Education 4.0 in Developing Economies

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Education 4.0 (EDUC4) was driven by the onset of the Fourth Industrial Revolution (4IR) to meet labor market requirements resulting from learning that is customized, flexible, accessible, and skills-based.

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1. Introduction

Education 4.0 (EDUC4) is a pedagogical approach that aligns with the fourth industrial revolution (4IR). It answers to the demands of the 4IR, in which the convergence of science and technology is utilized in augmenting manual processes for improved effectiveness and efficiency. EDUC4 recently captured the attention of policymakers, driven by the onset of 4IR. According to Fisk [1], a new vision of learning encourages learners to learn the skills and information they need and find the resources necessary to learn them. Learning is based on understanding where and how to comprehend, and performance is tracked through data-driven customization. For example, Dunwill [2] reported that technology innovations continually change the teaching method and the learning environment. The learning process in EDUC4 may require the use of virtual learning environments (VLEs) to combine natural and virtual materials [3], a smart blended learning process with adaptive Internet of Things (IoT) using wearables and intelligent sensors [4], and artificial intelligence (AI) for system automation [5]. In the context of EDUC4, curriculum design, especially in higher education institutions (HEIs), reflects technology-based environments [6]. As EDUC4 intends to enhance higher education, every stage of its implementation is crucial and may not be straightforward. For instance, education leaders may overlook the possible causal relationship of challenges (or barriers) surrounding such implementation. A system view of EDUC4 implementation is, thus, warranted to address this problem. To this end, this work systematically identifies and examines the barriers to EDUC4 implementation.

Several frameworks have recently surfaced, describing how EDUC4 can be applied. For instance, Thailand's higher education commission implements the third framework of its 15-year long-range plans, which focuses on improving its people's quality—the so-called "Thai people 4.0" blueprint [7]. Also, Malaysia redesigned its learning and teaching curriculum to meet the unknown demands of the 4IR. With this, the Ministry of Higher Education [8] launched the book "Framing Malaysia Higher Education 4.0: Future-Proof Talents" to develop and enhance individual potential and fulfill the nation's aspirations. Similarly, Singapore launched the Smart Nation initiative, which drives the pervasive adoption of digital and smart technologies [9]. These practices form some benchmarks for developing countries to follow, such as the Philippines. Economists have highlighted that anytime new technologies are brought into an economy, there is a considerable lag period for the technology to be fully adapted to a level where they generate demonstrable productivity impacts [10][11]. The difficulties arise from the fact that technology development necessitates sufficient and appropriate educational change.

As the concept of EDUC4 gains traction in the domains of education and innovation research, several challenges about its implementation have become noticeable. For instance, managing educational systems in EDUC4 requires a manifold of digital skills for using intelligent agents, mobile technologies, cloud computing, among others [12][13]. While these skills are commonly taught in technology-intensive degree programs (e.g., engineering, computer science, information technology, among others), they are not as common in education programs that focus more on pedagogies. From this observation, it can be interpreted that university training of educators is causal to the lack of education professionals with digital skills to facilitate the implementation of EDUC4. Thus, higher education is necessary for improving the skills of the workforce that could effectively meet the implementation requirements of EDUC4 [14].

Creativity is an essential human characteristic necessary in EDUC4 [7]. Puncreobutr [12] emphasized ten powerful EDUC4 teaching tools: visual learning, evolved currencies, personalization, gamification, social media, game-based learning, connectedness, project-based learning, and digital and physical merge. The instrumentation of these tools requires teachers to become dynamic and more adaptive, unlike the conventional rigid approach to pedagogy. Empirical works in the education domain largely support the utility of these tools in learning (e.g., [15][16][17]). Despite the presence of these

tools, education continues to be primarily considered through traditional lenses [18], which is apparent in the largely adopted formalist approaches of syntactical and formal knowledge [19]. However, the growth of new knowledge and its increasing availability via digital media suggest that educators need to become more flexible and creative in their instruction to be at par with industrial innovation. Infrastructure requirements (e.g., internet connectivity, digital communication suites, data centers and networks, digital hardware, among others) are essential to achieve this goal. Unfortunately, they are among the most difficult challenges HEIs need to address, especially in developing economies. Infrastructure to support information and communication technologies (ICTs) is one of the core components of EDUC4 [20], while financial resources are the drivers of educational reform [21]. The limited resources that characterize developing countries warrant the adoption of alternative infrastructures for implementing EDUC4. A systematic investigation of these barriers would benefit the implementation of EDUC4 in financially desperate regions.

