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A framework of personalized learning practice for modern higher education: Towards education 4.0

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Abstract

The Fourth Industrial Revolution has fundamentally transformed higher education by reshaping pedagogical approaches, knowledge acquisition processes, and the pursuit of sustainable educational goals. Outcome-based education has emerged as a dominant paradigm; however, limited research has critically examined how structured outcome-based pedagogy enhances cognitive development and informed decision-making in higher education contexts. This study addresses this gap by investigating the design and implementation of an outcome-based pedagogical framework that predefines learning outcomes aligned with knowledge application and educational decision-making. Using a structured pedagogical design approach, the study explores how clearly articulated outcomes influence teaching strategies and learner engagement. Findings indicate that personalized learning practices embedded within outcome-based pedagogy strengthen learners' cognitive skill development and deepen their understanding of disciplinary knowledge. The results further suggest that intentional alignment between learning outcomes, instructional design, and assessment enhances meaningful learning experiences. This study contributes to contemporary discourse on pedagogical transformation by offering a structured framework that supports sustainable educational development and adaptive learning environments.

Keywords: Cognitive development; higher education; outcome-based education; personalized learning; sustainable education.

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1. INTRODUCTION

Education is diversified as children, primary, secondary, higher secondary, higher, research, and so on, in many different aspects. Internationally, education researchers are seeking dynamic changes to make applicable in higher education, that is, research education, since the world development concept has become possibly true when modernity in higher education emerges. Modern education encourages learners to achieve more learning through knowing unknown facts and applying information to make decisions.

University higher education expediently changed under the shadow of the technological revolution. Adopting modern technology in education plays a pivotal role in upgrading learning and teaching approaches in educational sustainable development. The development pedagogy model approach and utilization of new research for innovative learning have been introduced in the learning ecosystem. This innovative learning in social transformation application and higher education sets a service-learning mission to achieve sustainable development in education discussed (García-Rico et al., 2021). Global sustainability is not possible if education is not included in society's development. Tilbury et al. (2002) employed two terminologies, namely education in sustainable development and education for sustainability, and subsequently classified education into three categories. The first category, formal education, refers to structured learning processes through which individuals develop capacities to think, work, live, and behave within institutional settings. The second category, non-formal education, denotes organized learning activities delivered through organizations and extension agents that provide systematic training opportunities outside conventional academic structures. The third category, informal education, encompasses learning processes accessible to individuals of all ages through media platforms such as television programs, radio broadcasts, and online portals. Education gives quality to a better life, as history tells us that education helps people to feel knowledgeable about life, as explained by Srivastava and Agnihotri (2022).

Outcome-based higher education encourages learners to research and learn in innovative ways. Outcome-based higher education assigns the terms 'teacher' and 'learners' at a granular level to the responsibility and activity for academic purposes. The teacher is most likely to provide guidelines for students towards the learning process and make academic content easier to learn. Besides, the 'learner' has other duties in education that involve learning approaches with relevant information as well, and learners act as an outcome of the study after teachers' learning process, as explained in (Killen, 2007). In another context, technology has reshaped modern education. Contemporary education emphasizes smart technologies with increasingly advanced applications, including precision education, particularly the integration of artificial intelligence in the education sector. Yang et al. (2021) and Liu and Yang (2024) extensively examined artificial intelligence simulation within educational systems in fostering learners' skills and developmental capacities through cognitive processes. Such integration facilitates the attainment of critical computational thinking, enables the identification of students' knowledge levels during the learning process, and supports more independent learning engagement.

Furthermore, modern higher education has begun to accept artificial simulation in experiments and fieldwork implementation. Bates et al. (2020) articulated that AI technology is infiltrating research education, and technology is considered a better opportunity than others to develop educational processes. This provides more access outcomes, information access, reduced time to learn, and material cost. Later, Schiff (2021) mentioned that AI application is technology-driven support for educational assessment and drew more attention to intelligent tutoring systems that reflect smart education outcomes that has large contrast with the traditional education process. The modern educational ecosystem demands dynamic technological approaches, claimed by Ane and Nepa (2021). During the COVID 19 period, smart technologies facilitated remote education among learners without interruption. In the pandemic era worldwide, educators recognized the necessity of innovative and technological integration within the educational ecosystem. The study investigated multiple dimensions of interactive learning patterns in higher education and graphically presented learners' perceptions regarding the ratio of interactive learning and the challenges of smart learning encountered by individual students, with data collected from Bangladesh and Nepal.

