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Developing Understanding of AI-Powered Personalized Learning Concept in TVET Institutions

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Abstract

This paper presents a conceptual model for integrating artificial intelligence (AI) into personalised learning systems within technical and vocational education and training (TVET) institutions. The proposed model utilizes AI technologies to create adaptive learning environments tailored to the unique needs and learning styles of individual students. The problem lies in the need for adaptive learning models that cater to individual learner needs while aligning with institutional goals and processes. The primary objective of this study is to develop an AI-powered personalised learning model that leverages EA to manage the complexities of implementation in TVET settings systematically. To formulate the proposed model, a qualitative research methodology was employed, involving semi-structured interviews with three practitioners from industry and academia in the field of AI and education. These interviews provided in-depth insights and perspectives on the feasibility, implementation, and potential impact of an AI-powered personalised learning model in TVET institutions. The integration of EA frameworks provides a structured approach to managing AI implementation while ensuring alignment with organisational objectives and processes. 11 factors emerged from three categories of learning theory. The significance of this research lies in its contribution to the existing body of knowledge by offering a comprehensive overview of the current state of AI and EA integration in personalised learning at TVET institutions. Overall, this conceptual model offers a comprehensive foundation for implementing AI-powered personalised learning in TVET institutions, aiming to transform traditional educational practices and better equip students with the skills they require for their future careers.

1. Introduction

Artificial intelligence (AI) has revolutionised higher education by enabling students to engage in learning at their convenience, thereby enhancing the flexibility of their educational experience and helping enhance their academic utilisation of AI as part of their educational process. A recent investigation conducted with more than 1,100

university students revealed that a significant number of participants possessed insufficient knowledge, and the use of questionnaires revealed that a substantial majority of students acknowledged the significance of AI in the educational sector (Putra Pratama et al., 2023). Higher education institutions (HEIs) need to adopt proactive strategies to integrate AI into their academic curricula via enterprise architecture (EA). This holistic model enables HEIs to synchronise their objectives and strategies with the integration of AI into their information technology infrastructures (Alamri, Abdullah, & Albar, 2018). This research aims to propose a conceptual model for integrating artificial intelligence (AI) into personalised learning systems within technical and vocational education and training (TVET) institutions of HEIs. The proposed model utilizes AI technologies to create adaptive learning environments tailored to the unique needs and learning styles of individual students. The significance of this study depends on its potential to transform the pace and effectiveness of student learning experiences by developing a model for aligning AI tools with personalised learning (PL) using an enterprise architecture (EA) framework. The model enables TVET institutions to align their teaching methods with individualised learning objectives, as AI-enhanced learning is expected to improve student engagement, motivation, independence, and achievement. The research aims to bridge the gap between the theoretical understanding and the practical implementation of personalized learning with AI, using an EA framework. The model provides a guideline for the integration of AI into educational practices, ultimately improving learning outcomes for students.

2. Related Work

The integration of artificial intelligence (AI) into personalised learning (PL) within TVET institutions represents a significant evolution in educational practices. This literature review explores the development of AI-driven PL models, focusing on the role of Enterprise Architecture (EA) frameworks in facilitating this integration. PL aims to shift from a 'one-size-fits-all' approach to a student-centred model, tailoring the learning process to individual needs (Fariani, Junus, & Santoso, 2022). This transformation is facilitated by AI, which provides tools for analysing learners' data, personalising learning paths, and providing adaptive instruction (Fariani, Junus, & Santoso, 2022; Khanal & Pokhrel, 2024; Kuleto et al., 2021). As HEIs increasingly adopt digital technologies to support personalised learning, they require a robust EA to ensure that these technologies are aligned with institutional goals (Abbas, Naz'ri Mahrin, & Maarop, 2021; Alamri, Abdullah, & Albar, 2018). EA provides a strategic and conceptual framework for defining how organisations function and operate, guiding the implementation of IT solutions, including AI systems; it helps in the alignment of educational objectives with industry needs and optimises resource utilisation (Alamri, Abdullah, & Albar, 2018). This review aims to synthesize existing literature on AI-driven PL in HEI, highlighting how EA frameworks support this integration, and identifying areas that require further research

2.1 Enterprise Architecture in Higher Education Institutions

The higher education landscape is undergoing rapid transformation, driven by technological advancements and the increasing need for institutions to be agile and responsive to the demands of the digital age (Abbas, Naz'ri Mahrin, & Maarop, 2021). Enterprise Architecture (EA) is a key framework for managing this level of complexity because it gives institutions a structured way to align their strategies, business processes, and IT infrastructure (Araya Guzman et al., 2018). EA helps in understanding an organisation's ecosystem, including business processes, data, applications, and technology, and facilitates the identification of solutions to achieve strategic goals. The role of EA is to provide a holistic view of an organisation, enabling better strategic alignment, resource efficiency, and adaptability to industry needs. It is recognised as critical for equipping the workforce with the skills necessary to thrive in the digital economy. Digital transformation involves not only adopting new technologies but also fundamentally shifting institutional processes and strategies to foster innovation and responsiveness (Abbas, Naz'ri Mahrin, & Maarop, 2021). The adoption of EA in TVET institutions of HEIs is essential to ensure they remain relevant and effective. By aligning strategic objectives with IT infrastructure and processes, EA can lead to better-prepared graduates and a more adaptable workforce. Studies have indicated that EA can foster the alignment of IT and business goals.

2.1.1 Enterprise Architecture Domain

Enterprise architecture (EA) is structured into domains, each addressing distinct aspects of an organisation's operations and technology. These domains provide a comprehensive view of the institution's ecosystem; they ensure alignment between business objectives and IT infrastructure. The domains also allow for better management of an organisation's complex systems. From Figure 1 below, the domains typically include the business domain, data domain, application domain, and technology domain (Alamri, Abdullah, & Albar, 2018). Each domain plays a critical role in the overall functioning of the enterprise and in achieving strategic goals; understanding these domains is essential for effective EA implementation.

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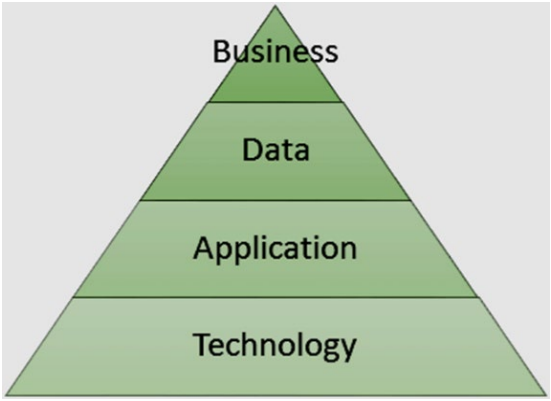

Fig. 1 *Enterprise architecture layers (Alamri, Abdullah, & Albar, 2018)*

The business domain is focused on capturing and defining the scope and requirements of university programmes (Alamri, Abdullah, & Albar, 2018). The business domain includes the institution's action plans, resources, and capabilities; it also oversees collaborators and businesses engaged in function provision and process orchestration to provide services to users.