Apart from the pedagogical-, human capital-, and infrastructure-related barriers highlighted in previous discussions, the fundamental challenge to EDUC4 implementation is mainly institutional. Hershock et al. [22] reported that institutional change among HEIs lags against the growth of technological innovations. Among the cited causes of the slow response of HEIs to technological change is the asymmetry in the strategies of institutions to implement EDUC4 and the capacity of learners to respond to or comply with its requirements. Thorell et al. [23] pointed out the need to align EDUC4 implementation strategies to the needs and capacities of learners. For instance, strategies implemented by HEIs may require learners to have computers, but, in developing countries, such a strategy may not be effective due to the limited capacity of most families to acquire one. HEIs may instead provide within-campus access to computers and local area networks (LANs), but this entails costs shared among learners through miscellaneous school fees—making EDUC4 inequitable to learners coming from financially desperate households. Government institutions are also concerned by these challenges, especially with the rising importance of the roles of digital devices in education. Investigating the role of government institutions in addressing these problems is a relatively unexplored topic in the EDUC4 literature. Such intervention is vital, especially in developing countries.

A major challenge in digital education lies with how policymakers can more effectively assess and scaffold the development of EDUC4 [24]. It is apparent from previous discussions that there is a need to develop public-private collaborations, promote change mindsets, and provide the vital skillsets for teachers and learners to implement EDUC4. Addressing these concerns is critical to producing resilient and productive professionals in this technology-driven environment [8]. Indrajit et al. [25] stressed that it is paramount for governments and top management of universities in developing economies to initiate proactive measures that address the financial impediments surrounding the implementation of EDUC4. Partnerships with the public sector and ventures with other industries might be essential to achieving this goal. However, the current literature provides limited information on the effectiveness of these courses of action.

2. Thematic Analysis of EDUC4 Implementation Barriers

From the identified 12 barriers of EDUC4 implementation, we extracted various themes that may be relevant in decision- and policy-making at the HEI level. **Table 1** shows a mapping of the barriers to specific themes, where a ? mark indicates such a mapping. It is crucial to note that a particular barrier (e.g., skills gap of the human capital) may be associated with different decision-making areas in an HEI organization. On this note, responding to such a barrier requires collective action from various role-players of the HEI. Thus, it would be more efficient to identify areas (i.e., themes) that are well-defined in an organization and then formulate corresponding response mechanisms. On the other hand, identifying those themes along with the barriers associated with those themes would facilitate economies of scale and economies of scope. This happens as a specific response strategy on a theme may target more than one barrier within the same theme; hence, desired targets are achieved more efficiently.

Table 1. Barriers relation to identified categories.

Barriers	Brief Description	Themes						
		Human Resources	Infrastructure	Financial	Linkages	Educational Management	Learners	Health and Environment
Cybersecurity threat	The threat of information leakage, security attacks, and misusage of technology.	?	?			?	?	

Barriers	Brief Description	Themes						
		Human Resources	Infrastructure	Financial	Linkages	Educational Management	Learners	Health and Environment
Costly	Implementation of EDUC4 is associated with higher costs (e.g., acquisition of equipment, maintenance).		?	?		?		
Skills gap of the human capital	Insufficient knowledge and experience of the human capital in using digital technology for education, including the lack of specific skills (i.e., critical thinking, emotional intelligence).	?	?	?	?	?		
Apprehensive stakeholders	Apprehension of some stakeholders (i.e., learners, educators, administrators) to EDUC4.	?			?	?	?	
Lack of training resources	The lack of training resources (i.e., facility, materials) for the professional development of educators.	?	?	?	?	?		
Lack of collaboration	Lack of collaboration with other sectors (i.e., community, government, other HEIs, industry) is essential in successfully implementing EDUC4.		?		?	?		
Knowledge gap for the customization of curriculum design	Current lack of knowledge to create a customized curriculum design to enhance learners' skills (i.e., creativity, critical thinking) and promote skills-based training.	?	?			?	?	

Barriers	Brief Description	Themes						
		Human Resources	Infrastructure	Financial	Linkages	Educational Management	Learners	Health and Environment
Insufficient available technologies	Due to the rapid advancement of technology, developing countries cannot catch up with those developed ones. Some technologies might be available in some countries but not in others.	?	?	?	?			
Health issues	Prolonged exposure to the technology may cause health issues in the physical and mental well-being of the learners and educators.	?	?			?		?
Time constraint for material preparation	Preparing and teaching in a virtual learning platform requires more time than the traditional one.	?				?		?
Complexity of learning platforms	The challenge that the users (i.e., learners and educators) face on utilizing the virtual learning platform.	?	?			?	?	
Insufficient foundation in basic education	Quality primary education of learners is essential in the implementation of EDUC4 on HEIs					?	?	

In identifying these themes, we evaluate the framework proposed by Miranda et al. [20] and appropriately customize such a framework to capture the broader scope of an HEI organization when EDUC4 is implemented. Miranda et al. [20] suggest four core components of EDUC4: competencies, learning methods, ICTs, and infrastructure. We extend these components into a more overarching scope within the decision-making borders of an HEI. A brainstorming session among HEI administrators was conducted to identify these components or themes cautiously. After a careful discussion and deliberation, while keeping the core components of Miranda et al. [20] into consideration, seven themes were generated: human resources, infrastructure, financial, linkages, educational management, learners, and health and environment. In addition, another brainstorming session associates each barrier with the themes. The association of barriers to themes signifies their inclusion within the scope of the themes. This mechanism allows response efforts of the HEI on a theme to address multiple barriers. In the following discussions, we (1) discuss each theme in the context of the associated barriers, (2) examine how these barriers play in developing economies.

