International Journal of Learning, Teaching and Educational Research
Vol. 23, No. 7, pp. 476-498, July 2024
https://doi.org/10.26803/ijlter.23.7.24
Received May 21, 2024; Revised Jul 5, 2024; Accepted Jul 31, 2024

Teachers' Views on the Interdependence of Humanity and Technology in Life Sciences Teaching and Learning within the Context of the 5IR

Zainul Moola, Thasmai Dhurumraj and Sam Ramaila*
University of Johannesburg
Johannesburg, South Africa

Abstract. The advent of the 5th Industrial Revolution (5IR) has brought a transformative shift to the educational landscape. The primary goal of 5IR is to address the inconsistencies observed in the preceding 4th Industrial Revolution (4IR). With a heightened emphasis on digitalization, Artificial Intelligence, automation, and the Internet of Things, there is a renewed focus on the role of humans in an era of rapid technological innovation. The impact of 5IR on Life Sciences education is particularly intriguing, prompting an exploration of the interplay between technology and humanity from the perspective of Life Sciences teachers. This research employs a mixed-method approach, incorporating both qualitative and quantitative methods. A questionnaire was used to assess the baseline knowledge related to 5IR, followed by interviews with two participants immersed in technology-rich environments, which are essential for a 5IR-aligned classroom. The findings suggest that a Life Sciences classroom integrating digitalization and humanistic approaches aligns with 5IR standards. In the context of 5IR pedagogy, the focus is on the teacher and learner, with technology serving as a complementary tool to enhance the learning experience. The study reveals varying degrees of understanding and application among participants regarding the coexistence of human and technological elements in their teaching practices. These findings highlight the challenges and opportunities teachers face as they navigate the evolving educational landscape. Grounded in connectivism as its theoretical framework, the research has implications for educational policymakers, curriculum developers, and teacher training programs, emphasizing the need for targeted interventions to align teaching practices with the demands of the 5IR. Ultimately, this study contributes to the ongoing discourse on the interdependence of humanity and technology in Life Sciences education within the framework of the 5IR.

Keywords: 5IR; humanism; interdependence; life sciences; personalisation

*Corresponding author: *Sam Ramaila; samr@uj.ac.za*

1. Introduction

The rapid advancements in technology and their integration into various aspects of human life have significantly reshaped the educational landscape. This transformation is particularly evident within the realm of life sciences, where the intersection of biological sciences and cutting-edge technologies presents both opportunities and challenges. In the context of the Fifth Industrial Revolution (5IR), characterized by a synergistic integration of humans and technology, understanding the nuanced views of teachers becomes increasingly critical. The 5IR emphasizes the human-centred approach, blending advanced technologies with human intelligence and creativity (Noble et al., 2022). This paradigm shift demands a re-evaluation of teaching and learning strategies, particularly in fields such as life sciences, where the boundaries between biological sciences and technological innovations are becoming increasingly blurred. Teachers, as the primary facilitators of knowledge and skill development, play a pivotal role in navigating this complex landscape.

The advent of the 5th Industrial Revolution (5IR) has ushered in an era of unprecedented technological advancements, profoundly transforming various sectors, including education. As we enter this transformative period, teachers find themselves at the intersection of humanity and technology, navigating the intricate interdependence that defines the modern educational landscape. This study delves into the dynamic realm of Life Sciences teaching and learning, aiming to illuminate teachers' perspectives on the symbiotic relationship between humanity and technology within the context of the 5th Industrial Revolution. The 5IR, characterized by the convergence of digital technologies, Artificial Intelligence, automation, and interconnected systems, presents unique challenges and opportunities for Life Sciences teachers (Nyagadza et al., 2022). As society experiences an unprecedented integration of advanced technologies into daily life, teachers play a pivotal role in guiding learners through the intricate interplay between human values and technological innovation (Janse van Rensburg et al., 2019). Understanding teachers' nuanced views is crucial to unravelling the complexities of preparing learners for a future where the boundaries between biological sciences and cutting-edge technologies are increasingly blurring.

In this context, Life Sciences teachers serve as both witnesses and facilitators of the evolving relationship between humanity and technology. Their insights into the challenges, ethical considerations, and pedagogical approaches within the 5IR framework provide invaluable perspectives that can shape the future of Life Sciences education. By exploring teachers' viewpoints, this study aims to contribute to the broader discourse on fostering a balanced and ethical approach to the interdependence of humanity and technology, thereby enriching the educational landscape in the context of the 5th Industrial Revolution. This study aims to explore teachers' perspectives on the interdependence of humanity and technology in life sciences education. By delving into their views, this research seeks to unravel the complexities of preparing learners for a future where technological advancements and biological sciences are deeply intertwined. Understanding these perspectives is crucial for developing effective educational strategies that not only enhance learning outcomes but also foster an appreciation for the symbiotic relationship between humans and technology in the 5IR era. Through this investigation, we aim to provide insights into the motivations, challenges, and opportunities associated with integrating technology in life sciences education. By highlighting teachers' nuanced views, this study contributes to the ongoing discourse on educational innovation and the future of teaching and learning in an increasingly interconnected and technologically advanced world.

2. Background and Contextualisation

Industry 5.0, initiated by the Japanese government, signifies a paradigm shift where advanced technology and sciences coexist with an increased emphasis on human collaboration with technology. In this era, acquiring skills to address emerging challenges using digital technology, intelligence, and economic strategies is crucial for creating a sustainable environment. The Japanese government, as noted by Fukayama (2018), incorporated Industry 5.0 incentives into the 5th Science and Technology Basic Plan, approved in 2016. Amidst globalization and digital advancements, societal values have become complex and diverse. Unlike a mere chronological progression, the 5th Industrial Revolution (5IR) is a deliberate effort to harness digital technology, promoting social and technological integration to improve the quality of life. Fukayama (2018) describes Industry 5.0 as a smart society driven by innovation, emphasizing the convergence of physical and cyberspace. Additionally, technology is positioned as a supportive tool for human adaptation and development.

The term Society 5.0, originating in Japan, signifies a transformative trajectory for humans. Suzuki (2021) underscores the shift from a traditional to a design-oriented education paradigm, emphasizing the integration of STEM education, Humanities, and Arts. The 5IR introduces a human-centric approach, focusing on human intuition alongside technological functionality, in contrast to the technology-centric ethos of the 4th Industrial Revolution (4IR). As the education landscape undergoes a generational shift, the need to align with the principles of 5IR becomes evident. Analysing technology integration in Japanese elementary classrooms, Blundell et al. (2022) reveal a tendency toward technology substitution rather than transformation. Maddikunta et al. (2022) extend this exploration to various sectors, asserting that Industry 5.0, through the collaboration of automation and human intelligence, induces personalization, requiring classrooms to facilitate complex implementations for evolving societal needs.