The data domain is responsible for the storage of information needed to facilitate planning within the business domain (Alamri, Abdullah, & Albar, 2018). It is considered the intelligence of the architecture, holding all necessary data; this domain captures data from various sources, including sensors and devices, apps, historical records, and third-party data. It includes infrastructures needed to gather, manage, process, and temporarily store real-time data. The application domain includes software applications that generate data; it facilitates the flow of information across the organisation (Alamri, Abdullah, & Albar, 2018). The technology domain encompasses the platforms and infrastructure required for automating business services (Alamri, Abdullah, & Albar, 2018). It includes elements such as big data processing, cloud computing, and service-oriented architecture. The technology domain provides the hardware and software infrastructures necessary for delivering digital services, and it includes locally or cloud-hosted servers and storage for real-time data.

2.1.2 Higher Education Institutions Digital Transformation

Digital transformation (DT) is a significant shift involving not just new technologies but also changes to business processes, organisational structure, and business models. For Higher Education Institutions (HEIs), DT is essential to adapt to the increasing use of technology and remain relevant in the digital era (Abbas, Naz'ri Mahrin, & Maarop, 2021). Enterprise Architecture (EA) is a key enabler that can facilitate DT initiatives in HEIs. DT affects various aspects of HEIs, including teaching and learning, organisational processes, culture, and management (Abbas, Naz'ri Mahrin, & Maarop, 2021). DT is the crucial step to apply AI technology within HEI, as there is a growing trend towards transforming teachers' knowledge, skills, and expertise to enhance their. As for Malaysia, it has introduced the National TVET Policy 2030 to enhance the quality and relevance of TVET programs by aligning them with industry demands. This policy has five main goals: comprehensive and synergistic governance, world-class quality and education pathways, efficient and productive industry collaboration, long-term funding for TVET, and promoting TVET as the main career choice. There is a strong emphasis on digitisation in TVET to adapt to the changing work landscape and globalisation challenges. The approach includes developing digital competencies among both educators and students, enhancing websites and applications to improve service delivery and stakeholder satisfaction, and implementing digital curriculum development to ensure quality education and productivity (Lokman et al.,2009).

Malaysia is using enterprise architecture (EA) to help TVET institutions go digital. MyGovEA Blueprint gives public sector agencies a framework, methodology, and implementation plan to help EA projects. EA helps institutions align their strategic goals with their IT infrastructure and processes, which makes them more strategic, resource-efficient, and able to adapt to industry needs. When DT is driven by EA, the technology infrastructure aligns with organisational goals, including sustainability (Stecher, Pohl, & Turowski, 2020). By implementing AI with EA through DT, students are better prepared for the demands of the job market. Students gain relevant skills and knowledge, enhancing their competence and future career prospects as personalized learning and adaptive content powered by AI improve learning quality, then students become more engaged, motivated, and independent in their learning (Owoc, Sawicka, & Weichbroth, 2021; Chen, Xie, Zou, & Hwang, 2020). AI will improve a lot of learning aspects for students. AI can expedite the learning process by providing personalized feedback to students, which can improve their learning outcomes (Putra Pratama et al., 2023; Vir Singh & Kant Hiran, 2022). AI can help in creating customized learning paths tailored to individual student needs and can also serve as a virtual tutor or intelligent assistant, supporting students with their studies, answering

questions, and managing their time (Putra Pratama et al., 2023). In conclusion, the strategic combination of DT, AI, and EA can lead to significant improvements in student performance in TVET institutions. By leveraging these tools, institutions can create more effective, personalized, and engaging learning environments that give better preparation to students for the digital economy.

2.2 Artificial Intelligence

AI is broadly defined as the ability of machines to perform tasks that typically require human intelligence, such as learning, problem-solving, and decision-making. It involves the development of computer systems that can mimic cognitive functions associated with the human mind (Kuleto et al., 2021; Sebesta & Davis, 2023; Chen, Xie, Zou, & Hwang, 2020). A more specific definition describes AI as a subset of IT that can sense their environment, comprehend the collected information, learn, and derive actions based on interpreted information and their implemented objectives. AI systems are designed to learn from experience and act autonomously, distinguishing them from traditional IT (Stecher, Pohl, & Turowski, 2020). AI has the potential to transform the way we learn and teach, as it can personalise the learning experience by adapting to individual needs; it is expected to improve student engagement and outcomes while also assisting educators with administrative and instructional tasks (Putra Pratama et al., 2023; Sebesta & Davis, 2023; Vir Singh & Kant Hiran, 2022).

AI is a key enabler of PL systems, which collect learner data and adapt accordingly. It can analyse large datasets to identify patterns and inform instructional design (Owoc, Sawicka, & Weichbroth, 2021; Fariani, Junus, & Santoso, 2022). AI allows for the creation of adaptive learning systems that adjust to each student's performance and provide personalised feedback, supporting learners with their specific needs (Owoc, Sawicka, & Weichbroth, 2021; Vir Singh & Kant Hiran, 2022; Putra Pratama et al., 2023). AI can also act as a virtual tutor or intelligent assistant, providing on-demand support and tailored guidance, which enables students to have one-on-one and focused support (Putra Pratama et al., 2023). AI can create customised learning paths tailored to individual student needs. By analysing student data, AI can offer insights into how students learn and help educators tailor their teaching methods; it can also help with automated grading and assessments (Vir Singh & Kant Hiran, 2022; Kuleto et al., 2021). The important step is to analyse learner diversity, which is a crucial first step in PL, using factors such as knowledge level, learning styles, and learner characteristics (Fariani, Junus, & Santoso, 2022). PL implementation has been shown to improve learning outcomes and increase learners' satisfaction, motivation, and engagement (Fariani, Junus, & Santoso, 2022). Additionally, it facilitates more engaging learning by adapting to a wide range of learning styles (Vir Singh & Kant Hiran, 2022). In conclusion, AI has the potential to transform education by creating tailored learning experiences that cater to individual needs, preferences, and learning styles. However, there is also a need to address the challenges and ethical considerations to ensure that AI is used effectively to enhance learning outcomes for all students.

2.3 Personalized Learning

Personalised learning is an educational approach that aims to tailor the learning experience to meet the unique needs, preferences, and interests of individual students (Bernacki, Greene, & Lobczowki, 2021; Khanal & Pokhrel, 2024). It represents a significant departure from traditional, uniform methods of instruction, emphasising the importance of accommodating learner differences to enhance the educational process. The goal of personalised learning is to create customised learning environments where students can progress at their own pace and achieve mastery of their desired expertise (Alamri, Watson, & Watson, 2021; Anton Robles Balida et al., 2023). There is an increasing focus on modifying instruction in higher education to meet the diverse needs of learners. This shift is driven by the understanding that students have different learning styles, preferences, and paces and that a one-size-fits-all approach may not be effective for all (Bernacki, Greene, & Lobczowki, 2021; Anton Robles Balida et al., 2023). In this new paradigm, the role of the instructor changes from a primary source of information to a facilitator of learning, who designs and guides individual learning experiences. This shift empowers students by giving them more control and agency over their education (Bernacki, Greene, & Lobczowki, 2021; Alamri, Watson, & Watson, 2021).