2.1. Human Resources

Human resources refer to the professionals (e.g., educators, managers, technicians) that accomplish the processes required to implement EDUC4 in HEIs. The human capital theory posits that the productivity of human beings is determined by their level of education and skills training [26]. In the context of EDUC4, it is desirable to have human resources skilled at digital technologies [27][28]. Lack of human resources with these skills **(B3)** is one of the most common barriers to EDUC4 implementation [29][30].

This barrier is prevalent in developing economies due to insufficient infrastructures and other resources that facilitate the training of professionals **(B5)** on digital technologies essential to the implementation of EDUC4 [20][31][32]. It is more relevant in developing countries having relatively lower computer literacy [33]. On the other hand, the limited experience of educators on EDUC4 would limit them to design a curriculum **(B7)** customized to fit the sophisticated EDUC4 system [20][34].

Cybersecurity threats **(B1)** also arise from the lack of technology-competent professionals in the education sector. Cybersecurity relies heavily on competent “techno-savvy” individuals [35][36][37] for keeping online “pirates” at bay. Lower computer literacy **(B3)** entails less competent human resources for jobs related to cybersecurity. These threats may brand EDUC4 less reliable and reduce stakeholders’ confidence towards it **(B4)** [6]. The lack of technology-competent professionals and insufficient infrastructures **(B8)** for operating EDUC4 technologies also has a negative impact on the perception of stakeholders towards the effectiveness of EDUC4 **(B4)** [6][36][38][39]. This apprehension towards technology-driven change can derail efforts to increase intention to adopt EDUC4.

This apprehension of stakeholders is enforced by ignorance about EDUC4 and the latent fear for change, especially with potential health implications **(B9)** [40][31]. For instance, prolonged exposure to digital devices has been associated with

health problems such as eye strains, insomnia, stress, and anxiety disorders [41]. Furthermore, the lack of experience in using digital devices could reduce the utility of digital technology in automating otherwise manual processes involved in instruction. For instance, novice users might take more time or incur more mistakes when preparing class discussions using digital technologies than the traditional method [42][43][44]. This issue is also attributed to the complexity of learning platforms required in EDUC4.

The implications of EDUC4 implementation barriers on human resources can be summarized into two main themes: technical and behavioral. Technical implications are directly related to the skills, reliability, productivity, and physical well-being of human resources in an education system. On the other hand, behavioral implications are related to the trust or confidence, satisfaction, and emotional well-being of educators in an education system. Determining these themes is essential in measuring the effects of interventions for addressing EDUC4 implementation barriers in the future. For instance, interventions targeted at minimizing technical implications may be assessed by direct measurements, e.g., pen-and-paper assessments for skills evaluation. On the other hand, those targeted at reducing behavioral implications may be evaluated through indirect methods, e.g., qualitative surveys.

2.2. Infrastructure

Infrastructure refers to a combined set of hardware, software, networks, facilities, among others (including information technology-related equipment and facilities), necessary to implement EDUC4. The unavailability of technology has been an identified barrier to EDUC4 implementation in developing economies. Malaysia's Ministry of Education recognized the need for reforms in response to EDUC4, including adjusting to new learning environments and using new technologies [45]. As Malaysia tries to turn itself into a developed economy, such shifts have caused challenges to educational institutions [46]. Limited and inefficient educational resources **(B5)**, outmoded teaching approaches **(B7)**, poor infrastructure **(B8)**, and a lack of close links between educational institutions **(B6)** are among the obstacles [47]. These barriers are more prominent in developing countries due to the lack of facilities and other resources **(B8)** that enable the implementation of EDUC4. EDUC4 requires adjusting traditional curricula to fit the IoT platforms. These platforms require critical thinking, problem-solving, communication, teamwork, and inventive thinking skills. Critical thinking and problem-solving skills, in particular, entail the ability to comprehend an issue and search for relevant information so that many points of view can be considered. Due to the nature of EDUC4 that is technology-driven, it demands innovative and creative thinking. A lack of digital proficiency among some educators **(B3)** would be a significant barrier with the new technology brought by remote learning. This may be overcome by conducting training programs and workshops for educators [31]. These barriers were made evident during the onset of COVID-19.

COVID-19 caused an unprecedented crisis across the board. In the education sector, a large part of the measures that countries have adopted in the face of the situation has been related to the suspension of face-to-face classes at all levels, which has given rise to three main fields of action: the deployment of distance learning modalities through the use of a variety of formats and platforms (with or without the use of technology), the support and mobilization of educational staff and communities, and attention to the health and integral well-being for both teachers and learners [48][49]. To cope with the abrupt switch to distance learning, both learners and educators used online teaching software and social media platforms with limited engagement [31]. They used Zoom, Google Classroom, Telegram, Free Conference, and WhatsApp extensively for more accessible communication with learners during the pandemic. Problems commonly faced in remote learning due to the insufficient availability of technology (no webcam) or unstable Internet connections, not only to Malaysia but also to other developing economies. The pandemic has brought with it not only the risk of infection but also health issues from long-term exposure to the new technology utilized in distance learning. These problems may be relevant in the long-term implementation of EDUC4.

