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A Framework for Integrating Emerging Technologies into Technical and Vocational Education and Training

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Abstract

Artificial Intelligence (AI), the Internet of Things (IoT), Virtual Reality (VR), and Augmented Reality (AR) are some of the trending technologies that are significantly impacting the world. AI aims to produce machines capable of tasks requiring thinking and intelligence. AI systems are exploding in all industries and all sectors of human activities. VR uses modelling and simulation to produce systems that enable people to interact with virtual objects in virtual environments. In contrast, AR modifies the real-world environment by adding computer-generated objects. The combination of VR and AR has led to the metaverse technology already used in industry and education. IoT is about using small devices connected to the internet to monitor and control physical objects or systems remotely or to collect valuable data from the environment. While all these technologies have great promises and potential positive impacts on education, there is no obvious way of integrating them into the educational system. This study aims to design a framework for assessing and integrating emerging technologies to their full potential in the Technical and Vocational Education and Training (TVET) systems. The research uses an exploratory design with secondary data collected from existing literature. The analysis of existing literature helped in identifying the key skills and competencies that TVET programmes must deliver. Then, the potential impacts of emerging technologies on these skills are derived. The study proposes 1) a method for assessing the potential of a technology and 2) a method for determining the highest possible level of integrating technology in TVET. The study also provides valuable recommendations to TVET institution administrators, trainers, and trainee. Therefore, this paper's main contribution is introducing a new framework for integrating AI, AR/VR and IoT into TVET education. TVET institutions administrators, trainers and trainee are the primary beneficiaries of the outcome of this research. The main limitation of this study is that its application requires expertise.

Keywords: ***AI, IoT, VR, AR, efficient educational systems***

Introduction

Artificial Intelligence (AI), the Internet of Things (IoT), Virtual Reality (VR), and Augmented Reality (AR) are some of the trending technologies that are significantly impacting the world. AI aims to produce machines capable of tasks requiring thinking and intelligence. AI systems are exploding in all industries and all sectors of human activities. VR uses modelling and simulation to produce systems that enable people to interact with virtual objects in virtual environments. In contrast, AR modifies the real-world environment by adding computer-generated objects. The combination of VR and AR has led to the metaverse technology already used in industry and education. IoT is about using small devices connected to the internet to monitor and control physical objects or systems remotely or to collect valuable data from the environment**.**

According to Yusoff et al. (2020), technical and vocational education and training (TVET) plays a vital role in developing a country. It aims at producing skilled and competent people required by the labour market. This research assumes that adopting the emerging technologies will contribute significantly to fulfilling TVET's mission by enabling efficient administrative and instructional systems. The assumption is justified by the various innovative applications that are being made from these technologies in other industries, including economy and development (Fraga-Lamas et al., 2021), business operations (Mukhopadhyay et al., 2021), agriculture and food industry (Misra et al., 2022), security and defence (Rai et al., 2021), and education (Ciolacu et al., 2019, Fitria, 2023). Unfortunately, to the best of my knowledge, there is no clear and standard approach to assess and leverage these technologies into education in general and TVET education in particular. Hence, the conduct of this research**.**

The purpose of the study is triple: 1) to provide a method for assessing technology for adoption, 2) to provide a framework for leaders, educators, and trainee of TVET education to adopt and integrate the emerging technologies into their systems easily, 3) to provide some practical recommendations to trainee, trainers, and leaders of TVET about how they can relate with these technologies for better performance.

Literature Review

Artificial Intelligence

From the findings of the study by Guan et al. (2020), education is among the sectors where AI technology has great potential to be applied. Tracing the use of AI in education from 2000 to 2019, the authors have established that AI has been used in education to provide personalised learning, tutoring systems, grading and evaluation systems, classroom management systems, and efficient systems for managing educational institutions.

In Baker et al. (2019), the applications of AI in education (AIEd) have been classified into three groups: 1) learner-oriented AIEd, 2) instructor-oriented AIEd, and 3) institutional system-oriented AIEd. These three categories cover the whole spectrum of activities in an educational system.