Su and Yang (2022) examined artificial intelligence teaching and learning applications and tools for early childhood education, in addition to artificial simulation supporting educational advancement in higher education. A comprehensive synthesis of research instruments and artificial intelligence learning tools implemented on educational platforms was provided, including Zhorai, WeChat, Teachable Machine, PopBots, Cognimates AI platform, and PlushPal. Artificial intelligence exerts a substantial influence on children's education in relation to creativity, self-regulation skills, and computational thinking. Subsequently, He (2023) proposed a distributed intelligent model based on artificial intelligence simulation and machine learning algorithms to ensure data security in educational institutions, thereby preventing unauthorized disclosure of sensitive institutional information while addressing internet related challenges through smart technologies.

1.1. Literature review

Higher education teaching and learning practices are interconnected in fostering sustainable societies through the enhancement of knowledge, skills, understanding, construction, and decision making. Education for sustainable development involves continuous improvement of learning processes to strengthen learners' cognitive capacities. This approach encompasses outcome-based study content, and instructors articulate learning outcomes in alignment with course objectives. Higher education develops well prepared graduates who contribute as decision makers at the national level. Modern learning practices guide learners to rely on developed competencies, and responsibility is assigned for learning, analysis, evaluation, and the advancement of cognitive capacities. Traditional education demonstrates clear evidence of learning in relation to remembering and memorizing capacities, whereas sustainable development in education is emphasized within contemporary higher education. In contrast to traditional education, absence of pedagogical design aligned with learning outcomes is frequently observed. Diverse cases addressed within education 4.0 are shaped by pedagogical learning design. When one pedagogical approach does not effectively support learner development, alternative pedagogical designs are implemented to nurture skill enhancement. In accordance with pedagogical design, education recommends varied learning outcomes to promote personalized learning. The authors examine prior research to classify education, including technological integration, and discuss the influence of pedagogical design in higher education, outcome-based education frameworks, teaching and learning assessment techniques shaping education 4.0, and pedagogical design as an innovative force within teaching and learning systems to achieve sustainable educational management goals.

1.1.1. Education classification

The contemporary world is experiencing rapid and seamless technological transformation across social activities, lifestyle patterns, web environments, agriculture, and education. The central concept of education 4.0 extends learning from foundational stages to advanced levels in order to enable learners to compete in real situations through the application of creative knowledge. A metaphorical perspective is frequently adopted to explain the process of educational development. Internet technology has facilitated access to information from any location. The Internet has evolved from Web 1.0 to Web 4.0. Successive web facilities have created extensive opportunities for users, culminating in Web 4.0. Web 4.0 features introduce intelligent interaction for accessing global information, described as read write execution (Aghaei et al., 2012). Ane and Yasmin (2019) reviewed the Industrial Revolution 4.0 characterized by advanced technology, emphasizing that this technological transformation enhanced educational quality within sustainable development. Advanced technology is closely associated with Web 4.0 and its enriched applications in education. The Industry 4.0 revolution has substantially transformed education management, directing educational progress toward improved future-oriented systems. Education 4.0 requires adaptation to new expertise, management instruments, questionnaires, innovative leadership, and problem solving in authentic contexts (Cope and Kalantzis, 2019), while recognizing education 1.0 as an earlier stage in which educational artifacts evolved alongside technological shifts during the industrial revolution.

The technological revolution has influenced education since the introduction of computers into classrooms. Students access online materials and assessments, observe instructional videos, obtain knowledge resources, and complete academic tasks through digital devices. Education 1.0 is distinctly differentiated from education 2.0. Students employ Web 2.0 technologies and develop expertise through engagement with blogs and messenger-based study groups. Education 3.0 promotes open and flexible learning activities, fostering strong learner engagement and ownership of educational processes (Keats and Schmidt, 2007). This stage incorporates social networking across course content, enabling knowledge sharing among student communities through Web 3.0 features. The authors establish a conceptual linkage between industry, technology, and education, followed by educational classification. Education 1.0 reflects a traditional chalk and board approach in which instruction is teacher centered with minimal interaction. Education 2.0 enables internet access facilitated by Web 2.0 during the industrial revolution. Education 3.0 adopts online based electronic learning models for distance learners and researchers. Education 4.0 represents comprehensive integration of advanced technology, enabling knowledge sharing between teachers and learners with technological support.