Nevertheless, adopting technology to improve learning in EDUC4 has many advantages but entails some drawbacks that impede implementation. With such large amounts of data and sophisticated educational systems **(B11)** [36], data privacy issues **(B1)** become a significant challenge. Moreover, despite the positive impact of EDUC4 in facing disruptive changes and global trends, specific considerations must be critically examined. Successful implementation of EDUC4 requires a considerable investment from the government to aid in infrastructure development. For instance, the Massive Open Online Courses learning concept is only workable if the Internet coverage is inclusive and meets the quality standards [50], which may not be observed in developing economies.

2.3. Financial

The teaching and learning process has evolved as a result of the rapid advancement of technology. The transition of HEIs from their previously well-adapted nature of education to EDUC4 is a much-needed reform that will equip learners with skills that conform to future labor market requirements [35]. In this advancement, according to Lee (2020), technology is gradually replacing human capital **(B3)** in nearly all tasks, including transportation, manufacturing, health, and security. A

lack of consumer technology **(B8)** and expertise, managerial support, and economic advantages from digital initiatives are identified as impediments in adopting such transition among the human resource [23].

To adapt to current societal settings, initiatives and programs must match educational institutions' demands and requirements [20]. Some HEIs have already been setting the basis for a new approach to higher education [37] and examining how the sector may adapt to employment requirements by investing in innovative technology (e.g., sensors, cyber-physical systems, IoT, modified adaptive resonance theory neural networks, automation of machines) [35]. As part of EDUC4 implementation, investments in digital technologies have unknown economic advantages and significant financial investment needs.

2.4. Linkages

Cross-sector linkages and partnerships of HEIs are in high demand and a crucial factor in a successful EDUC4 implementation. Cross-sector linkages are based on a whole institution approach, which considers that universities operate within complex environments. All parts of this environment need to be considered when implementing sustainability strategies and innovation (e.g., EDUC4) [51]. Hence, a great variety of actors need to be involved in realizing them. The challenges of linkages and collaboration strategies between HIEs and the emerging global and local skill providers make educational reform more complex among developing economies [6]. The lack of collaboration **(B6)** between HEIs and external sectors, especially the industrial sector, leads to the inability of the curricular offerings to provide learners with a good set of skills necessary to address the gap of the human capital, a prevalent barrier of implementing EDUC4. Thus, it is essential for HEIs to reach out for collaboration and linkages with external sectors since such linkages are a gateway for HEIs to develop essential modern training procedures necessary for the implementation of EDUC4 [28].

The benefits gained from the linkage of HEIs with industries, public institutions, and professional and local communities include the promotion of ICT usage in creating learning networks and sharing knowledge and support necessary for interdisciplinary learning and research. It implies that the availability of technology necessary for the implementation of EDUC4 and the training materials often rely on the strength of these linkages [7]. Thus, the lack of institutional and external support would lead to the availability of technologies and training resources becoming insufficient. On the other hand, the apprehension of stakeholders **(B4)** in the implementation of EDUC4 is considered one of the factors that weaken the linkage between stakeholders and hinder realizing innovation initiatives [36]. EDUC4 requires high implementation cost **(B2)** [35]. HEIs, especially public HEIs, usually rely on external sectors for financial funding to support significant investments [50]. Thus, having apprehensive internal and external stakeholders would hinder the implementation of EDUC4.

2.5. Educational Management

Educational management processes involve the arrangement and deployment of systems that ensure the implementation of policies, strategies, and innovation initiatives throughout a set of integrated practices to achieve educational goals [52]. Almost all the barriers in EDUC4 implementation are associated with educational management. The most compelling one is the customization of the curriculum design **(B7).** An essential component of EDUC4 is designing an enhanced curriculum that caters to learners' technical and soft skill competencies necessary to address labor market needs. For instance, the demand for a human resource with knowledge and skills in machine automation requires HEIs to rethink educational aims and redraft contemporary curricular designs, such as setting machine automation as a significant subject in simulation and control systems in engineering education [29]. Thus, for educational management, the challenge lies in developing an effective and efficient curriculum design that caters to the demands of globalization, focusing on developing a set of necessary skills to address such needs.

One of the elements of EDUC4 is virtual engagement between learners and educators **(B11)**. Advances in technology significantly support distance education which gives rise to virtual classrooms. The effectiveness of this type of virtual setting lies in the available infrastructure and its efficiency [43]. Virtual platforms can be complex and challenging to navigate, which leads to a slow learning and instruction pace. It is also important to note that virtual learning implies prolonged screen time **(B9)**, which can be detrimental to the well-being (i.e., mental and physical) of educators and learners [40]. Moreover, the considerable amount of data caused by the complex design of the learning platforms poses a threat to data privacy [36] **(B1)**. Another challenge brought by virtual classrooms is the time constraint for material preparation **(B10)**. For educators, preparing the necessary virtual environment and materials for successfully conducting effective instruction requires more time and effort compared to the traditional way of instruction [42].

