national curriculum, then subjected to a de facto national standardized test." Educational leadership is often linked to formal roles within schools, such as principals or head teachers. Consequently, research frequently centers on these positions as key leadership sources in educational settings. Nonetheless, leadership in schools isn't limited to these roles. Informal leaders, like specialist leaders, derive their influence from their expertise in specific

subjects or their ability to engage groups of learners. Similarly, certain individuals exert leadership through their social influence among peers, shaping opinions and attitudes. Leadership transcends traditional roles; it's a dynamic process rather than merely a position of authority.

Developing nations and their 'development partners' view education as a key global commodity essential for economic growth. However, education in these countries often lags in adapting to new economic concepts, such as the 4IR. While developed countries themselves struggle to align their education systems with this concept, developing nations often attempt to emulate them. This raises the question: does adopting an 'international product' of education truly aid in national and international development? Alam (2021) suggests that education in developing countries is gradually aligning with that of advanced economies in both quantitative and qualitative terms. Developed nations' education systems produce skilled graduates who enhance foreign income, primarily through high-skilled industries. In contrast, developing economies typically rely on low-skilled sectors for foreign income. This discussion of education in developing countries is framed within the 'Dependency Theory'.

Discussion and conclusion

There seems to be a broad consensus that the 4IR has a major impact on the education sector, with some researchers, such as Hong (2022), also calling for reforms to the curriculum or, as AlMalki and Durugbo (2023), even the entire education sector. Already visible as well as expected consequences are relatively well researched. This stands in contrast to possible options that could mitigate these dynamics and soften their impact on stakeholders in the education sector. One interesting finding is that it seems that a scientifically developed framework that could help solve potential 4IR problems has either not been found yet with existing research or we just did not find any so far. Either way, literature research has shown that there is a serious research gap regarding possible mitigations, which-considering the gravity and speed of the dynamics of the 4IR-should be urgently addressed. This includes, for example, alternative educational approaches such as Community Based Learning (CBL), Waldorf or Pestalozzi pedagogy. Interestingly, where there is relevant work regarding the CBL, the results are generally very positive. Therefore, the study of possible ways to use CBL to mitigate potential negative impacts of the 4IR on students seems highly promising.

Similarly, there doesn't seem to be a lot of research into the job security of teachers, which is surprising given that their replacement by AI seems reasonably predictable. Researchers are urging leaders in particular to take the issue seriously and address it proactively, even though not only them but all stakeholders in the education arena are or will be severely affected by the 4IR.

Among the challenges that the 4IR may pose for the education sector, some common denominators have emerged, as the following summary shows:

1. Skill Gaps: Rapid technological advancements require new skills, leading to gaps in traditional education systems.

2. Curriculum Relevance: Updating curricula to include emerging useful technologies and interdisciplinary skills is a significant challenge.

3. Access to Technology: Ensuring equal access to new technologies for all students, preventing a digital divide.

4. Teacher Training: Educators need continuous professional development to keep pace with technological changes.

5. Ethical and Social Issues: Educating students and deciders about the ethical use of technology and its social implications. Social participation in decision-making processes.

6. Adaptation to Change: Institutions must be flexible to quickly adapt to technological and methodological changes.

This article argues for further analyses regarding possible mitigations of the issues identified and calls for existing studies on the digitalization of student life to be evaluated and applied to the current and foreseeable situation. This is particularly true for the impact on students' brains, which has been researched and summarized for teachers and managers so that they have practical tools at their disposal. All this should happen before technologies such as virtual reality (VR) with its massive deception of the senses are unleashed on students.

Considering the profound impacts of the Fourth Industrial Revolution on society, it is crucial to have public discussions and democratic decision-making processes. This ensures that developments in technology and automation are managed in ways that benefit society broadly, address inequalities, and consider ethical, cultural, and economic impacts. Engaging the public in

these conversations can help in crafting policies that support sustainable and inclusive growth, promoting equity in access to technology and education, and ensuring that changes in employment and industry do not disproportionately disadvantage certain groups.

Managers in the education sector should-if they have not already done so-conduct risk and change assessments promptly and continuously in order to enable the institutions concerned to implement new technologies and methods as effectively as possible. Staff training as well as content-related, structural and technical adjustments require time, which tends to be in short supply given the highly dynamic nature of technical change.

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