The impending advent of the 5th Industrial Revolution prompts reflection on existing technologies and humanity's inherent inclination to address existential challenges. While industrial revolutions have historically propelled societal development, challenges persist. Kayembe and Nel (2019) advocate for an industrialized society to enhance social and economic prospects, stressing the role of education in equipping learners with critical thinking skills for contemporary challenges. Differentiating 4IR and 5IR, Maddikunta et al. (2022) emphasize that while 4IR prioritizes automation, 5IR places human ingenuity at the forefront, calling for educational reform. Education 5.0 seeks a coalition of humans and autonomous machines, highlighting the need for professionals with both specialized machine and operator competence.

Industry 5.0, as described by Lu et al., (2021), is not a chronological sequel but a complementary emergence, presenting unforeseen challenges and emphasizing the connection between human and machine intelligence. The shift from Industry 4.0 to Industry 5.0 brings about scalability, efficiency, and a societal focus. Society 5.0 in Japan integrates artificial intelligence, digitization, and robotics to address ecological and social imperatives. As each industrial revolution brought about substitution in education, Industry 5.0 aims to unify physical and virtual spaces, emphasizing smart learning technologies that synergize technological innovation with human components. The 5th Industrial Revolution, while still shrouded in uncertainty, signals a transdisciplinary era, requiring a critical shift in education paradigms for intelligent learning.

Motivations for integrating technology in education, as highlighted by Lai and Bower (2019), often centre on achieving learning objectives and boosting learner motivation. However, the fifth industrial revolution emphasizes the need for personalization and humanization in tandem with technological integration, recognizing the integral role of humans in achieving social cohesion. It is against this backdrop that the study explored the research question: What are teachers' views on the interdependence of humanity and technology in Life Sciences teaching and learning within the context of the 5IR?

3. Introduction of Industry 5.0

The continuous evolution of technology has given rise to Industry 5.0, transforming the landscape of teaching, and learning through innovative technologies that enhance the educational process. However, merely using technology as a tool for facilitating Life Sciences teaching, as seen in Industry 4.0, places undue emphasis on learning technology itself, potentially compromising the effectiveness of the educational experience. In contrast, Industry 5.0 recognizes technological ingenuity while placing equal value on human expertise, emphasizing coexistence and sustainability. While Industry 5.0 may initially appear focused on manufacturing systems, its implications for education are significant and warrant thorough exploration (Ghobakhloo et al., 2023).

In Industry 5.0, Life Sciences teaching and learning view the learner as a change agent actively engaged in curriculum development. Imparting essential skills such as collaboration, analytical thinking, critical reasoning, and creativity becomes imperative, placing human qualities at the core of education. Education in Industry 5.0 must align with current industrial demands, considering factors such as the labour market to tailor learning trajectories and development accordingly (Mohamed Hashim et al., 2024). Technological infrastructure and digital learning remain integral to the Industry 5.0 learning experience, serving as enablers of meaningful learning rather than ends in themselves (Mohamed Hashim et al., 2024).

Industry 5.0 seeks the coexistence of humans and technology with a shared purpose, steering towards growth and development (Lu et al., 2021). Unlike Industry 4.0, which heavily relies on automation and optimization, Industry 5.0 prioritizes the re-humanization of education in conjunction with technology. Significant technological advancements over the past two decades, including in hardware and software, have been termed "disruptive". The fusion of Artificial Intelligence and information has led to digital transformation, prompting profound changes in teaching, and learning methodologies, especially in response to the widespread effects of the COVID-19 pandemic.

While Industry 5.0 is still evolving, scholars and industry practitioners have offered various definitions emphasizing human-centricity, personalization, and technology. Maddikunta et al. (2022) describe 5IR as a collaborative effort between humans and machines to enhance production efficiency. Pant et al. (2020) highlight a human-centred environment that fosters adaptability and learning, promoting collaboration between humans and technology, termed as Cobots. Draghici et al. (2019) stress the synergy between humans and smart systems for increased efficiency, combining human innovation with technology. Lu et al. (2021) underscore Industry 5.0's core tenets of resilience, human-centricity, and sustainability, and emphasizing a systematic approach. Overall, Industry 5.0 signifies a shift towards a more human-centred, sustainable society that integrates social and environmental aspects with technology.

4. Society 5.0

In 2016, the Japanese Cabinet initially introduced and embraced the vision of a new society, aiming to enhance both technological capabilities and quality of life, hence termed as 5IR (Charrua-Santos et al., 2020). This concept envisions a highly intelligent society where interactions among humans, non-humans, and between humans themselves are better understood. According to Huang et al. (2022), Society 5.0 represents a perspective where human-centricity and technological innovation guide societal development towards economic prosperity and the resolution of social challenges. The integration of physical and cyberspace, as highlighted by Charrua-Santos et al. (2020), is seen as unlocking the full potential of information and communication technology (ICT), with the internet facilitating the connection between the physical and cyber realms to realize Society 5.0.

In contrast, Industry 4.0, initiated by Germany in 2011, is characterized by automation and cyber systems, aiming primarily at enhancing productivity (Xu et al., 2021). Fukayama (2018) delineates the objective of Society 5.0 as striving for a comprehensive system that fosters economic prosperity and tackles societal issues, emphasizing connections between the cyber and physical worlds to foster inclusivity and improve lives. Ema (2020) underscores the human-centeredness of Society 5.0, while Sudibjo et al. (2019) describe it as a technology-driven society integrating the cyber and physical realms. Fukayama (2018) further emphasizes the combination of physical and cyber elements to generate actionable data for addressing modern challenges. Yulianto (2021) interprets Society 5.0 as aiming to adjust needs to enhance the quality of life for all communities, although this approach may inadvertently undermine human capacity, placing humans at the forefront of technology control.

Although Society 5.0 is a Japanese national strategy, its alignment with the Sustainable Development Goals (SDGs) grants it global significance, as highlighted by Ema (2020). The SDGs, established by the UN, serve as a developmental agenda aimed at enhancing human prosperity. Sudibjo et al. (2019) assert that Society 5.0, akin to Industry 5.0, prioritizes humanism in advancing science and technology. Huang et al. (2022) emphasize humanism as a critical aspect of both Society 5.0 and Industry 5.0, striving to activate human creativity and evolve into a resilient and sustainable era.