Another barrier associated with educational management is the skills gap of the human capital **(B3)** in providing quality instruction. This is due to the insufficient knowledge and experience of the teachers in using new technologies and the inability to execute required pedagogies for a new curriculum designed to cater to EDUC4 requirements [50]. This barrier is

associated with the lack of training resources **(B5)** for professional development, which could be a case of insufficient institutional support in educational management. Aside from that, skills- and knowledge-gap and differences in learners' learning pace (B12) are highly associated with the teachers' guidance and curriculum design [40]. Moreover, since implementing EDUC4 is a costly initiative **(B2)** which is heavily dependent on institutional support (i.e., funding) and monitoring to be successfully employed, the lack of this support subsequently leads to unsuccessful transition of education systems to EDUC4 [53], particularly relevant in developing economies. This consequence is brought by having apprehensive stakeholders **(B4)**. Without the support of these stakeholders and the lack of collaboration with external and internal stakeholders **(B6)**, initiatives in the EDUC4 implementation would be hindered. Hence, institutional support in HEIs is essential in carrying out innovation strategies to accomplish educational goals.

2.6. Learners

A shift of pedagogy brought by the adoption of EDUC4 has driven teaching practices to focus on catering to the individual needs of learners. In particular, the efforts of HEIs for EDUC4 must ensure the development and enhancement of learners' technical and methodological skills. Thus, it is evident that the implementation of EDUC4 brings forth challenges that directly confront the learners who must adapt to this change. Moreover, the capacity of the learners to adapt to EDUC4 has a significant impact on the success of implementation. It is noticeable in developing economies that learners' competency is highly challenged. In fact, the study conducted by Hinostroza [54] showed that the learners' more advanced ICT skills are significantly dependent on their economic, social, and cultural capital. Thus, a need to consider the learners' capacity to implement EDUC4 in developing economies is necessary.

EDUC4 encourages educational institutions to focus on a skills-based teaching approach rather than the traditional instructional method. Furthermore, the curricula in EDUC4 need to cater to the individual needs of the learners and allow them to acquire skills and knowledge **(B7)** that are unique to human beings to compete in the machine-dominated era [55]. This poses a challenge since this particular process has not been widely executed, and the resources to be regarded as references are limited. To address this challenge, Mogoş et al. [36] emphasized the relevance of the learners in the development of their curriculum, wherein their input on the content and flexibility of their courses are regarded as critical. Moreover, the curriculum design needs to consider the learners' skills and knowledge gap and the difference in learning pace **(B12)** [40]. This particular gap is identified by Bonfield et al. [37] as a challenge posed by emerging technologies. The skills gap is highly notable in developing economies, where most people have no access to new technologies [54]. Thus, there is a limited familiarity with the usage of those technologies.

Contemporary learners are digital natives who prefer e-learning platforms [43] and online assessment [42]. However, the use of smart products in the classroom, which obtains data that may disclose classified information unknown to users, including the school, poses a considerable dilemma on cyber security **(B1)**. Furthermore, Mogos et al. [36] highlighted the learners' excessive usage of data due to the complexity of the educational system that poses a threat to data privacy since learning confined in a classroom has shifted to learning through different platforms. Software, mobile applications, digital libraries, coursework-specific technologies, and the likes are essential means, and educators combine these platforms for best results. Multiple system interconnections may also discourage learners **(B4)** whose basic education background was in a conventional way of learning. Furthermore, learners still have a skeptical attitude towards the usage of ICT tools for learning purposes. However, Sarsar et al. [39] emphasized that this skepticism can be reduced if ICT tools should be integrated into the designed curriculum.

2.7. Health and Environment

Mentorship of state-of-the-art educators, digitally inclined learners, and technology-based learning environments are necessary for EDUC4. Smart classrooms are enhanced by augmented reality, and those virtual classrooms are emerging in today's learning [56]. However, the dominance of this type of learning engagement requires a significant amount of time spent interacting virtually rather than socially. In EDUC4, learners spend more time in digital resources than reading books and interacting with educators online rather than face-to-face [7]. Cyber collaboration among learners and the HEI community is increasingly popular in an EDUC4 environment. Such a type of more virtual engagement has made both teachers and learners digitally connected but socially disengaged. Lawrence et al. [57] highlighted that technology-driven learning makes learners disconnected from the real world.