2.3.1 Definitions

The U.S. Department of Education's Office of Educational Technology defines personalised learning as "instruction that is paced to learner needs, tailored to learning preferences, and tailored to the specific interests of different learners" (Bernacki, Greene, & Lobczowki, 2021; Alamri, Watson, & Watson, 2021). This definition highlights the importance of adapting the pace of learning, the instructional approach, and the content to suit individual students (Bernacki, Greene, & Lobczowki, 2021; Alamri, Watson, & Watson, 2021). Other definitions emphasise the importance of students' voices and choices by allowing them to actively participate and design their learning. A key feature of personalised learning is that it allows students to have a say in what, how, when, and where they learn individualisation. While differentiation involves using various instructional strategies for different groups

of learners, and individualisation provides the opportunity for students to proceed at their pace, both approaches still rely on the teacher to set the overall learning objectives and methods (Alamri, Watson, & Watson, 2021). Personalisation, on the other hand, shifts the role of the teacher to a facilitator of individual learning, allowing students to have more control and agency over their learning (Alamri, Watson, & Watson, 2021). Due to this, online education technology plays a crucial role in enabling personalised learning, facilitating adaptive assessments, differentiated instruction, and personalised learning experiences (Alamri, Watson, & Watson, 2021; Anton Robles Balida et al., 2023; Bernacki, Greene, & Lobczowki, 2021).

2.3.2 Learning Theories

The articles discuss various learning theories that underpin PL models, noting that these theories are often used implicitly in PL research (Fariani, Junus, & Santoso, 2022; Walkington & Bernacki, 2020). The article talks about two theories: humanism theory and the constructivism theory. The humanist theory says that both knowledge and emotions are important for learning, and it supports a student-centred approach where students build their knowledge. The constructivism theory says that learning is a personal process where students build their knowledge from their experiences. It emphasises providing opportunities for learners to develop their knowledge rather than just receiving instructions. Lev Vygotsky's sociocultural theory, a key part of constructivism, states that knowledge is built through social interaction (Fariani, Junus, & Santoso, 2022). Collaborative Learning Theory in PL is strongly related to this theory, as it emphasizes that knowledge is built through the learner's social interaction with the environment (Fariani, Junus, & Santoso, 2022). Connectivism theory is relevant to the information age and emphasises establishing and maintaining network connections that are relevant, up-to-date, and flexible to support student-centred learning. It suggests learners should be capable of finding and applying knowledge when and where it is needed, rather than memorising everything (Fariani, Junus, & Santoso, 2022).
Another learning theory that is mentioned in the article is mastery learning theory; this theory is based on the idea that students can master learning content if given the necessary time and support (Walkington & Bernacki, 2020). Next is differentiation theory, which involves tailoring instruction to meet individual learning needs and preferences (Walkington & Bernacki, 2020). The self-determination theory emphasises autonomy, competence, and relatedness as key factors in motivation; it suggests that providing choices can promote greater perceptions of autonomy (Walkington & Bernacki, 2020). Interest theory focuses on the role of interest in learning and motivation and on how connecting learning to personal interests can be beneficial (Walkington & Bernacki, 2020). Funds of knowledge theory highlight the importance of drawing on the cultural and experiential knowledge that students bring to the classroom (Walkington & Bernacki, 2020). Situated cognition theory suggests that learning is embedded in the context of the learner's environment (Walkington & Bernacki, 2020). The final theory is the strengths-based learning theory. This approach involves students reflecting on and setting goals with teachers, measuring their strengths, choosing activities related to their strengths, and receiving affirmation related to those strengths (Walkington & Bernacki, 2020).

With these theories, Walkington and Bernacki (2020) come up with a conceptual framework for PL that emphasises three key dimensions: depth, grain size, and ownership. These dimensions help analyse and distinguish various approaches to PL and how they relate to learning theories. The first dimension, the depth of personalisation, refers to the extent to which PL considers the authentic and lived experiences of learners (Walkington & Bernacki, 2020). It ranges from surface-level personalisation, such as including a student's name or favourite food in a task, to deep personalisation, which connects to meaningful learner characteristics like career goals or incorporates learner interests in ways that are authentically linked to the content (Walkington & Bernacki, 2020; Isa et al. 2015). For example, a course centred around a learner's career trajectory is a deeper form of personalisation than simply using a student's name to solve a math problem. Having students' model personally relevant data or curate interest-based collections are also examples of deeper personalisation (Walkington & Bernacki, 2020). The key idea is that deeper connections to learners' lives can have a more significant impact on their motivation and learning (Walkington & Bernacki, 2020).

Next is the second dimension, which is the grain size for personalisation. This dimension refers to the scale at which personalisation is applied, from individual learners to groups of learners based on specific or general parameters (Walkington & Bernacki, 2020). The size can vary from a broader geographic area or reading level. For medium grain size, adapting to smaller groups of students matched on specific dimensions, such as career pathways (Walkington & Bernacki, 2020). The small grain size would provide a different learning experience for each student, often through adaptive technology or by leveraging student expertise and individual interests. Examples of small-grain size personalisation would be adaptive technology systems or leveraging student expertise and interests (Walkington & Bernacki, 2020). This dimension implies that personalised learning does not always need to be one-on-one or uniquely tailored to everyone; it can be scaled to groups of learners in various ways.

The final dimension is the ownership of learning; this dimension pertains to the degree of control and choice learners have in the learning situation. It can range from designs that do not allow student choice and implement

automatic adaptivity through a technology system to those that explicitly consider students' autonomy and agency and designs that allow learners to drive instruction and select their content (Walkington & Bernacki, 2020). Some designs involve automatic adaptivity, driven by a technology system where student choice is not emphasised. Other designs consider students' autonomy and agency or allow learners to be drivers of their instruction and content selection (Walkington & Bernacki, 2020). The central idea here is that the extent to which students are given control over their learning process can significantly influence their engagement and learning outcomes (Walkington & Bernacki, 2020).

In summary, Walkington and Bernacki's (2020) framework in Figure 2.3 below provides a way to analyse PL by focusing on the depth of personalisation, the grain size at which it is implemented, and the degree of student ownership involved. These dimensions are intertwined with learner characteristics, choice, and adaptability, which significantly shape the learning experience. The framework recognises that different approaches to PL can be effective in different contexts and for different learners (Walkington & Bernacki, 2020). It emphasises that PL is not a single approach but rather a collection of methods that should be tailored to the needs and characteristics of learners (Walkington & Bernacki, 2020).