Industry 5.0 focuses on manufacturing systems enabling customization and personalization through innovative technologies, with potential applications in other sectors like education, whereas Society 5.0 primarily concerns itself with the connectivity between the cyber and physical domains (Huang et al., 2022). While differing in concept and value realization, as noted by Huang et al. (2022), both Industry 5.0 and Society 5.0 ultimately aim for human-centricity, stability in addressing social issues, and economic development. Sudibjo et al. (2019) outline five key tenets of Society 5.0, emphasizing the utility of IT for sustainability, a community-centred approach, human-centricity, core values of inclusivity, effectiveness, sustainability, and intelligence, and the overarching objective of improving economic prospects.

5. Theoretical Framework

The study is grounded in connectivism as its underlying theoretical framework. Connectivism is a learning theory that emphasizes the role of social and technological networks in the learning process (Downes, 2019). Unlike traditional learning theories that focus on individual cognitive processes, connectivism posits that knowledge is distributed across a network of connections and that learning consists of the ability to construct and traverse these networks. Connectivism is highly relevant to the study of teachers' views on the interdependence of humanity and technology in life sciences education within the context of the Fifth Industrial Revolution (5IR). The 5IR, characterized by the harmonious integration of advanced technologies and human capabilities, aligns closely with the principles of connectivism, which emphasizes the importance of networks and connections in the learning process. Connectivism offers a valuable lens through which to examine teachers' views on the interdependence of humanity and technology in life sciences teaching and learning. By focusing on the principles of networked learning, knowledge distribution, and continuous adaptation, this study can contribute to a deeper understanding of how educators are preparing learners for the complexities of the 5IR.

Voskoglou (2022) underscores that learning is a fundamental cognitive process universally applicable to individuals. Downes (2019) highlights connectivism as a framework that leverages digital technology to enhance learning, necessitating adaptation to dynamic environments. Naidoo and Govender (2021) advocate for technology-enhanced pedagogies, asserting that connectivism benefits from the widespread and continuous use of technology. However, integrating such technology into educational settings may require adjustments in the didactic process. The global proliferation of digital and technological tools since the advent of the Fourth Industrial Revolution (4IR), alongside rapid technological advancements, has the potential to supplant traditional instructional methods (Naidoo & Govender, 2021). In a theoretical exploration, Naidoo and Govender (2021) suggest that connectivism aligns with constructivism but is enhanced by technological interventions. While recognizing the potential for teaching and learning success, they caution that the accessibility of these technologies carries implications for performance and achievement. They also highlight connectivism's importance in mathematics education, fostering higher-order thinking skills. Despite its emphasis on collaborative and communicative support, which resonates with humanistic principles, connectivism adheres to the standards of the Fifth Industrial Revolution (5IR) by advocating for technology integration in education.

6. Purpose of the Study

The study delves into the interdependence of technology and humanism in the Life Sciences domain against the backdrop of the Fifth Industrial Revolution (5IR). The investigation is guided by the following objectives:

(a) Investigate the nexus between technology and humanism in the teaching and learning of Life Sciences within the framework of 5IR.
(b) Explore teachers' perspectives on the correlation between humanism and technology in the context of Life Sciences.
(c) Propose a theoretical framework for Society 5.0.

7. Methods

7.1 Research Design

The study used explanatory sequential design. Sequencing in mixed methods research refers to the chronological arrangement of methods in the research design (Mele & Belardinelli, 2019). A sequential design in mixed methods research involves two consecutive phases in data collection. Sequencing can either take an explanatory form, where quantitative data collection precedes qualitative data collection, or an exploratory form, where qualitative data collection precedes quantitative collection with the aim of triangulation (Mele & Belardinelli, 2019). The second phase of data collection aims to refine the results obtained from the first phase, as the initial data may not be sufficiently revealing or expected.

According to Giri et al. (2021), this research design comprises two distinct phases, starting with the collection and analysis of quantitative data before transitioning to the collection and analysis of qualitative data. The objective is to investigate and elaborate on a quantitative finding by utilizing qualitative data. In essence, once a predictor has been identified through statistical outputs, qualitative measures such as interviews may be used to gain insight and detail (Giri et al., 2021). Mele and Belardinelli (2019) assert that the inclusion of a qualitative phase contributes to refining the findings, requiring a critical shift in theoretical assumptions from a post-positivist view to a constructivist one. The researcher initially adopts a post-positivist objective view before transitioning to a constructivist paradigm to capture multiple perspectives and gain in-depth insights (Giri et al., 2021).

7.2 Participants and Sampling Procedure

The study participants consisted of teachers from high schools located in two districts within Gauteng Province in South Africa. English medium schools were selected, specifically those with Life Sciences instructors who had access to technological teaching and learning resources along with internet connectivity. The target demographic comprised teachers employed by the Department of Basic Education. The survey involved 50 participants from the specified districts, with an additional three individuals chosen purposively for interviews, laying the groundwork for subsequent case studies.

7.3 Research Instruments

In the study, both a questionnaire and an interview guide were utilized as research instruments to collect data. The questionnaire was developed by the researchers based on the objectives of the study. The questionnaire included closed-ended questions (Likert scale). The Likert scale questions aimed to quantitatively measure teachers' views on the interdependence of humanity and technology in life sciences education within the context of the Fifth Industrial Revolution (5IR). The validity of the questionnaire was ensured through careful design and alignment with the study objectives. Pilot testing and feedback from experts or a small sample of teachers have been used to refine the questionnaire and ensure clarity and relevance.

The interview guide was also developed by the researchers, considering the specific themes and questions of interest. The interview guide consisted primarily of open-ended questions. The interview aimed to delve deeper into teachers' perspectives, allowing for a more nuanced exploration of their views, experiences, and challenges related to the integration of technology in life sciences education. It provided an opportunity to uncover additional insights not captured in the questionnaire. The validity of the interview guide was ensured through iterative refinement based on feedback from pilot interviews or expert reviews. Researchers employed techniques such as member checking (where participants review transcripts or summaries of their interviews) to enhance validity and credibility. Both the questionnaire and interview guide served complementary roles in gathering comprehensive data for the study. The questionnaire provided structured quantitative data through Likert scale responses, while the interview guide offered qualitative data through open-ended discussions. Together, these instruments aimed to capture a broad range of perspectives and insights regarding the interplay between humanity and technology in life sciences education within the framework of the 5IR.