As EDUC4 is taking advantage of technology, learners' screen time is significantly increasing. Prolonged screen time negatively affects health, including mental health [40][31][58] **(B9)**. Social contact is crucial to keeping one's mental health sound, which has become a limitation with the implementation of EDUC4. Potential tradeoffs in digital tools include loneliness paradox and Zoom fatigues [59]. This barrier is relevant both in developed and developing economies. In the Philippines (i.e., as a developing economy), where Internet speeds are significantly slower than those in the developed world, teachers and learners are more exposed to digital screens, which may have adverse health impacts. The exact number of tasks would require higher screen time at slower Internet speeds than those working with faster speeds. In

addition, with the presence of virtual classrooms, educators would require a significant amount of time in teaching material preparation [60], [42] **(B10)**, in contrast to the traditional classroom setup. Most of the time spent preparing for teaching materials is consumed in front of screens, which may have detrimental health effects. Thus, health and environmental issues become an essential point of discussion in the implementation of EDUC4.

References

1. Fisk, P. Education 4.0 … the Future of Learning Will Be Dramatically Different, in School and Throughout Life. 2017. Available online: https://www.peterfisk.com/2017/01/future-education-young-everyone-taught-together/ (accessed on 15 May 2021).
2. Dunwill, E. 4 Changes that Will Shape the Classroom of the Future: Making Education Fully Technological. 2016. Available online: https://elearningindustry.com/4-changes-will-shape-classroom-of-the-future-making-education-fully-technological (accessed on 7 July 2021).
3. Huba, M.; Kozak, S. From e-Learning to Industry 4.0. In Proceedings of the 2016 International Conference on Emerging ELearning Technologies and Applications (ICETA), Stary Smokovec, Slovakia, 24–25 November 2016; pp. 103–108.
4. Ciolacu, M.I.; Svasta, P. Education 4.0: AI Empowers Smart Blended Learning Process with Biofeedback. In Proceedings of the 2021 IEEE Global Engineering Education Conference (EDUCON), Vienna, Austria, 21–23 April 2021; pp. 1443–1448.
5. Vodenko, K.V.; Lyausheva, S.A. Science and education in the form 4.0: Public policy and organization based on human and artificial intellectual capital. J. Intellect. Cap. 2020, 21, 549–564.
6. Jamaludin, R.; McKAY, E.; Ledger, S. Are we ready for Education 4.0 within ASEAN higher education institutions? Thriving for knowledge, industry and humanity in a dynamic higher education ecosystem? J. Appl. Res. High. Educ. 2020, 12, 1161–1173.
7. Buasuwan, P. Rethinking Thai higher education for Thailand 4.0. Asian Educ. Dev. Stud. 2018, 7, 157–173.
8. Tapsir, S.H.; Puteh, M. Framing Malaysian Higher Education 4.0: Future-Proof Talents; Ministry of Higher Education Malaysia: Putrajaya, Malaysia, 2018.
9. Smart Nation and Digital Government Office. Smart Nation: The Way Forward. Available online: https://www.smartnation.gov.sg/files/publications/smart-nation-strategy-nov2018.pdf (accessed on 10 April 2021).
10. Russow, L.C. Digitization of Education. J. Teach. Int. Bus. 2003, 14, 1–11.
11. Penprase, B.E. The Fourth Industrial Revolution and Higher Education. In Higher Education in the Era of the Fourth Industrial Revolution; Gleason, N.W., Ed.; Springer: Singapore, 2018; pp. 207–229.
12. Puncreobutr, V. Education 4.0: New challenge of learning. St. J. Humanit. Soc. Sci. 2016, 2, 92–97.
13. Benešová, A.; Tupa, J. Requirements for Education and Qualification of People in Industry 4.0. Procedia Manuf. 2017, 11, 2195–2202.
14. Butt, R.; Siddiqui, H.; Soomro, R.A.; Asad, M.M. Integration of Industrial Revolution 4.0 and IOTs in academia: A state-of-the-art review on the concept of Education 4.0 in Pakistan. Interact. Technol. Smart Educ. 2020, 17, 337–354.
15. Esperanza, P.J.; Himang, C.; Bongo, M.; Selerio, E., Jr.; Ocampo, L. The utility of a flipped classroom in secondary Mathematics education. Int. J. Math. Educ. Sci. Technol. 2021.
16. Lee, M.-K. Flipped classroom as an alternative future class model?: Implications of South Korea's social experiment. Educ. Technol. Res. Dev. 2018, 66, 837–857.
17. Drijvers, P. Empirical Evidence for Benefit? Reviewing Quantitative Research on the Use of Digital Tools in Mathematics Education. In Uses of Technology in Primary and Secondary Mathematics Education; Springer: Cham, Switzerland, 2018; pp. 161–175.
18. Abrams, S.S.; Merchant, G. The Digital Challenge. International Handbook of Research on Children's Literacy, Learning, and Culture; John Wiley & Sons, Inc.: Malden, MA, USA, 2013; pp. 319–332.
19. Oxman, R. Digital architecture as a challenge for design pedagogy: Theory, knowledge, models and medium. Des. Stud. 2008, 29, 99–120.
20. Miranda, J.; Navarrete, C.; Noguez, J.; Molina-Espinosa, J.-M.; Ramírez-Montoya, M.-S.; Navarro-Tuch, S.A.; Bustamante-Bello, M.-R.; Rosas-Fernández, J.-B.; Molina, A. The core components of education 4.0 in higher education: Three case studies in engineering education. Comput. Electr. Eng. 2021, 93, 107278.
21. Zajda, J. (Ed.) Second International Handbook on Globalisation, Education and Policy Research; Springer: Dordrecht, The Netherlands, 2015.