Several other studies on the use of AI in education include Zhai et al., (2021), Kaplan-Rakowski et al., (2023), Su & Yang, (2023), Baidoo-Anu & Owusu Ansah, (2023), and Denhere & Moloi, (2021). The literature analyses also show that AI adoption is low compared to the available potential.

Internet of Things

In the systematic literature review Hassan et al. (2021), affirmed that "Overall ICT enablement in TVET education is very low. Industry, academia, researchers, TVET policy makers, TVET training providers, and donors/funding agencies need to focus on this aspect". In the review, IoT has been identified as one of the areas where the focus should be.

During the COVID-19 pandemic, an attempt to provide remote laboratory solutions to electrical engineering trainee in Indonesia has used IoT and IoT platforms to build a system called "Integrated IoT Trainer (LRioT)" to serve for practical work in electrical engineering teaching (Nugraha et al., 2021). The initial results of this study were interesting and

demonstrated that it is possible to implement remote online practicum laboratories using IoT technology.

Virtual Reality and Augmented Reality

The combination of VR and AR has been seen as one of the latest technologies that can significantly impact education. Fitria (2023) stated:

> "AR and VR are the solutions for trainers and trainee as a medium in the teaching and learning process. AR embellishes existing reality with image elements, sound effects, or text. While VR creates a new simulation environment that presents a specific topic to trainee in an engaging, interactive, and experiential way".

Other studies that consider VR/AR in education include (Bazavan et al., 2021, Duarte et al., 2020, Elmqaddem, 2019 and Huang et al., 2019).

Summary and Literature Gaps

In summary, the use of the four trending technologies, AI, IoT, VR and AR, has been sufficiently studied by researchers, and many solutions based on these technologies have been proposed to address different educational problems. However, the combination of the four technologies has not been studied in the TVET context. Secondly, there is no methodology for assessing these technologies and integrating them into the ICT systems of TVET institutions. This research seeks to fill these two gaps.

Methodology

This research uses an exploratory design with secondary data collected from existing literature. The underlying assumption behind the research is that if the skills expected from TVET graduates and trainers, as well as the efficiency expected from TVET administration are known, it is possible to evaluate the possible use of emerging technologies towards the delivery of these skills and performances. Through intense exploration of existing literature, the required skills, and performance levels of TVET were identified, and useful technologies were also determined. This research followed a three-step process. First, this study of the related works is done with the double aim to 1) explore the use cases of the emerging technologies and 2) identify literature gaps concerning the adoption and integration of technology in education. Second, a method of technology assessment is elaborated. Finally, the last step describes the proposed framework.

Findings

Expected Skills and Efficiency

TVET is mandated to produce people with the skills and competencies that the labour market requires. To achieve this goal, TVET institutions must identify the expected skills of their graduates, identify other factors (including skills and competencies of TVET trainers) that influence the learning and development of trainers and then explore to determine which technologies facilitate the acquisition of the skills or impact the other elements.

Expected Skills of TVET Graduates

Through a summary and consolidation of the study conducted by Tuenpusa et al. (2021) and other studies, Table 1 was compiled which describes the fundamental skills that contribute to producing the desired outcome from TVET graduates as well as the technologies that can be leveraged to build those skills efficiently.

Table 1

Learning Skills and Impacting Technologies

Categories		Skills	Technologies
STEM	Science	Observation	AI, VR/AR
		Experimentation	AI, IoT, VR/AR
	Technology	Digital communication tools	AI
		Using databases	AI
	Engineering	Electrical	AI, IoT, VR/AR
		Electronics	AI, IoT, VR/AR
	Math	Analysing data	AI
		Logical reasoning	AI
4Cs		Critical Thinking	AI, VR/AR
		Communication	AI
		Collaboration	AI, IoT, VR/AR
		Creativity	AI, IoT, VR/AR
Other		Problem-solving	AI
		Inquiry	AI