Keser and Semerci (2019) proposed that education 4.0 reflects the industrial revolution and that the concepts of smart, digital, and network have significantly transformed educational standards. Education 4.0 demonstrates strong alignment with smart technologies, and advanced technologies are anticipated throughout educational environments. Hussin (2018) further discussed emerging trends in education 4.0, including learning from any location at any time, learner choice, personalized learning, and project-based learning. Ane et al. (2020) reviewed and explained that smart teaching methods constitute the foundation of education 4.0, emphasizing classroom environments in which objects are connected to internet accessibility and knowledge sharing is facilitated. The survey findings indicated a learner preference for smart devices and intelligent approaches rather than traditional methods, thereby encouraging self-directed learning through personalized learning techniques.

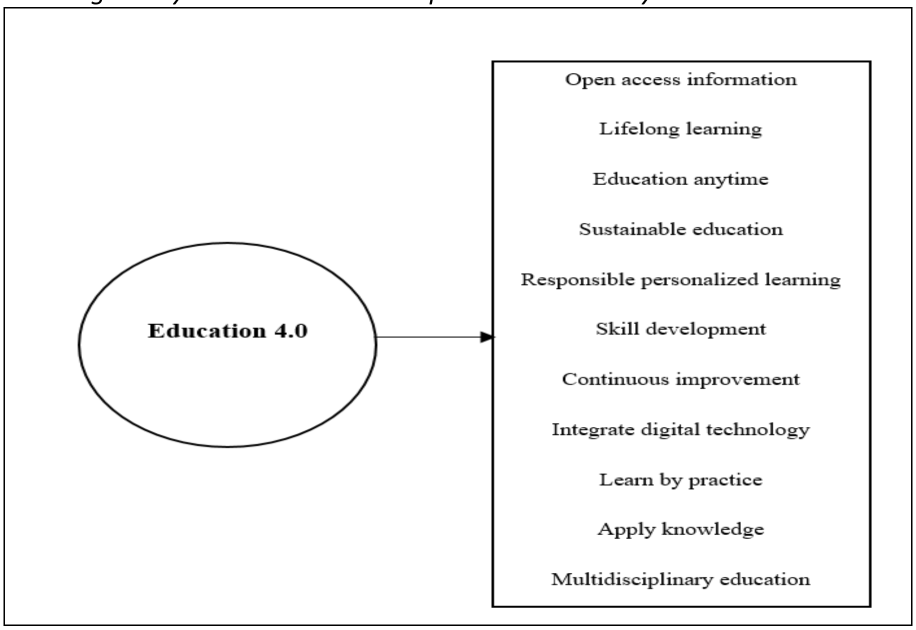
1.1.2. Personalized learning design in education4.0

Personalized learning pedagogy has transformed instructional practice and pedagogical style. Students acquire meaningful knowledge that can be applied beyond formal education (Ali et al., 2025). Over time, education 4.0 encounters challenges, enhances educational facilities, and strengthens education management systems. The labor market demands graduates possessing advanced soft skills and practical work experience. Consequently, education 4.0 requires continuous revision of pedagogical approaches to learning. Yusuf et al. (2022) conducted a literature review on pedagogical classification practices and the effective implementation of pedagogical strategies within education 4.0, identifying design factors related to soft skills development, curriculum structure, learning modules, assessment strategies, and classroom experience. Education 4.0 pedagogical practice has progressed beyond version 1.0, which emphasized remembering and memorizing through reading and writing exercises. Education 4.0 has established pedagogical models aligned with technological advancement, incorporating smart technologies, artificial intelligence, big data, virtual reality, augmented reality, and robotics (Ogodapola, 2023).

A personalized learning framework provides opportunities for learners to engage with emerging technologies in response to global educational transformation (Huang et al., 2025). Contemporary learning design not only restructures the overall education system but also strengthens technological literacy related to knowledge application, evaluative capacity, and constructive idea generation. Digital pedagogy and outcome-based learning have facilitated the transition from education 1.0 to education 4.0. Chigbu et al. (2023) emphasized education 4.0 as a pedagogy-based learning design that enhances learner assessment through personalized learning. Patiño et al. (2023) indicated that pedagogical practice within education 4.0 has evolved from static and unsustainable learning outcomes toward dynamic and sustainable outcomes supported by active learning, thereby characterizing innovative educational learning outcomes.