22. Hershock, P.D.; Mason, M.; Hawkins, J.N. Introduction: Challenges in the Leadership of Innovation and Development in Education in a Globalizing Asia Pacific. In Changing Education; Springer: Dordrecht, The Netherlands, 2007; pp. 1–26.
23. Thorell, M.; Fridorff-Jens, P.K.; Lassen, P.; Lange, T.; Kayser, L. Transforming students into digital academics: A challenge at both the individual and the institutional level. BMC Med Educ. 2015, 15, 48.
24. Tan, J.P.-L.; Choo, S.S.; Kang, T.; Liem, G.A.D. Educating for twenty-first century competencies and future-ready learners: Research perspectives from Singapore. Asia Pac. J. Educ. 2017, 37, 425–436.
25. Indrajit, R.E.; Wibawa, B.; Suparman, A. University 4.0 in Developing Countries. Int. J. Sociotechnology Knowl. Dev. 2021, 13, 33–59.
26. Nafukho, F.; Hairston, N.; Brooks, K. Human capital theory: Implications for human resource development. Hum. Resour. Dev. Int. 2004, 7, 545–551.
27. Chen, Z.; Zhang, J.; Jiang, X.; Hu, Z.; Han, X.; Xu, M.; Savitha, V.; Vivekananda, G.N. Education 4.0 using artificial intelligence for students performance analysis. Intel. Artif. 2020, 23, 124–137.
28. Lea, Q.T. Orientation for an Education 4.0: A New Vision for Future Education in Vietnam. Int. J. Innov. 2020, 11, 15.
29. Liljaniemi, A.; Paavilainen, H. Using Digital Twin Technology in Engineering Education–Course Concept to Explore Benefits and Barriers. Open Eng. 2020, 10, 377–385.
30. Alabi, M.O.; De Beer, D.J.; Wichers, H.; Kloppers, C.P. Framework for effective additive manufacturing education: A case study of South African universities. Rapid Prototyp. J. 2019, 26, 801–826.
31. Alakrash, H.M.; Razak, N.A. Education and the Fourth Industrial Revolution: Lessons from COVID-19. Comput. Mater. Contin. 2021, 70, 951–962.
32. Zamora-Antuñano, M.A.; Rodríguez-Reséndiz, J.; Segura, L.R.; Cruz Pérez, M.Á.; Altamirano Corro, J.A.; Paredes-Garcia, W.J.; Rodríguez-Reséndiz, H. Analysis of Emergency Remote Education in COVID-19 Crisis Focused on the Perception of the Teachers. Sustainability 2021, 13, 3820.
33. Ngeno, B.C.; Sang, H.C.; Chemosit, C. Teacher Computer Literacy in Selected Public Primary Schools in Ainamoi Sub-County in Kericho County, Kenya. East Afr. J. Educ. Stud. 2020, 2, 1–7.
34. Ramírez-Montoya, M.S.; Loaiza-Aguirre, M.I.; Zúñiga-Ojeda, A.; Portuguez-Castro, M. Characterization of the Teaching Profile within the Framework of Education 4.0. Future Internet 2021, 13, 91.
35. Hariharasudan, A.; Kot, S. A Scoping Review on Digital English and Education 4.0 for Industry 4.0. Soc. Sci. 2018, 7, 227.
36. Mogoş, R.I.; Bodea, C.N.; Dascălu, M.I.; Safonkina, O.; Lazarou, E.; Trifan, E.L.; Nemoianu, I.V. Technology enhanced learning for industry 4.0 engineering education. Rev. Roum. Sci. Technol.–Électrotechn. et Énerg. 2018, 63, 429–435.
37. Bonfield, C.A.; Salter, M.; Longmuir, A.; Benson, M.; Adachi, C. Transformation or evolution?: Education 4.0, teaching and learning in the digital age. High. Educ. Pedagog. 2020, 5, 223–246.
38. Popkova, E.G.; Zmiyak, K.V. Priorities of training of digital personnel for industry 4.0: Social competencies vs technical competencies. Horizon 2019, 27, 138–144.
39. Sarsar, F.; Kale, Ö.A.; Andiç-Çakır, Ö.; Gueorguiev, T.; Evstatiev, B.; Georgieva, T.; Kadirova, S.; Mihailov, N.; Różewski, P.; van Leeuwen, M. Multicultural investigation of the students' acceptance of using digital learning materials in laboratory classes. Comput. Appl. Eng. Educ. 2021, 29, 883–896.
40. Suhaimi, H.; Adam, A.; Mrwan, A.G.; Abdullah, Z.; Othman, M.F.; Kamaruzzaman, M.K.; Hagos, F.Y. Analysis of combustion characteristics, engine performances and emissions of long-chain alcohol-diesel fuel blends. Fuel 2018, 220, 682–691.
41. Battashi, N.A.; Al Omari, O.; Sawalha, M.; Al Maktoumi, S.; Alsuleitini, A.; Al Qadire, M. The Relationship Between Smartphone Use, Insomnia, Stress, and Anxiety Among University Students: A Cross-Sectional Study. Clin. Nurs. Res. 2021, 30, 734–740.
42. Boca, G. Factors Influencing Students' Behavior and Attitude towards Online Education during COVID-19. Sustainability 2021, 13, 7469.
43. Bujang, S.D.A.; Selamat, A.; Krejcar, O.; Maresova, P.; Nguyen, N.T. Digital Learning Demand for Future Education 4.0—Case Studies at Malaysia Education Institutions. Informatics 2020, 7, 13.
44. Azman, M.N.A.; Kamis, A.; Kob, C.G.C.; Abdullah, A.S.; Jerussalem, M.A.; Komariah, K.; Budiastuti, E. How Good Is My Guru: The Lecturers' Percieved Usefullness and Attitude. Cakrawala Pendidik. 2020, 39, 422–431.
45. Cheok, M.L.; Wong, S.L. Frog Virtual Learning Environment for Malaysian Schools: Exploring Teachers Experience. In ICT in Education in Global Context; Springer: Singapore, 2016; pp. 201–209.
46. Ahmad, J.M.; Badusah, A.Z.; Mansor, A.; Karim, A.; Khalid, F. The application of 21st century ICT literacy model among teacher trainees. Turkish Online J. Educ. Technol. 2016, 15, 151–161.