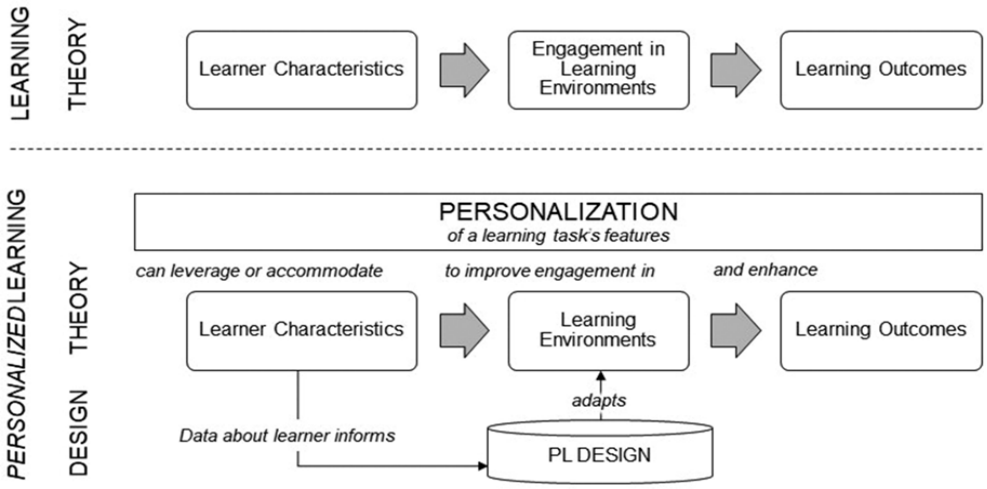

Fig. 2 *General model of assumptions of learning theories, and the augmentation of learning through personalization of a learning environment to individual learners (Walkington & Bernacki, 2020)*

Referring to Figure 2, there are three elements in the learning theory, which are learner characteristics, engagement in learning environments, and learning outcomes. With the theory outlined in the figure, the student's learning processes are visible. Walkington and Bernacki's framework emphasises that learning theories assume that the characteristics of learners influence engagement and learning outcomes; these characteristics inform the depth and grain size of personalisation (Walkington & Bernacki, 2020). For example, understanding a learner's background or career goals can lead to deeper, more meaningful personalisation. Learner characteristics are also linked to the choices students make when given agency and control, as these choices reflect their interests and needs (Walkington & Bernacki, 2020). Choice also plays an important part in PL theory, as the framework acknowledges its importance in enhancing intrinsic motivation and engagement. The choice is closely tied to ownership, as providing students with choices allows them to take greater control of their learning. This approach is further related to self-determination theory, as choice may promote greater perceptions of autonomy. However, the framework also acknowledges that choices can sometimes diminish learning if students do not challenge themselves (Walkington & Bernacki, 2020).

The last part that affects and is an important part of PL design is adaptability. Adaptability allows the system to make changes based on the learner's desires, while flexibility allows the system to make changes itself. The optimal design depends on the intended goals and theories that guide it. While adaptivity can be efficient, it is noted It is crucial to provide opportunities for learners to make their own choices (Walkington & Bernacki, 2020). The framework suggests that the use of technology can enable adaptability and adaptivity and that it is important to consider the trade-offs of each (Walkington & Bernacki, 2020).

2.3.3 Components

Based on research questions from Fariani, Junus, and Santoso (2022), which are, "What PL components are used in the PL model in the higher education context?" The study identified PL components that directly align with the characterisation of learners in Walkington and Bernacki's framework, as shown in Figure 2 above. The first component is the learner's knowledge level; this component pertains to a learner's existing knowledge. This

component encompasses the learner's background knowledge, current knowledge level, and feedback results. Background knowledge is what a learner possesses before starting a learning activity or course. It is a characteristic that influences how they approach new information (Fariani, Junus, & Santoso, 2022). The current knowledge level is the knowledge a learner has acquired at a given point during the learning process. It reflects their progress and influences their subsequent learning needs (Fariani, Junus, & Santoso, 2022). Feedback results are the feedback received from previous learning activities, which can be used to refine learning (Fariani, Junus, & Santoso, 2022). The learner's knowledge level is a key characteristic that affects the pace, depth, and type of learning materials they require and how they can be grouped with other learners.

The next component is the learner's characteristics; this component directly relates to the various traits and attributes that define a learner. This component encompasses profile data, learning style, and learner personality. Profile data includes demographic information such as gender, age, and educational background. While demographic data can be a source of inequity in learning and might not be considered a learning characteristic per se, they can be aspects that focus on a learner's awareness and control over their cognitive processes. It includes learning objectives, learning scenarios, learner attention, and learner engagement. Learning objectives include the specific goals or outcomes a learner sets for themselves (Fariani, Junus, & Santoso, 2022). Learning scenarios relate to the learning contexts, environments, and situations that are suitable for the learner (Fariani, Junus, & Santoso, 2022). Learner attention considers the learner's focus and level of engagement in the learning process (Fariani, Junus, & Santoso, 2022). Learner engagement looks at the level of active involvement a learner exhibits throughout the learning experience (Fariani, Junus, & Santoso, 2022). Metacognitive skills are crucial for self-regulated learning. Understanding these characteristics allows for personalisation, which supports the development of effective learning strategies, attention, engagement, and learner autonomy (Sulaiman et al., 2024; Hamidi et al. 2022). The research question from Fariani, Junus, & Santoso (2022) directly addresses learners' characteristics by identifying the key components used to analyse learner diversity in personalised learning. These components, including knowledge level, learning style, personality, interaction patterns, and metacognitive awareness, are all essential for developing PL models that are tailored to the individual learner (Fariani, Junus, & Santoso, 2022). By leveraging these characteristics, PL can provide students with more effective, engaging, and personalised learning experiences.

3. Methodology

This research employs a qualitative research approach to explore the applications of AI-powered personalised learning models in HEIs. The research seeks to further understand the components of AI-powered personalised learning models in TVET institutions using semi-structured interviews from experts' perspectives in a TVET setting. A semi-structured interview is an approach to qualitative methods with the strength of obtaining a profound understanding of a phenomenon from the people (Creswell, 2012). The necessary exploration is to expand the understanding of the issues and challenges in real settings. Appropriate research methodology creates a platform for proper activity in relevant areas, and it guides the researchers in the right direction. According to Kumar (2011), the focus of a qualitative study is to understand, explain, explore, discover, and clarify the situations, feelings, perceptions, attitudes, values, beliefs, and experiences of a group of people. Hence, this study uses a qualitative approach to identify components of AI-powered personalised learning models in TVET institutions and to formulate an AI-powered personalised learning model in TVET institutions. Figure 3 shows the process of conducting this study.