7.4 Data Collection Procedures

Quantitative data were collected by distributing a questionnaire, specifically utilizing a baseline questionnaire to gather information and evaluate participants' current comprehension of the Fifth Industrial Revolution. Conversely, qualitative data were gathered through structured interviews with three selected Life Sciences teachers teaching at well-equipped schools ranked within the upper quintile, indicating their access to technological devices and the internet. The incorporation of both qualitative and quantitative data aims to enhance the overall validity of the study. The questionnaires were distributed online through platforms like email, survey tools such as Google Forms and SurveyMonkey. Participants were typically given a specified time frame to complete the questionnaire, which could range from a few days to a couple of weeks, depending on the study's logistics and participant availability. Clear instructions were provided to participants regarding the purpose of the study, confidentiality of responses, and how to complete the questionnaire. Interviews were conducted face-to-face and online via Zoom. The interview guide included open-ended questions designed to explore various aspects related to the integration of technology in life sciences education within the context of the Fifth Industrial Revolution (5IR). Example topics included perceptions of technology's impact on teaching and learning, challenges faced, strategies employed, and future expectations. Each interview lasted between 30 minutes to one hour, depending on the depth of discussion and participant responses. The duration allowed for in-depth exploration of participants' views and experiences while ensuring feasibility within the study's timeframe.

7.5 Data Analysis

Analysing quantitative data utilized SPSS version 26. Both inferential and descriptive statistics were used for quantitative data analysis. Regarding data collected from interviews, axial coding was utilized to systematically categorize and subcategorize information. The categorized data were then transcribed into themes. Thematic analysis, rooted in hermeneutics and addressing non-numeric data, involved the crucial process of identifying patterns, where emerging themes or codes formed the basis for subsequent categorization and analysis (Dowell et al., 2019). A comparative analysis was then conducted among the identified themes, involving a qualitative evaluation of codes derived from two or more datasets. Additionally, the examination aimed to identify variations in the expression of themes among the participants.

7.6 Ethical Considerations

The Research Ethics Committee of the institution where the study was conducted granted permission to proceed (Ethical Clearance: Sem-2020-031). The research procedures were thoroughly explained to the participants, who participated voluntarily. Pseudonyms were used to maintain anonymity and confidentiality. Informed consent was obtained from all participants, who were also allowed to withdraw from the study at any point without any consequences.

8. Findings Emanating from Quantitative Data

Table 1 presents the Cronbach's alpha values for the examined constructs. It is crucial to note that while Cronbach's alpha provides insights into internal consistency, it doesn't offer details regarding item difficulty and equivalency. In this study, the Cronbach's alpha coefficient was generated by inputting data from Likert scale-type questions in the questionnaire. The data was collected through a questionnaire administered using Google Forms, and the SPSS (Statistical Package for Social Sciences) program was employed.

Table 1: Constructs investigated

Construct	Cronbach's alpha
C1: Use of technology in the 21st century	0.915
C2: The demand for digital technology	0.910
C3: Co-existence of human and technology	0.920
C4: Effect of technology in Life Sciences	0.905
C5: Enabler of effective and meaningful learning	0.912
C6: The value of humans in 5IR	0.915

The researchers manually captured and processed the Likert scale responses, resulting in a statistical output of 0.913. The Likert scale ranged from 1 ("strongly disagree") to 5 ("strongly agree"), offering nuanced insights into varying degrees of agreement, satisfaction, frequency, or likelihood. A total of 6 Likert scale questions were utilized in the study, and participant responses from various districts, comprising 50 Life Sciences teachers, were recorded, and analyzed to determine the internal consistency of the study.

Table 2 below presents descriptive statistics for six constructs (C1 to C6). Each construct's mean, standard deviation, variance, skewness, and kurtosis are provided along with their respective standard errors.

Table 2: Descriptive statistics

Construct	Mean		SD	Variance	Skewness		Kurtosis	
	Stat.	SE	Stat.	Stat.	Stat.	SE	Stat.	SE
C1	4.1800	.15304	1.08214	1.171	-1.682	.337	2.661	.662
C2	4.1200	.14182	1.00285	1.006	-1.387	.337	2.129	.662
C3	4.3600	.13018	.92051	.847	-2.103	.337	5.482	.662
C4	4.4600	.13158	.93044	.866	-2.492	.337	6.860	.662
C5	4.5000	.12857	.90914	.827	-2.546	.337	7.380	.662
C6	4.6400	.12041	.85141	.725	-3.352	.337	12.322	.662

Note: SD = standard deviation, Stat. = statistic, SE = standard error

The means of the constructs ranged from 4.1200 to 4.6400, indicating generally high values, suggesting that respondents rated these constructs quite favourably. Standard deviations ranged from 0.85141 to 1.08214, indicating relatively moderate variability in responses. As expected, variance values followed the standard deviation, showing the spread of responses around the mean. All constructs showed negative skewness, indicating that the distributions were skewed to the left. Higher negative skewness values for C3, C4, C5, and C6 suggested a more pronounced left skew, with most responses clustering at the higher end of the scale. Kurtosis values were all positive, indicating that the distributions were more peaked than a normal distribution (leptokurtic). C6 had the highest kurtosis value (12.322), suggesting a very sharp peak with heavy tails, meaning many responses were concentrated around the mean with a few extreme values.

In summary, the descriptive statistics indicated that respondents rated all constructs favourably with relatively low variability. The negative skewness suggested that higher ratings were more frequent, while high kurtosis values, especially for C6, indicated sharp peaks in the distribution. This information could be used to understand the overall favourable perception of these constructs and the consistency in responses. These patterns were valuable for identifying the constructs' reliability and underlying respondent behaviour.

9. Findings Emanating from Qualitative Data

The subsequent discourse involved a thematic analysis derived from the coding procedure. The ensuing data was acquired through structured interviews. Respondents engaged with a series of questions delving into the application of 5IR in the Life Sciences classroom. The objective of this discussion was to evaluate and underscore the participants' existing comprehension of 5IR and its associated concepts. It is imperative to note that the questionnaire functioned as a preliminary study, laying the groundwork for more in-depth interviews.

9.1 Nexus between Technology and Humanism in the Teaching and Learning of Life Sciences within the Framework of 5IR

The advent of industrialization has spurred advancements in knowledge transfer, giving rise to transformative innovations that reshape how we absorb and integrate information. Industrialization, in contemporary discourse, often intertwines with digital and technological progress, forming the overarching theme of technology. While responses like ICT, digitalization, and online may appear distinct, they collectively fall under the broader theme of technology. Digitalization denotes the utilization of computers and reliance on automated functions through user interaction. In contrast, ICT encompasses technological tools facilitating the transmission, storage, creation, or distribution of knowledge or information. The term "online" pertains to interconnectedness. The diverse responses reveal underlying themes, as exemplified in the excerpt below.