47. Razak, N.A.; Alakrash, H.M.; Sahboun, Y. English language teachers' readiness for the application of technology towards fourth industrial revolution demands. Asia-Pacific J. Inf. Technol. Multimed. 2018, 7, 89–98.
48. Abuhammad, S. Barriers to distance learning during the COVID-19 outbreak: A qualitative review from parents' perspective. Heliyon 2020, 6, e05482.
49. Conto, C.A.; Akseer, S.; Dreesen, T.; Kamei, A.; Mizunoya, S.; Rigole, A.; Unicef. COVID-19: Effects of School Closures on Foundational Skills and Promising Practices for Monitoring and Mitigating Learning Loss; Technical Report; 2020. Available online: https://www.unicef-irc.org/publications/pdf/COVID-19_Effects_of_School_Closures_on_Foundational_Skills_and_Promising_Practices_for_Monitoring_and_Mitigating_Learning_Loss.p (accessed on 14 July 2021).
50. Halim, M.; Shokheh, M.; Harun, M.; Ebrahimi, M.; Yasin, Z.; Romadi. The Insight of the Industrial Revolution 4.0 in the Higher Education System. Int. J. of Innov. Creat. Chang. 2019, 7, 148–163.
51. Walsh, L.; Kahn, P. Collaborative Working in Higher Education: The Social Academy; Routledge: New York, NY, USA, 2009.
52. Amanchukwu, R.N.; Stanley, G.J.; Ololube, N.P. A review of leadership theories, principles and styles and their relevance to educational management. Management 2015, 5, 6–14.
53. Ramísio, P.J.; Pinto, L.; Gouveia, N.; Costa, H.; Arezes, D. Sustainability Strategy in Higher Education Institutions: Lessons learned from a nine-year case study. J. Clean. Prod. 2019, 222, 300–309.
54. Hinostroza, J.E. New Challenges for ICT in Education Policies in Developing Countries: The Need to Account for the Widespread Use of ICT for Teaching and Learning Outside the School. In ICT-Supported Innovations in Small Countries and Developing Regions; Educational Communications and Technology: Issues and, Innovations, 1st ed.; Lubin, I., Ed.; Springer: Cham, Switzerland, 2018; pp. 99–119.
55. Anito, J.C., Jr.; Morales, M.P.E. The Pedagogical Model of Philippine STEAM Education: Drawing Implications for the Reengineering of Philippine STEAM Learning Ecosystem. Univers. J. Educ. Res. 2019, 7, 2662–2669.
56. Sharma, P. Digital Revolution of Education 4.0. Int. J. Eng. Adv. Technol. 2019, 9, 3558–3564.
57. Lawrence, R.; Ching, L.F.; Abdullah, H. Strengths and Weaknesses of Education 4.0 in the Higher Education Institution. Int. J. Innov. Technol. Explor. Eng. 2019, 9, 511–519.
58. Pandya, A.; Lodha, P. Social Connectedness, Excessive Screen Time During COVID-19 and Mental Health: A Review of Current Evidence. Front. Hum. Dyn. 2021, 3, 684137.
59. Holt-Lunstad, J. Social isolation and health. Health Aff. Health Policy Brief 2020.
60. Ambani, S.N.; Lypson, M.L.; Englesbe, M.J.; Santen, S.; Kasten, S.; Mullan, P.; Lee, C.T. The Surgery Fellow's Education Workshop: A pilot study to determine the feasibility of training senior learners to teach in the operating room. J. Surg. Educ. 2016, 73, 741–748.