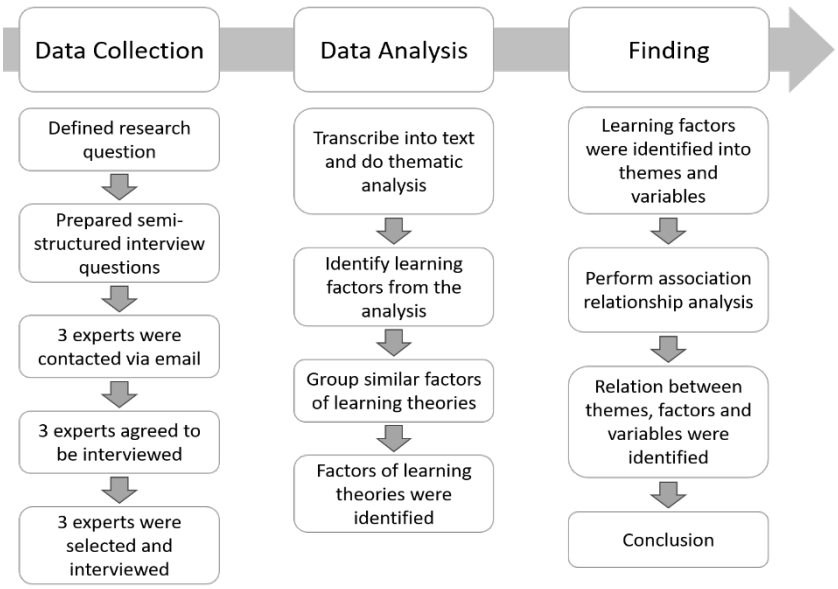

Fig. 3 *Overview of the research approach*

The activities involve conducting semi-structured interviews with individuals working as lecturers in the IT industry who have extensive experience in using AI. A purposive sampling technique will be employed to select participants who can provide in-depth insights into the application of AI in their respective fields. The semi-structured interview format allows for flexibility in questioning while ensuring that key topics are covered. Interviews will be recorded, transcribed, and analysed using thematic analysis to identify common themes and patterns in participants' responses. Data is analysed using text mining techniques to extract insights from large volumes of text.

The research process begins with the definition of a clear research question, which guides the entire study. Semi-structured interview questions are then prepared to gather in-depth information from participants. Three experts relevant to the research topic are contacted via email, and all three agree to participate in the study. These experts are subsequently selected and interviewed using the prepared questions. Following the interviews, the data is transcribed into text format, and a thematic analysis is conducted to identify key themes and patterns. From this analysis, learning factors are identified and grouped into coherent categories or themes, which are then recognized as specific learning theories.

The findings are organized into broader themes and specific variables. An association relationship analysis is performed to identify relationships and associations between these themes, factors, and variables. The relationships between the identified themes, factors, and variables are established and documented. Finally, conclusions are drawn based on the identified relationships and findings from the analysis. This structured approach to conducting qualitative research ensures a comprehensive understanding of the data collected and analyzed.

4. Result

This research culminates in the development of a comprehensive model that integrates artificial intelligence (AI) into personalized learning (PL) within the framework of enterprise architecture (EA) for TVET institutions. This model strives to transition from a rigid, universal approach to a flexible, student-focused educational journey.

The EA framework serves as the foundational layer for the model. It provides the necessary structure for aligning technology, processes, and resources to achieve institutional goals. The EA framework helps to ensure that the implementation of AI is strategically aligned with the overall objectives of the HEI.

Learner Analysis & Modelling.

Learner modelling creates individual learner models based on the collected data. These models categorize students based on their learning styles and knowledge levels. Diversity analysis using machine learning algorithms to analyze learner diversity based on knowledge level and characteristics. The AI-driven personalization stage uses AI to adapt the learning experience based on the learner models created in the previous stage. Implementing the model within a personalized e-learning system, often integrated into an existing Learning Management System (LMS). The model may also be implemented in the form of a recommendation system or an intelligent tutoring system.

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The Sankey diagram in Figure 4 illustrates the intricate relationships between three main categories—Learner Characteristic (27), Learner Environment (28), and Learner Outcome (37)—based on interview analysis. The diagram highlights the connections between these categories and various components, such as creativity, effectiveness, experience, support, influence, and institutional aspects. The width of the connecting flows indicates the strength or frequency of these relationships, emphasizing the complexity of interactions within the learning process. Key components identified on the right side of the diagram include Higher Order Thinking (12), Independence (16), Social Influence (9), Institutions (15), Motivation (13), Efficiency (11), Ethics (4), and Opportunity (12), with numbers representing their prominence in the analysis. This visualization effectively demonstrates how learner characteristics, environments, and outcomes are interrelated, providing valuable insights into the factors that influence learning. Table 1 shows the excerpt from the interviews that indicate the emerging factors from the learning theory.