Expected Skills of TVET Trainers

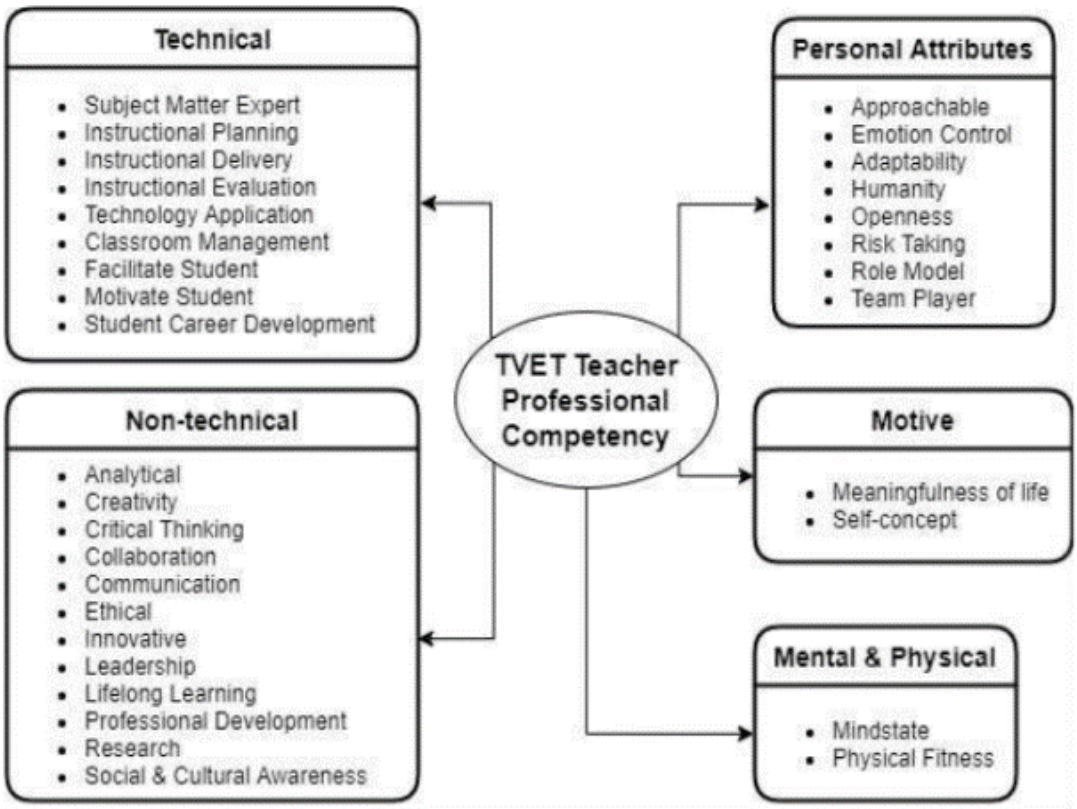
Analysing the following studies Omar et al. (2020) and Jafar et al. (2020), in Table 2 summarises the skills of TVET trainers. Figure 1 about the trainer professional competency framework is extracted from the second study.

After considering the skills for learning and teaching, it is necessary to explore what is needed for TVET institutions to operate efficiently. Leadership and management are critical to the effectiveness and efficiency of institutions. From this point of view, we want to identify the functions of leaders and managers in TVET institutions and then determine how emerging technologies can assist in the execution of these functions.

With the analysis of Nkau, (2021) and Sithole et al., (2022), and other related studies, Table 3 is derived to summarize the essential leadership and management functions that are critical to the efficiency of TVET institutions and indicate which technologies can support those functions.