> *"It affects the way Life Sciences teaching and learning occurs in a positive way, as it gives teachers an opportunity to incorporate technology in their lessons, to help learners connect content with reality. Teachers get to have access to various teaching resources that encourage an effective teaching and learning environment in the classrooms."*

There is a recognized acknowledgment that technology stems from industrialization, allowing for a systematic and cohesive learning experience. Elayyan (2021) contends that industrial revolutions emerge from advancements in technology, science, and society. In the given response, the logical inference is a positive impact, reflected in an affirmative response. The participant emphasizes the relevance and contextualization of Life Sciences teaching and learning by establishing connections. This represents an affordance and impact of industrialization on Life Sciences education, contributing to a resource-rich repository with insightful information for both teachers and learners. The integration of technologies, such as ICTs, fosters a conducive learning environment, encouraging active engagement and independent thinking. The implication drawn from this response suggests practical applications of industrialized technologies that operate for the benefit of Life Sciences teaching and learning.

Flexibility is a crucial aspect of a fifth industrialist learning environment. Some participants refer to the concept of flexibility facilitated through technological integration. Flexibility, in this context, signifies adaptability to various pathways of learning provided by digital technologies. The participant's response below reflects this sentiment.

> *"Educational technology provides learners with more flexibility in accessing and creating information as well as sharing knowledge. I believe these developments empower learners in finding new ways to take advantage of how much control they have which motivates them to learn more."*

The participant mentions "access", indicating the freedom to acquire, identify, and effectively utilize databases. "Educational technology" encompasses any technology designed to enhance and redefine instructional environments. The participant suggests that it is these digital technologies that provide flexibility and open broader horizons for exploring access to information. This empowers learners to achieve by adapting to the meaningful and engaging use of technology in a Life Sciences class.

9.2 Teachers' Perspectives on the Correlation between Humanism and Technology in the Context of Life Sciences

The smooth incorporation of digital technologies into the Life Sciences classroom is apparent from the participants' responses. According to Sudibjo et al. (2019), learning is impacted by technological advancements, thereby enhancing efficacy and practicality. The participant's response below seeks to emphasize how their experience in a Life Sciences classroom is facilitated by industrialization.

> *"Teaching and Learning in Life Sciences has changed drastically, for example, since the 4th Industrial Revolution (4IR) we now rely on PowerPoint presentations as opposed to writing on the blackboard. Pupils tend to enjoy interactive lessons which are online such as playing Kahoot."*

The participant is aware of the transformative nature of industrialization, noting a "drastic" change in the approach to Life Sciences teaching and learning. There is a slight misstep in linking 4IR to PowerPoint presentations, as the use of PowerPoint presentations is more aligned with 3IR. The incorporation of PowerPoint presentations signifies an alternative approach and has become widespread as a countermeasure to traditional teaching methods. The participant's comparative thought aims to highlight the evolution of technology through successive industrial revolutions, illustrating the shift from the "blackboard" to "online" as methodological strategies. An example of gamification is mentioned to reinforce this perspective, with the participant utilizing an interactive technological learning tool called Kahoot to supplement and support learning. Moreover, this learning tool employs Artificial Intelligence to generate questions based on the selected unit or topic, aligning to some extent with the concept of a fifth industrialist Life Sciences classroom.

Digitalization in education is intended to promote E-learning, necessitating the implementation of collaborative and project-based learning models while fostering a hybrid or blended approach to learning. The participant's response below illustrates their perspective on the impact of industrialization on Life Sciences.

> *"It gives benefits of digital tools in online education. Adds integrity and inclusivity to online education."*

The reference to online education is highly relevant to the concept of 5IR. The participant recognizes the necessity for learning to take place online and emphasizes the importance of inclusivity for all learners. The assertion of a hybrid or blended learning model aligns with the participant's assertion that 5IR demands seamless integration. Sudibjo et al. (2019) affirm that unconventional methods, like distance learning through technology, ensure the accessibility of quality education regardless of time and location. This approach supports independent and learner-centred autonomy. Digital tools facilitate the adaptation of information for computer operation, enhancing efficiency and accessibility. The outcome is an effective learning management system that is dynamic and optimized for the learner.

The comprehension of 5IR can be ascertained by delineating its characteristics. The diagram presented above showcases the codes and themes derived from the open-ended questionnaire. Participants exhibit a basic understanding of the concept, with many referencing the co-existence of humans and machines. However, their responses lack depth and insight, offering vague mentions of human and technology. Participants struggle to contextualize their responses within the realm of Life Sciences education. Despite the question's clarity and lack of ambiguity, the critical commentary elicited from participants fell short. The following is an example of a participant's response.

> *"Robots and smart machines working alongside people with added resilience and sustainability goals included."*

While the statement is theoretically sound and relevant to 5IR, it is important to note that 5IR extends its influence beyond the confines of education and is also pertinent to sectors like manufacturing. The participant seems unaware of this broader application. Moreover, Lu et al. (2021) introduces a 5IR perspective encompassing manufacturing systems, automation, and production. The term "sustainability" in this context implies utilizing digital technologies to mitigate environmental impact, and its direct relevance to Life Sciences teaching and learning is not immediately evident. Although robotics is an emerging STEM subject in education and could contribute to the vision of a 5IR classroom, the participant once again alludes to it within the context of manufacturing systems. Another participant response is provided below.

> *"A period in the world where machine meets the human. A collaboration between the two and a sharing of skills in that union."*

The inadequacy in the Fourth Industrial Revolution (4IR) lay in its overreliance on digital technology while neglecting the human element. The Fifth Industrial Revolution (5IR) emerges as an effort to rectify this flaw. The participant's comment underscores the integration of technology and human elements. However, the emphasis on human centrality becomes evident, aligning with Lu et al.'s (2021) socio-technical approach to promote inclusivity of humans. In a technology-driven society, teachers serve as subject specialists, and according to Lu et al. (2021), technological innovations are intended to benefit people. This signifies a paradigm shift from a digitally led society to one centred around human need. The response below provides an additional interpretation of 5IR.

> *"The industrial revolution has brought back the importance of human intelligence in the progression of our world, especially since technology for years has been seen as a concept that is taking over the world, but little did we realize that no matter what it will always be dependent on human beings. I understand the 5th industry revolution to be a concept that is for sustainability, as it fosters a more balanced working relationship between human and technology."*

Saxena et al. (2020) emphasize the indispensable role of human intelligence and thought processes in the context of the Fifth Industrial Revolution (5IR). Contrary to rendering humans obsolete, digitalization will necessitate skilled workers to guide and navigate machines, particularly through the application of human intelligence in cognitive computing. The participant recognizes human intelligence as the driving force behind learning, advocating for human-centeredness in a predominantly digital world. The term "balance" is employed to convey the idea of co-existence and a collaborative workspace.