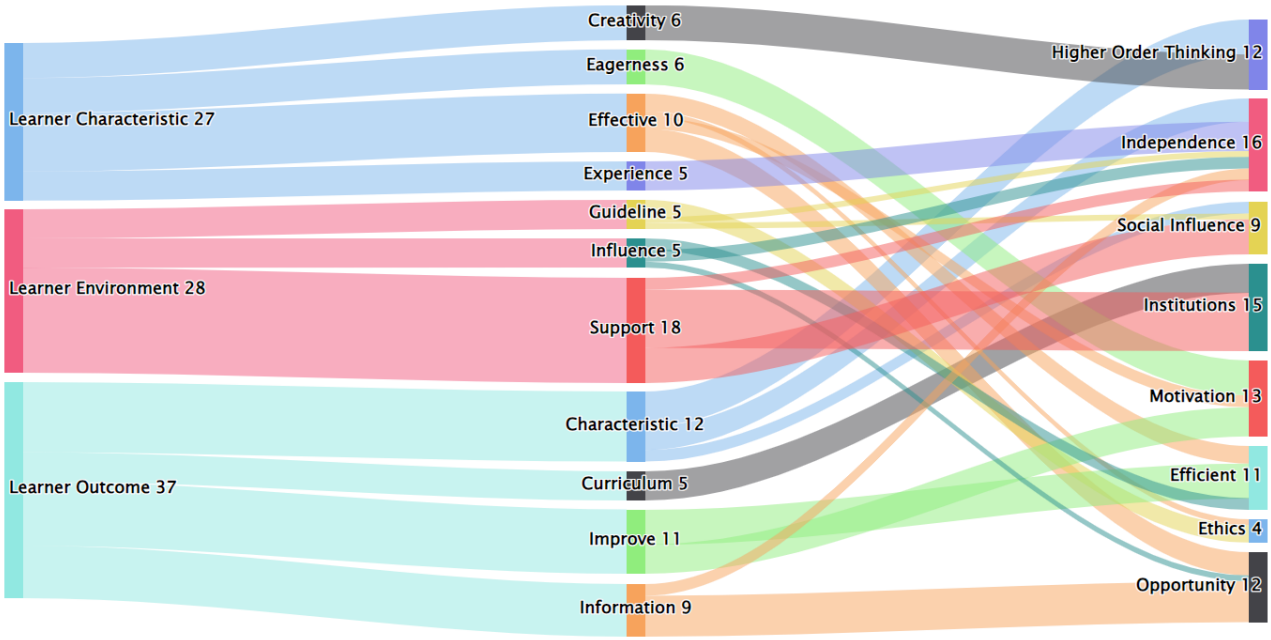

Fig. 4 *Sankey diagram of learner theories: factors and variables*

Table 1 *Excerpts of semi-structured interview*

Categories	Factors	Excerpts	Results
Learner Characteristics	Creativity	"Creativity is an essential aspect of learning, yet not all students recognize its value. Teachers can observe whether creativity is being utilized, as it often manifests in students' ability to deliver content in their unique way. When students embrace their curiosity and eagerness to explore, it further showcases their creative abilities and enhances their learning experiences. Encouraging learners to understand and appreciate creativity is vital for their growth and intellectual development." (Experts 1 & 2)	The excerpts emphasize the importance of creativity in learners. They suggest that many students fail to recognize the value of creativity, but educators can still identify its presence. Creativity becomes evident when students present their ideas in unique ways. Additionally, it highlights that fostering curiosity and eagerness to explore contributes significantly to developing creativity in learners.

Categories	Factors	Excerpts	Results
	Eagerness	"Students possess unique learning characteristics influenced by their interests, cognitive abilities, and experiences, which shape their eagerness to learn and engage. Creativity and curiosity play significant roles in driving their motivation, especially when utilizing AI tools that provide relevant and tailored content. By understanding these learner characteristics and tailoring educational materials accordingly, educators can create meaningful learning experiences. For example, using AI tools to generate personalized content for specific audiences, like hospital doctors, demonstrates how aligning teaching strategies with learner traits enhances engagement and effectiveness. This approach emphasizes the importance of leveraging AI to support learners in achieving their full potential." (Experts 2 & 3)	These excerpts highlight the importance of tailoring learning experiences to individual students' unique characters, shaped by their interests, cognitive abilities, and experiences. They emphasize that creativity and curiosity drive learners' eagerness to engage with tools like AI, which can enhance educational experiences when used effectively. Real-world applications, such as utilizing AI to create relevant content for specific audiences, demonstrate how understanding learner characteristics leads to successful and meaningful learning outcomes.
	Effective	"AI tools have revolutionized education by providing learners with unrestricted access to information and knowledge, enabling them to brainstorm ideas and discover new insights. These tools foster creativity and engagement, allowing students to explore content tailored to their interests and learning styles, such as visual, auditory, or kinesthetic preferences. By analyzing learning data, AI can address individual needs, as shown in examples like using facial recognition to support special students or creating personalized content for specific audiences, such as hospital doctors. Proper guidelines and ethical considerations are essential to ensure AI is integrated responsibly, maximizing its potential to enhance learning experiences and meet diverse educational requirements." (Experts 1, 2 & 3)	These excerpts highlight how AI empowers learners to access unlimited information and knowledge, fostering creativity and engagement. AI tools enable brainstorming, personalised learning, and support diverse learning styles, such as visual, auditory, and kinesthetic. By analyzing learning data, AI can address individual needs, as seen in applications like facial recognition to enhance education for special students. When paired with proper guidelines and ethical considerations, AI becomes a powerful tool for tailoring educational content, as demonstrated in examples like creating slides for doctors. Effective integration ensures responsible and impactful use in education.

Categories	Factors	Excerpts	Results
	Experience	"Each student possesses a unique learning character shaped by their cognitive abilities, interests, and experiences, as well as external influences like family and environment. These experiences play a significant role in character development, becoming integral to who they are. While AI cannot replace the essential role of teachers in guiding and nurturing students, it can serve as a supportive tool to enhance learning experiences, providing new opportunities for personalization and engagement. By combining human guidance with AI support, education can become more effective and tailored to individual needs." (Experts 3)	These excerpts highlight that each student has a unique learning character influenced by their cognitive abilities, interests, and experiences. Character development is shaped externally, often by significant life experiences, such as family or environment. When these experiences dominate, they become a core part of the individual's character. While AI cannot replace the pivotal role of teachers, it can effectively support and enhance the overall learning experience, complementing human guidance.
Learning Environments	Support	"A supportive environment, backed by clear guidelines from lecturers and universities, plays a crucial role in encouraging students to adopt AI tools without fear of stigma, such as the misconception that AI promotes laziness. Consistency among lecturers is essential to prevent confusion, ensuring all educators understand how AI can enhance learning. However, challenges like limited access to technology, high costs of premium AI tools, and insufficient infrastructure hinder equitable adoption. Providing technological support, such as 24-hour AI-monitored computer labs, alongside fostering social interactions like group discussions, ensures that AI complements rather than replaces the human touch in education. Additionally, developing students' soft skills, including communication and presentation abilities, is equally important, as the effective use of AI requires a balance between leveraging technology and maintaining essential human interactions. By addressing these factors, institutions can create an inclusive and productive environment for integrating AI into education." (Experts 1, 2 & 3)	The excerpts underline the importance of creating a supportive and consistent environment for adopting AI tools in education. Universities and lecturers must address stigmas, such as the misconception that AI use promotes laziness, to encourage openness among students. Clear guidelines and aligned policies among educators are crucial to prevent confusion and promote the effective use of AI tools. Infrastructure and technological access, such as laptops, internet, and 24-hour AI-monitored computer labs, are essential, as a lack of resources creates barriers for students. While AI can enhance learning, social interactions, like group discussions and coaching, remain vital, as AI should complement rather than replace human connection. Additionally, financial costs, including expensive tools and devices, present challenges, especially for students with limited means. Institutions must prioritize fostering students' communication and soft skills alongside AI integration to prepare them for practical application and success in both academic and professional settings.

Categories	Factors	Excerpts	Results
	Guideline	"A well-structured and supportive learning environment plays a pivotal role in encouraging students to adopt AI tools effectively. Universities and lecturers must establish clear guidelines to address any misunderstandings or stigmas, such as the misconception that AI promotes laziness, which can discourage students from utilizing these tools. By providing consistent policies and fostering a shared understanding among educators, institutions can create clarity and remove confusion surrounding AI usage. Additionally, the integration of soft skills development alongside AI adoption is crucial, ensuring students can communicate effectively and maximize the potential of these tools. Clear and comprehensive guidelines are essential to align students and lecturers in the successful implementation of AI technologies within the educational framework. (Experts 1 & 2)"	These excerpts emphasize the importance of establishing clear guidelines within the learning environment to support the effective use of AI tools. Universities and lecturers play a crucial role in fostering a positive environment by providing structured policies, which not only encourage students to adopt AI but also help them develop essential soft skills. A lack of clear guidelines on the usage of AI tools can lead to confusion among students and hinder their understanding. Therefore, a well-defined framework is vital for both students and lecturers to ensure consistent and effective integration of AI in education.
	Influence	"In the future, AI generative tools like ChatGPT will play a significant role in providing information and aiding learning. However, the focus should not solely be on using these tools but also on how students apply and present the knowledge gained from them. By fostering a shared understanding and consistent use of AI tools, learners can better comprehend the scope of their application in education. This approach will not only enhance their ability to leverage AI but also help them develop essential skills like communication and presentation. Ultimately, these tools empower students to become effective leaders, benefiting their personal growth and future success. " (Expert 1 & 2)	These excerpts emphasize the future potential of AI generative tools like ChatGPT, which will not only provide information but also help students effectively apply and present what they learn. By fostering shared understanding and consistent usage, learners can maximize the benefits of AI tools. This approach supports the development of essential skills, such as communication and presentation, enabling students to grow into quality leaders. Ultimately, the primary beneficiaries are the students themselves, who must actively leverage AI tools to enhance their learning and personal growth.