Figure 1

TVET Trainer Professional Competency Framework in Industry 4.0 Era



Source: (Jafar et al., 2020)

Table 2

Trainers Skills and Technologies

Categories	Skills	Technologies
Technical	Domain expertise	AI, VR/AR
	Effective Interaction with trainee	AI, VR/AR
	Using diverse teaching strategies/methods	AI, IoT, VR/AR
	Technology application in teaching	AI, IoT, VR/AR
	Using Lab equipment	AI, IoT, VR/AR
	Applying safety practices in Workshops	AI, IoT, VR/AR
	Explaining content related to skills practices	AI
	Managing Classroom	AI, IoT, VR/AR
Non-Technical	Life Long Learning	AI, VR/AR
	Being Innovative	AI, IoT, VR/AR
	Being ethical	
	Having social and cultural awareness	AI, IoT, VR/AR

Efficiency in TVET Institutions

Table 3

Leadership and Management Functions and Supporting Technologies

Functions	Supporting Technologies
Setting directions	AI
Building relationships and developing people	AI
Redesigning the organisation to support desired practices	AI, IoT
Managing campus effectively and efficiently	AI, IoT, VR/AR
Employee engagement and participation in decision-making	AI
Effective communication between employees and managers	AI, IoT
conducting monitoring and evaluation	AI
Provision of effective training for staff	AI, VR/AR

The four levels are ordered from bottom to top according to the added value of the integration. The first two levels - "Substitution" and "Augmentation"- enhance the function, whereas the last two levels - "Modification" and "Redefinition"- transform the function. The model suggests that one should aim at the highest level possible for more added value when integrating technology.

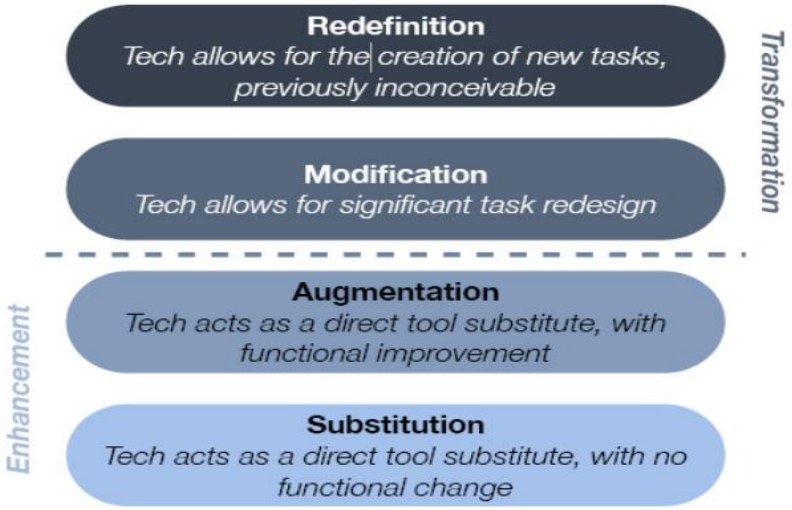
Technology Integration

From the sections in Table 3, it can be concluded that the emerging technologies AI, IoT, and VR/AR can support TVET trainers, trainees and leaders in their respective roles or expectations. Therefore, these emerging technologies must be integrated into the TVET educational system at all possible levels**.**

The SAMR (Substitution, Augmentation, Modification and Redefinition) model for technology integration into vocational education is a well known reference that is adopted in this study. The SAMR model suggests how technology should be integrated efficiently to serve the purpose of vocational education without disturbing the system (Aprinaldi et al., 2018). The model, as shown in Figure 2, identifies four levels of integration.

Figure 2

The SAMR Model of Technology Integration



Source: (Aprinaldi et al., 2018)

Proposed Framework

Functions/objectives/expectations (FOE). These correspond to the objects for which the technology is applied. In the case of this study, these are the skills expected of TVET graduates, the skills of trainers, and the functions of leadership/management.

Technology assessment. The assessment of a technology gives a score that indicates how important the technology is for the institution. The assessment of a technology consists of identifying all the functions/objectives where the technology is useful. For each case, determine the score by considering the level of integration according to the SAMR model. The scores are 1 for substitution, 2 for augmentation, 3 for modification and 4 for redefinition. The final score of any given technology is the sum of all the scores of FOEs where that technology is useful.