Figure 1

Education 4.0: learning ability and educational scope in the university



Education 4.0 integrates advanced technology with pedagogical design to ensure innovative instruction for students. Figure 1 illustrates pedagogical learning materials supporting personalized learning within the framework of education 4.0. University level higher education adopts personalized learning approaches that guide instructors in fostering analytical thinking, justification, evaluation, and creativity. In addition, instructional focus is directed toward learner weaknesses identified through performance outcomes. Personalized learning eliminates monotonous teaching and learning practices such as conventional question and answer methods. Advanced university study proposes curriculum oriented pedagogical design to enhance both instructional effectiveness and learner performance.

Education 4.0 is structured through multiple progressive stages of personalized teaching and learning practice. Within a sustainable education policy framework, responsibility for learning is emphasized. Education functions as a reciprocal communication process between instructors and learners. Education 4.0 encourages application of acquired knowledge and skills in practical contexts. Once developed, skills are continuously refined throughout the lifespan, as a sustainable world requires appropriate education facilitated through education 4.0 infrastructures. Instruction extends beyond theoretical questioning and promotes multidisciplinary engagement with education and independent learning practice.

1.1.3. Outcome-based learning framework

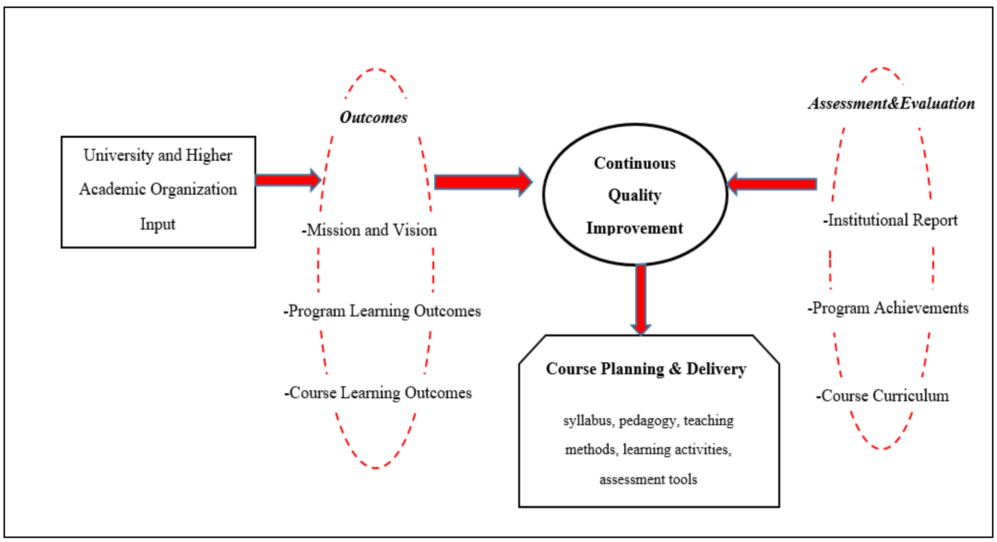
Education 4.0 technology consistently supports personalized teaching and learning frameworks and incorporates outcome-based learning standards. Predictive education systems utilize computer aided models to facilitate nonverbal, face-to-face interaction with academic agents in classroom settings. Higher education emphasizes these opportunities for distance laboratory work and practical exercises. In domains such as artificial intelligence, AI simulation, programming, and other science or engineering research, educational practices align with education 4.0 principles due to the effectiveness of outcome based learning and timely application. Zawacki-Richter et al. (2019) reviewed AI and adaptive learning technologies in higher education, highlighting their pedagogical impact on teaching and learning assessment. Ane and Nepa (2024) indicated that AI drives automation within the teaching and learning ecosystem. Traditional educational systems are increasingly adapting expert technologies to achieve meaningful change in higher education. Outcome based and personalized learning have advanced higher education on a broad scale.