However, the response below indicates that some participants may not fully comprehend the concept of 5IR. While acknowledging the role of technology, the response lacks coherence, failing to specify various innovations or technologies and their applications in Life Sciences classrooms. It reflects a misinformed interpretation of 5IR, highlighting that not all Life Sciences teachers may be adequately prepared for the imminent changes brought by 5IR.

> *"I think it is a revolution whereby technology will be advanced to the point in which it will be linked and connected to our thought process or nervous system".*

Based on the participants' responses, it is evident that a comprehensive understanding of 5IR is not universally achieved. Familiarity with 5IR is often determined by the recognition of key words or phrases associated with it. The phrase "co-existence of human and machine" emerges as the most cited understanding yet lacks contextualization. While some segments of responses demonstrate relevance, they do not contribute to a cohesive understanding of the concept in its entirety. Key terms such as "human-centred", "technology", and "digital" indicate a basic grasp of the concept. Conversely, incoherent, and inaccurate responses highlight a lack of familiarity. Given that 5IR is a nuanced and intricate concept, Life Sciences teachers would benefit from exposure and training to effectively comprehend and integrate it into their educational environments.

Personalization holds significance within the context of 5IR, representing a crucial approach in a classroom aligned with the principles of the fifth industrial revolution. The following are participants' interpretations that capture the essence of personalization.

> *"Personalized learning includes adapting instructions so that effective learning can take place for each individual learner. This may include using methods that link to each individual student's learning style, for example, using more diagrams or videos if a student is a visual learner. This is also important when giving constructive feedback. Personalized feedback is essential and is part of the learning process."*

Personalization involves recognizing the skills gap among learners. The participant employs the term "adapting" to articulate personalization, emphasizing that teachers consciously modify their strategies to cater for individual learners' needs. Additionally, the participant highlights the consideration of learning styles in personalizing teaching, listing various multimedia elements to appeal to both auditory and visually inclined learners. The significance of "feedback" is underscored as a crucial step in personalizing learning, allowing teachers to tailor the learning experience based on individual strengths and weaknesses. While the participant demonstrates insight into this approach and its processes, there is a need for a more explicit application of digital or technological personalization in alignment with a 5IR classroom. The following response presents another participant's perspective on personalization in a Life Sciences classroom.

> *"I think Personalized learning is an approach that focuses on unique needs, strengths, interests, and goals of each learner. It rules out the one-size-fits-all approach, it recognizes that leaners have different learning styles and preferences and seeks to provide them with the most effective learning experience possible."*

The term "unique needs" signifies differences in cognitive abilities, emphasizing the need for adaptive learning to facilitate meaningful learning experiences. This implies considering cognitive demands in relation to individual learner abilities. The Life Sciences teacher is entrusted with the task of creating a flexible learning environment and rejects a uniform "one size fits all" approach. The participant's viewpoint is coherent and aligns with the previous participant's emphasis on learning styles. Both participants argue that personalized learning in a Life Sciences classroom is influenced by accommodating diverse learning styles and delve into pedagogy. However, personalization also introduces enhanced learning through contextualization, specifically one shaped by digitalization. The following participant's perspective offers complementary and novel insights.

> *"To understand that each and every learner in your class is unique concerning all aspects of life and must be taught and be given an opportunity to learn at his own pace/level of understanding so that he can perform at his own utmost best."*

The element of pace is vital in the context of personalization, as time plays a crucial role in performance. The participant emphasizes the "uniqueness" in learning, alluding to personalized learning. The recurrent theme of customized learning suggests that Life Sciences teachers need to tailor their teaching methods to suit individual learners. The participant sees this as a motivating factor to enhance performance. This response aligns with the individualistic and unique needs, as well as adaptive strategies mentioned by previous participants. The earlier discussions on the concept of personalization point towards the theme of differentiated learning, reflecting a teaching philosophy that recognizes and addresses the diverse needs of a Life Sciences classroom. This theme is widespread and consistent with the insights provided by participants.

10. Interpretation of Key Findings in Terms of the Underlying Theoretical Framework

Connectivism proposes that learning involves the process of linking nodes or sources of information. Within the study, teachers' perspectives may indicate recognition of the diverse array of information sources available through technology in Life Sciences education. The symbiotic relationship between humanity and technology can be likened to a complex network, where learners and Teachers collaborate with various resources to deepen their understanding of Life Sciences. Connectivism emphasizes technology's role in facilitating connections between individuals and information. Teachers' viewpoints in the research suggest an acknowledgment of technology as a tool that enriches the interconnectedness of human comprehension and scientific knowledge. This encompassed leveraging digital platforms, online materials, and collaborative tools to foster a more dynamic and interactive learning environment.

Connectivism underscores the significance of collaborative and participatory learning. The study's findings elucidate how teachers perceive the interplay between humanity and technology in cultivating collaborative learning opportunities. Teachers emphasized utilizing technology to create spaces for learners to interact, exchange ideas, and collectively build knowledge in Life Sciences. Connectivism also underscores the importance of learners adapting to rapidly changing information landscapes. Teachers' perspectives in the study reflect an awareness of the dynamic nature of the Fifth Industrial Revolution (5IR) and the necessity of preparing learners to navigate and learn from evolving technological advancements. This involves instilling a mindset of continuous learning and adaptability in both teachers and learners.

Moreover, Connectivism fosters critical thinking and knowledge construction through active engagement with information networks. Teachers' viewpoints in the study underscore technology's role in developing critical thinking skills in Life Sciences education. This entails guiding learners in evaluating information, synthesizing knowledge from diverse sources, and critically analysing the relationship between humanity and technology within the context of 5IR. In summary, interpreting the study's key findings through the lens of Connectivism emphasizes the interconnected, collaborative, and evolving nature of teachers' perspectives on the relationship between humanity and technology in Life Sciences education amid the Fifth Industrial Revolution.

11. Implications for Pedagogic Innovation in Life Sciences Teaching within the Context of the 5IR

The study offers several implications for pedagogic innovation. The 5IR is characterized by the integration of advanced digital technologies, AI, and automation. Teachers need to incorporate these tools into Life Sciences curricula to enhance learning experiences. This includes using AI for personalized learning, virtual and augmented reality for interactive labs, and IoT for real-time data analysis. Despite the technological advancements, the human element remains crucial. Pedagogic strategies should ensure that technology complements rather than replaces human interaction, emphasizing empathy, ethical considerations, and social skills.