Categories	Factors	Excerpts	Results
Learner Outcomes	Improve	“AI tools significantly enhance the quality and efficiency of students' work and assignments by helping them systematically prepare tasks, improve their writing, and deepen their understanding. Tools like QuillBot and Grammarly assist with paraphrasing and rephrasing, promoting originality and reducing plagiarism by offering alternative suggestions. AI also enables lecturers to embed its use in assignments or teaching, fostering students' readiness to apply AI effectively in their learning. While optional usage depends on how proactive and consistent lecturers are, the benefits of AI are undeniable, particularly in improving the structure and creativity of written work. By making rephrasing manageable and supporting originality, AI empowers students to deliver higher-quality outcomes while learning to use these tools responsibly and effectively. “(Experts 1, 2 & 3)	These excerpts highlight the significant advantages of AI tools in enhancing students' work and assignments. AI helps to systematically prepare tasks, improve writing quality, and deepen understanding. Tools like QuillBot and Grammarly assist with paraphrasing and rephrasing, promoting originality and reducing plagiarism by offering alternative suggestions. The integration of AI in learning, whether through assignments or lectures, allows students to develop AI readiness and apply it effectively. However, the extent of AI's use may vary depending on the proactivity of lecturers or whether AI integration is mandated institutionally. Overall, AI provides powerful support for students, enabling them to work more efficiently and creatively.
	Information	"Students today have access to vast amounts of information and data, which can greatly enhance their learning if used effectively. Critical thinking is essential to transform this information into meaningful knowledge, as raw data alone does not equate to understanding. Unlike previous generations who relied on books, modern students benefit from free and accessible tools like ChatGPT to find and organize information quickly. However, to maximize these tools, clear instructions and detailed inputs are necessary, as AI cannot interpret intentions without guidance. AI tools act as guides that help streamline the learning process, making it more efficient and enabling students to organize their ideas while fostering deeper learning." (Experts 1 & 3)	These excerpts highlight the abundance of information and data accessible to students today, aided by tools like AI. Critical thinking is essential to transform this information into meaningful knowledge. While previous generations relied on books for learning, modern students can access vast amounts of free content with ease. However, simply having access to data is not enough—details and clear instructions are necessary to optimize the use of AI tools like ChatGPT, which serve as guides rather than replacements for creativity. By helping to organize ideas and quickly find relevant information, AI tools enhance learning outcomes and improve efficiency.

Categories	Factors	Excerpts	Results
	Characteristics	"Critical thinking, planning, and synthesis are essential for transforming raw data into meaningful knowledge, setting students apart in their learning journeys. While AI tools like ChatGPT and Bing AI can guide this process by organizing information and offering suggestions, their effectiveness relies on clear instructions and thoughtful usage, as they cannot operate without user direction. Additionally, it is vital to verify the accuracy of AI-generated content and not blindly trust these tools. Educators play a crucial role in integrating AI into personalized learning, adapting tasks to align with students' unique characteristics while maintaining the human touch in education. Balancing technological advancements with humanity ensures that education focuses on fostering deeper understanding and enriching the learning experience beyond basic knowledge" (Experts 1 & 3)	These excerpts emphasize the importance of critical thinking, planning, and synthesis in transforming information into meaningful knowledge. Previous scholars succeeded due to their ability to think critically, and students today must similarly develop these skills to organize and apply knowledge effectively. Personal characteristics and thoughtful presentation also influence how ideas are perceived. While AI tools like ChatGPT and Bing AI can offer valuable suggestions, users must provide clear details, verify information accuracy, and avoid blindly trusting these tools. From an educator's perspective, AI facilitates personalized learning, but integrating such technologies requires balancing technical advancements with human values, ensuring that education retains its focus on humanity and deeper understanding beyond basic knowledge.
	Curriculum	"Programme Learning Outcomes (PLOs) and Course Learning Outcomes (CLOs) play a crucial role in determining how AI tools influence education. To ensure consistent and effective integration of AI, it is essential for institutions to embed AI within their curriculum at the top level. When PLOs incorporate AI, it naturally aligns CLOs with this integration, fostering a cohesive framework for learning outcomes. Without this embedding, the use of AI tools may remain optional for lecturers, leading to inconsistencies in application. By mandating AI in both PLOs and CLOs, universities can provide clear direction and maximize the benefits of AI for students and educators alike." (Experts 2)	These excerpts emphasize the necessity of aligning Programme Learning Outcomes (PLOs) and Course Learning Outcomes (CLOs) to effectively integrate AI into education. The inclusion of AI within the curriculum at the institutional level ensures that its use is consistent and mandatory, rather than optional for lecturers. By embedding AI into both PLOs and CLOs, universities and faculties can influence learning outcomes in a structured and cohesive manner, promoting readiness and effective application of AI tools in education.

5. Discussion

The proposed AI-powered personalized learning model, embedded within an Enterprise Architecture (EA) framework, represents a significant advancement in how TVET Institutions can approach teaching and learning. This discussion will explore the key aspects of the model, its potential impact, and considerations for future development, all while drawing from the supporting literature.

The model's reliance on an EA framework is crucial. EA provides a structured approach to align IT infrastructure with the strategic objectives of the HEI. By using an EA framework, TVET Institutions can ensure that the implementation of AI is not ad-hoc but rather a part of a coherent institutional strategy. This approach helps institutions manage digital complexity and adapt to digital transformation (DT) effectively. The use of EA

allows TVET Institutions to systematically integrate new technologies such as AI into their operations, ensuring these technologies support institutional goals.

The use of AI also enables real-time adjustments to the learning environment. The model can guide the learning experience. This adaptive nature ensures that students are always presented with the right level of challenge and support, enhancing learning outcomes. The model aims to enhance learning outcomes, student satisfaction, motivation, and engagement. Studies have shown that personalized learning can lead to improved academic performance and a more positive learning experience. By allowing students to learn at their own pace and focus on their interests, the model promotes student independence and achievement. The creation of personalized learning analytics dashboards will help learners and educators monitor progress and identify areas for improvement.