Threshold. The threshold defines the level at which a score indicates that the technology is deemed useful to be considered. The threshold value is, by default, calculated by multiplying the number of FOEs by two - see Equation 1.

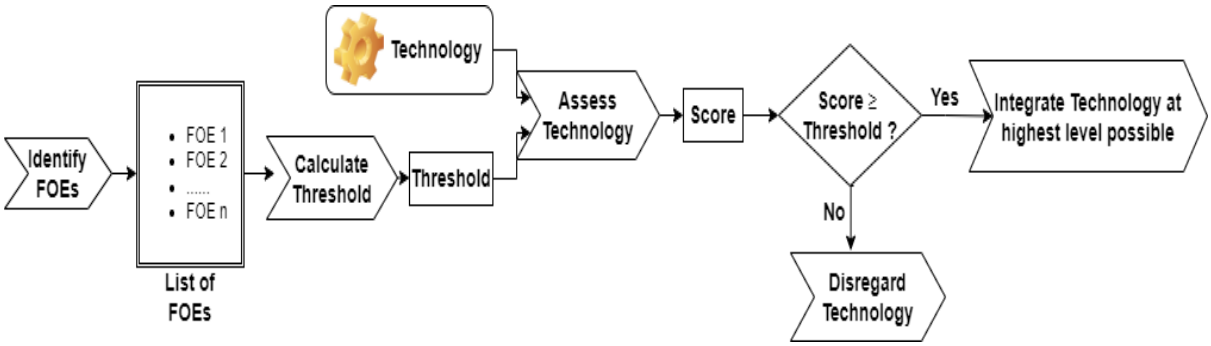
$$Threshold = 2 * |\text{FOE}| \quad (1)$$

The formula indicates that by default, each FOE is expected to be integrated at least at the "augmentation" level.

Description of the Framework

Figure 3

Graphical Description of the Proposed Framework



To use this framework, one must first identify the list of all FOEs. From this list, the threshold that a technology must meet to be considered for integration is calculated. Given that the threshold is a technology can be assessed and its score computed, the computed score is compared to the threshold; if the score is higher or equal to the threshold, the technology is eligible for integration; otherwise, that technology should be disregarded.

Conclusion

The main result of this research is elaborating a framework for integrating emerging technologies into TVET educational systems for more efficiency and effectiveness. The proposed framework is based on the SAMR model, and its merit lies in its simplicity and practical way of approaching technology selection, assessment, and integration. One major limitation of this work is that determining if a technology can support a given FOE is not easy. Likewise, even if one can guess the technology is useful, determining the appropriate level according to the SAMR model is not easy. However, with the involvement of expert technologists, the framework can be used effectively.

In summary, this research has fulfilled its objective: to design a framework for integrating emerging technologies into TVET educational systems. The study surveyed existing literature to determine the skills expected for both trainers and trainees of TVET, as well as leadership and management functions necessary for the efficient operation of TVET institutions. Next, the FOEs are mapped with the technologies that can support them; each mapping is given a score value from 1 to 4 following the SAMR model. Finally, a framework has been proposed and explained. The study's main limitation is that applying the framework requires expert technologists.

Recommendations

Inferring from this study, the following recommendations can be formulated for trainers, trainee, and leaders of TVET institutions:

- TVET leaders need do their best to evaluate and integrate valuable technologies into their institutional ICT systems. While integrating the technologies, the IT personnel and

domain experts should ensure that the integration is done at the highest possible level. For each adopted technology, the leaders have to ensure that provision is made for training trainers and trainee where applicable.

- TVET leaders should ensure that they set aside an investment budget for technology adoption and integration so that their institutions can remain current and relevant in the 21st century – the 4IR and 5IR era.
- TVET trainee must effectively use all technologies available to acquire the necessary skills and competencies of the dynamic labour market.

The author firmly believes that if the proposed framework is implemented and all involved parties follow the recommendations given, TVET institutions can achieve their mission of providing competent and skilled people required by the labour market and positively impact their nations' development. The limitation identified will be addressed in future research works.

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