Teachers must be proficient in new technologies and understand their educational potential. Ongoing professional development and training programs should be established to keep teachers up to date with technological advancements and pedagogic strategies. Curricula need to be dynamic and adaptable, incorporating interdisciplinary approaches that blend Life Sciences with technology. This will prepare learners for a future where these fields are increasingly interconnected. With the influx of information and automation, critical thinking and problem-solving skills are paramount. Pedagogic practices should prioritize these skills, teaching learners how to analyse, evaluate, and create new solutions using technology.

Teachers should address the ethical and social implications of biotechnological advancements. This includes discussions on privacy, bioethics, and the societal impact of technologies in Life Sciences. It is imperative to create learning environments that are flexible and student-centred, allowing for personalized learning pathways. This includes adaptive learning technologies that tailor content to individual student needs and learning styles.

The study highlights the need for a balanced approach that leverages technological advancements while maintaining the essential human aspects of education. By integrating advanced technologies, focusing on human-centred pedagogy, and continuously training teachers, teachers can innovate their teaching practices to meet the demands of the 5IR. These changes will not only enhance the learning experience but also prepare learners for a future where the interdependence of humanity and technology is paramount.

12. Proposed Theoretical Framework for Society 5.0

The study's proposed theoretical framework for Society 5.0 emerges from a comprehensive synthesis of literature, emphasizing the seamless integration of human-centric principles and advanced technologies to elevate quality of life and tackle pressing societal challenges. At its core, Society 5.0 embodies several key elements that underscore its transformative potential:

Core Principles: Society 5.0 places utmost importance on human-centricity, aiming to enhance human well-being through innovative technological applications. It leverages technological ingenuity to harness the full potential of advanced technologies, ensuring sustainable development aligned with global Sustainable Development Goals (SDGs).

Components: Central to Society 5.0 is the integration of Physical Space—encompassing real-world interactions and environments—and Cyber Space—

comprising digital realms and interactions. The seamless fusion of these realms creates a cohesive, interconnected society where technology serves as a catalyst for progress and inclusivity.

Key Tenets: Key tenets of Society 5.0 include the utility of Information Technology (IT) as a cornerstone for sustainability, a community-centred approach fostering inclusivity and communal well-being, and a steadfast commitment to prioritizing human needs and creativity. Its core values—encompassing inclusivity, effectiveness, sustainability, and intelligence—are instrumental in guiding societal transformation.

Interactions and Outcomes: Interactions within Society 5.0 are characterized by enhanced human-to-human connectivity facilitated through digital means, alongside collaborative human-to-non-human interactions involving AI and machine interfaces. This synergy fosters economic prosperity through technological advancements and addresses complex social challenges through data-driven insights and digital tools.

Enabling Technologies: Enabling technologies such as Artificial Intelligence (AI), Internet of Things (IoT), Augmented Reality (AR), Big Data and Analytics, and Blockchain form the bedrock of Society 5.0's technological infrastructure. These innovations empower societies to optimize resource utilization, improve decision-making processes, and drive sustainable economic growth.

Educational Transformation: In the realm of education, Society 5.0 heralds the advent of Education 5.0, where technology is seamlessly integrated to personalize and enhance learning experiences. Emphasizing critical thinking, creativity, and adaptability, Education 5.0 equips learners with the skills needed to thrive in a digitally driven world.

Global Appeal: With a steadfast alignment with SDGs, Society 5.0 ensures global relevance and sustainability across diverse sectors beyond manufacturing, extending its transformative impact to education, healthcare, governance, and beyond. Its adaptive approach ensures that societies worldwide can harness its principles to foster inclusive growth and address contemporary challenges.

In essence, Society 5.0 represents a paradigm shift towards a harmonious integration of human ingenuity and technological prowess, promising a future where innovation serves as a catalyst for societal advancement, economic prosperity, and sustainable development on a global scale.

The study's proposed theoretical framework for Society 5.0 is illustrated in Figure 1 below.