In conclusion, the AI-powered personalized learning model for TVET Institutions within an EA framework offers a promising approach to enhancing education. By embracing AI technologies and focusing on learner diversity, TVET Institutions can create more effective and engaging learning experiences for students. However, the ethical use of AI, the importance of learning theories, and the continuous need for research must be considered to fully realize the model's potential.

Based on the findings discussed above, Figure 5 shows the proposed Conceptual model of AI-powered personalised learning theories. The resulting model will produce a personalized e-learning system that includes personalized user interfaces that can customize each student based on their learning style and preferences. Adaptive learning materials are resources and activities that adjust to each student's level of knowledge and pace of learning. Intelligent Feedback which is timely and tailored feedback to guide students. Also, individualized learning pathways can be customized learning pathways that are adapted based on student interactions. This model represents a significant step toward achieving effective and scalable personalized learning in TVET Institutions. By leveraging AI within an EA framework, the model provides a clear pathway for integrating technology into educational practices, ultimately enhancing the learning experience for all students.

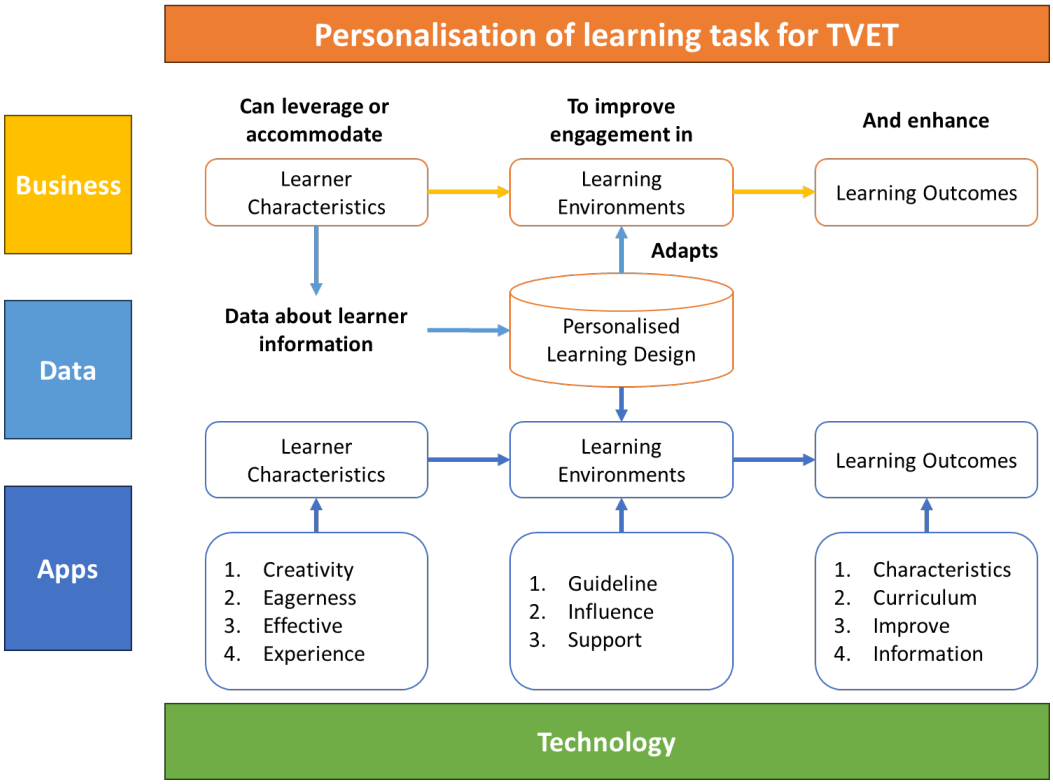

Fig. 5 *AI-powered personalised learning conceptual model*

6. Conclusion

Based on the preceding discussion, the following conclusions can be drawn regarding the implementation of an AI-powered personalised learning model within an EA framework for TVET institutions. The integration of AI-powered personalised learning within an EA framework is crucial for TVET. EA ensures that technology implementations are strategically aligned with institutional goals, promoting a cohesive and efficient approach to digital transformation. Such an approach avoids ad-hoc adoption and ensures that AI initiatives support the broader educational mission of the institution.

The model emphasises the importance of understanding and responding to learners' diversity through AI-driven personalisation. The process involves creating detailed learner models based on individual characteristics such as prior knowledge, learning styles, and preferences. Using machine learning and other AI technologies, TVET institutions can provide customised learning experiences, including adaptive content, personalised learning paths, and intelligent tutoring systems.

AI technologies, including Intelligent Tutoring Systems (ITS), recommender systems, and Natural Language Processing (NLP), are vital in creating engaging and effective learning environments. These technologies can dynamically adapt the learning experience based on real-time feedback, ensuring that students receive the appropriate level of challenge and support and thereby enhancing learning outcomes. The implementation of personalised learning models is expected to improve learning outcomes, student satisfaction, and overall engagement. By allowing students to learn at their own pace and focus on their interests, these models can enhance motivation and a sense of achievement.

The model can enhance its efficacy by addressing gaps in current research and practice. This approach includes focusing on the affective aspects of learning, such as student motivation and emotion, and making explicit use of established learning theories in PL design. Future directions include expanding research to include hands-on learning and blended learning environments and ensuring the ethical use of student data.

AI is transforming higher education by enabling flexible learning experiences, though many students lack the necessary skills to effectively use AI tools. Personalised learning (PL) is an effective approach that allows students to advance at their pace in environments that suit them, align with their preferences. Many students recognise the importance of AI in education. To integrate AI effectively, TVET Institutions should adopt a proactive strategy via EA, a framework that aligns objectives with technology infrastructure.

There remains a need for more empirical studies to establish causal relationships between personalised learning efforts and learning outcomes. Further research should also explore student perspectives on AI tools to better understand how they interact with these technologies. Additionally, more research is necessary to evaluate the impact on critical thinking skills and long-term effectiveness.

In conclusion, the integration of AI-powered personalised learning models within an EA framework offers a promising path for TVET institutions to enhance teaching and learning. By strategically aligning technology with institutional goals, TVET institutions can create more student-centred, effective, and engaging educational experiences. However, to fully realise the potential of these models, there must be continuous attention to ethical considerations, the application of learning theories, and a commitment to ongoing research and improvement.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm their contribution to the paper as follows: ***study conception and design:*** *Surya Sumarni Hussein, Anitawati Mohd Lokman;* ***data collection:*** *Amirul Amin Muhamad Noor;* ***analysis and interpretation of results:*** *Amirul Amin Muhamad Noor;* ***draft manuscript preparation:*** *Surya Sumarni Hussein, Muhammad Wisnu Alfiansyah, Mastura Mustaffa. All authors reviewed the results and approved the final version of the manuscript.*

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