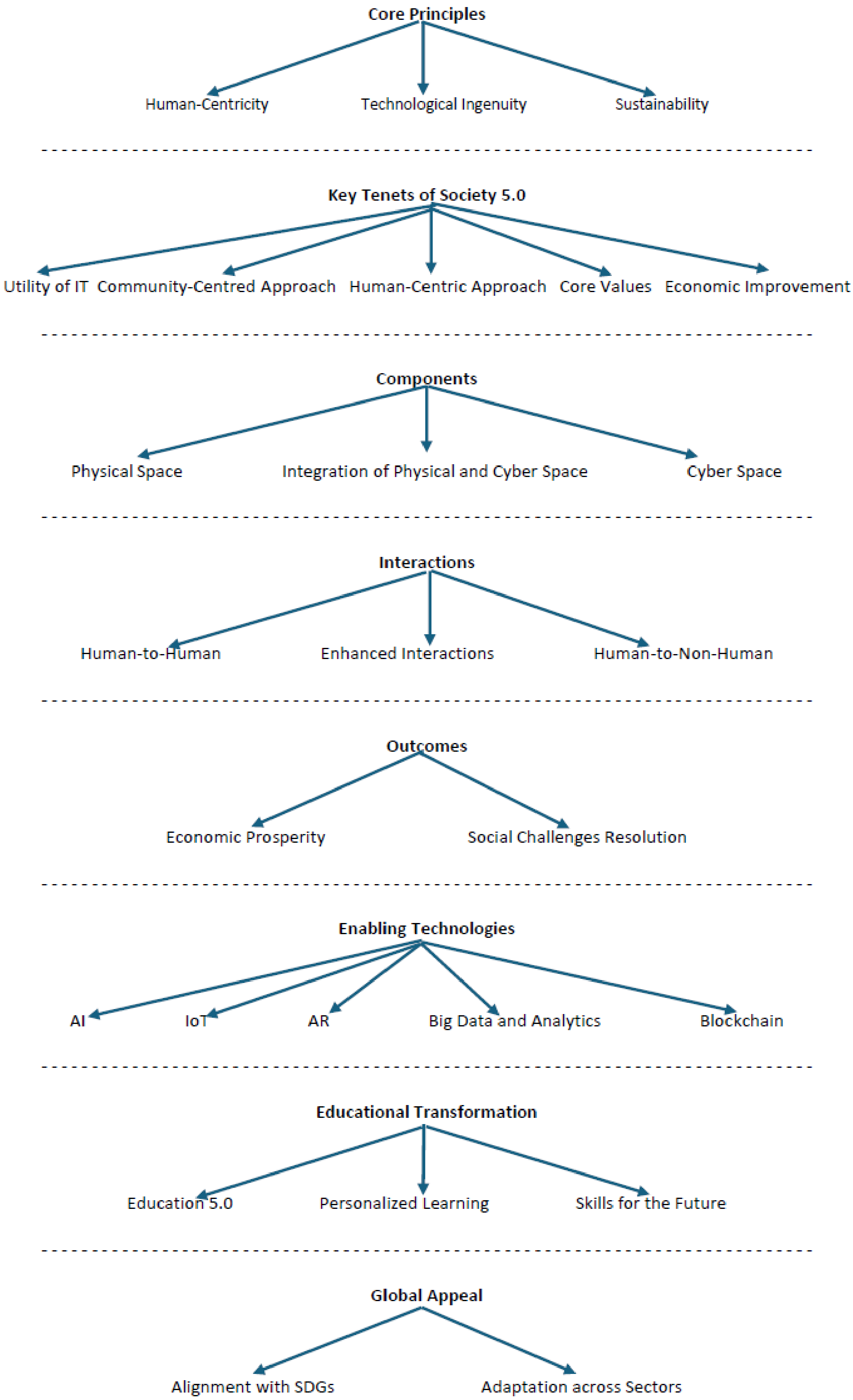

Figure 1: Proposed theoretical framework for Society 5.0

13. Discussion

The study explored teachers' views on the interdependence of humanity and technology in life sciences education within the context of the Fifth Industrial Revolution (5IR). Teachers generally perceive technology as beneficial for enhancing learning outcomes and preparing students for the technologically advanced future of the 5IR. Despite the benefits, challenges such as technological infrastructure limitations and resistance to change were identified as barriers to effective integration. Teachers emphasized the need to maintain a balance between technological advancements and human-centric educational practices to ensure holistic development. These findings align with previous studies (e.g., Naidoo & Govender, 2021) emphasizing the dual role of technology in education: as an enabler of learning innovation and as a factor requiring careful implementation strategies to maximize effectiveness. The findings suggest that while teachers recognize the transformative potential of technology, successful integration hinges on addressing practical challenges and maintaining a focus on human-centric educational goals. This interpretation is supported by literature on educational technology adoption (e.g., Downes, 2019), which underscores the importance of adaptive strategies and pedagogical alignment in leveraging technology for educational improvement.

The study's findings hold several implications for educational practice and research. Policymakers can use insights from this study to develop frameworks that support effective technology integration while safeguarding educational values. Training programs can be tailored to help teachers overcome resistance and build competencies in integrating technology into pedagogical practices. This study contributes to the body of knowledge by highlighting nuanced perspectives on the interplay between humanity and technology in education, particularly within the evolving landscape of the 5IR. These implications build upon existing research (e.g., Voskoglou, 2022) that emphasizes the need for adaptable educational strategies to meet the demands of a technology-driven society.

Despite its contributions, the study faces several limitations. The study's findings may not be fully representative due to the sample size or specific demographics of participants. The timeframe of data collection may limit the depth of insights gained. To address these limitations, future research could expand the sample size to increase diversity and representativeness, conduct longitudinal studies to track the long-term impact of technology integration on educational outcomes and explore collaborative research initiatives to develop comprehensive frameworks for sustainable technology integration in education.

14. Conclusion

In exploring teachers' perspectives on the interplay between humanity and technology in life sciences education amidst the Fifth Industrial Revolution (5IR), this study has illuminated critical insights into the evolving landscape of educational practice. The findings underscore a nuanced understanding of how teachers perceive and navigate the integration of advanced technologies within pedagogical frameworks aimed at preparing learners for a future characterized by technological innovation and interconnectedness. Teachers generally embrace technology as a catalyst for enhancing learning outcomes and fostering student readiness for the dynamic challenges of the 5IR. They acknowledge the transformative potential of technological integration but also highlight challenges such as infrastructure limitations and the need for ongoing professional development to effectively leverage these tools. Moreover, there is a strong emphasis on maintaining human-centric educational values amidst technological advancements, ensuring that learners' holistic development remains a central focus.

The study's findings suggest that successful technology integration in life sciences education requires a balanced approach that harmonizes technological innovation with humanistic educational principles. It emphasizes the importance of adaptive teaching strategies and continuous professional development to address the complexities and opportunities presented by the 5IR. These insights not only inform educational policy and practice but also contribute to ongoing discussions on how best to prepare students for a future where the boundaries between biological sciences and cutting-edge technologies are increasingly blurred.

By shedding light on teachers' perspectives, this study contributes to the scholarly discourse on educational technology and the evolving role of educators in shaping future generations. It calls for further research into effective pedagogical strategies, the impact of technology on student engagement and learning outcomes, and the development of inclusive educational practices that harness the benefits of technological advancements while mitigating potential challenges.

In conclusion, teachers play a pivotal role in navigating the interdependence of humanity and technology in life sciences education within the 5IR. Their insights and experiences underscore the need for collaborative efforts among educators, policymakers, and researchers to foster an educational environment that balances innovation with human values. Moving forward, integrating these findings into educational frameworks will be crucial for empowering teachers and students alike to thrive in a technologically advanced and interconnected world.

15. Recommendations

Based on the findings of the study, the following recommendations are proposed to enhance pedagogic practices and align them with the demands of the 5th Industrial Revolution:

(a) Implement ongoing professional development programs focused on the latest technological advancements and their applications in Life Sciences education. Workshops, webinars, and hands-on training sessions should be regularly conducted to keep teachers updated.

(b) Provide specialized training on integrating specific technologies such as AI, virtual reality, and data analytics into classroom activities, ensuring teachers are confident and competent in using these tools.

(c) Redesign curricula to incorporate interdisciplinary modules that blend Life Sciences with technology, ethics, and social sciences. This approach will prepare learners for a holistic understanding of how these fields intersect.

(d) Develop adaptive learning pathways within the curriculum that use AI and data analytics to personalize learning experiences based on individual student needs and progress.
(e) Emphasize the development of critical thinking and problem-solving skills. Use real-world case studies and problem-based learning (PBL) methods to challenge learners to think critically about the interplay between technology and biological sciences.
(f) Create flexible, technology-enhanced learning environments that support various teaching and learning styles. These spaces should facilitate collaboration, hands-on experiments, and the use of digital tools.
(g) Implement personalized learning technologies that adapt to the individual needs and learning paces of learners, ensuring that each student can engage with the material in a way that suits them best.

These recommendations aim to create a balanced and effective approach to integrating technology into Life Sciences education, addressing both the opportunities and challenges presented by the 5th Industrial Revolution. By focusing on professional development, curriculum redesign, ethical education, personalized learning, collaboration, and supportive policies, teachers can better prepare learners for a future where the interdependence of humanity and technology is paramount.

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