Petersen and Batchelor (2019) projected that by 2027, robotic technologies will conduct assessments in educational settings. Outcome based learning enhances complex learning opportunities, and educators are required to adopt modern educational technologies to improve learner performance under education 4.0 frameworks. The socio-economic context of education is influenced by outcome based pedagogical approaches as proposed by Domínguez Figaredo (2020). Pedagogical practices emphasize alignment between learning outcomes and technological education policies oriented toward education 4.0. Outcome based learning ensures that learner achievements correspond with instructional objectives. Higher education institutions are encouraged to adopt outcome-based education frameworks (OBE), with Figure 2 illustrating the OBE structure for outcomes and assessment.

Pedagogical design in higher education incorporates the OBE framework to guide teaching and learning practices. Educators are expected to follow this framework throughout the process of course design and content delivery. Universities and higher academic institutions establish mission and vision outcomes for academic curricula, maintaining continuous improvement cycles between learning outcomes, assessment, and evaluation. Program and course learning outcomes are developed to correspond with learners' academic performance, and course planning and delivery activities are refined to achieve targeted program and course learning outcomes.

Figure 2

OBE framework with outcomes and assessment tools



1.1.4. OBE and Pedagogy design for higher education

Universities and higher education institutions are significantly influenced by the design and mapping of courses to program learning outcomes. Course learning outcomes (CLOs) are systematically aligned with program learning outcomes (PLOs). CLOs establish specific objectives guided by Bloom's taxonomy, including remembering, understanding, applying, analyzing, evaluating, and creating. PLOs represent the overall learning achievements attained by students. Learners progress through courses based on continuous summative assessment. Instructors design course outlines mapped to program-based outcomes as defined by Bloom's taxonomy. For instance, the skill of remembering is linked to selected program outcomes, with certain outcomes verified and others cross checked for alignment. Similarly, the development of creativity is associated with program learning outcomes PLO2, PLO4, and PLO9. PLO goals are established by higher education authorities. Figure 3 illustrates the mapping of course learning outcomes to program learning outcomes..

Figure 3

CLO mapping PLO in OBE design for education4.0

Course Learning Outcomes (CLO)	Program Learning Outcome (PLO)									
	PLO 1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10
CLO1 -Remember				x					x	
CLO2 -Understand	x					x				
CLO3 -Apply			x				x		x	
CLO4 -Analyze	x					x			x	
CLO5 -Evaluate		x			x					
CLO6 -Create		x		x					x	

1.1.5. Assessment strategy and technique in education4.0

Universities implement outcome-based education in advanced courses and research programs to support personalized skill development for learners. Outcome based education establishes higher study objectives guiding the teaching and learning process. This approach emphasizes instructional strategies through systematic assessment and evaluation procedures. As learners adapt to emerging learning opportunities, instructors are equipped to modify teaching methods in alignment with updated course curricula. Learners participate in both continuous and summative assessments. Continuous assessments are conducted weekly or monthly to monitor progress in relation to class content, including quizzes, class tests, group discussions, presentations, homework, and collaborative assignments. Summative assessments occur at the end of academic terms or annually.

Learners record lesson notes during lectures and key instructional sessions. Instructional practices may involve direct and indirect methods. Direct methods occur when learners pose questions to instructors to acquire knowledge, whereas indirect methods involve assignments, problem solving, and independent exploration. Learners engage in project work to enhance practical skills, conduct company visits, and analyze case studies, representing indirect learning models. Figure 4 presents an overview of teaching and learning strategies along with corresponding assessment techniques.

Figure 4

Assessment strategy and technique in education 4.0

Teaching learning strategy	Assessment Technique
Class Lecture	Quizzes
Laboratory Demonstration	Practical Exam
Supervision	Assignments
Question/ answer	Theory Exams
Case Report Analysis	Practical Group Work
Group Discussion	Class Presentation
	viva

1.2. Purpose of study

This study provides a synthesis of data driven educational assessments and applications capable of transforming traditional education into modern education, referred to as education 4.0. The higher education system is required to adopt smart and innovative instructional approaches to enhance learners' cognitive skills. A novel and innovative paradigm is recommended for implementation by instructors and learners, particularly within research and higher education contexts. This paper proposes pedagogical learning strategies applicable to higher education. The principal contribution of the study lies in articulating learning approaches that support personalized learning development. Experimental research is designed based on an outcome-based learning framework to guide educational institutions, enabling both instructors and learners to apply acquired knowledge in decision making and to construct advanced levels of knowledge in authentic scenarios.

2. METHODS AND MATERIALS

2.1. Experiment configuration and discussion

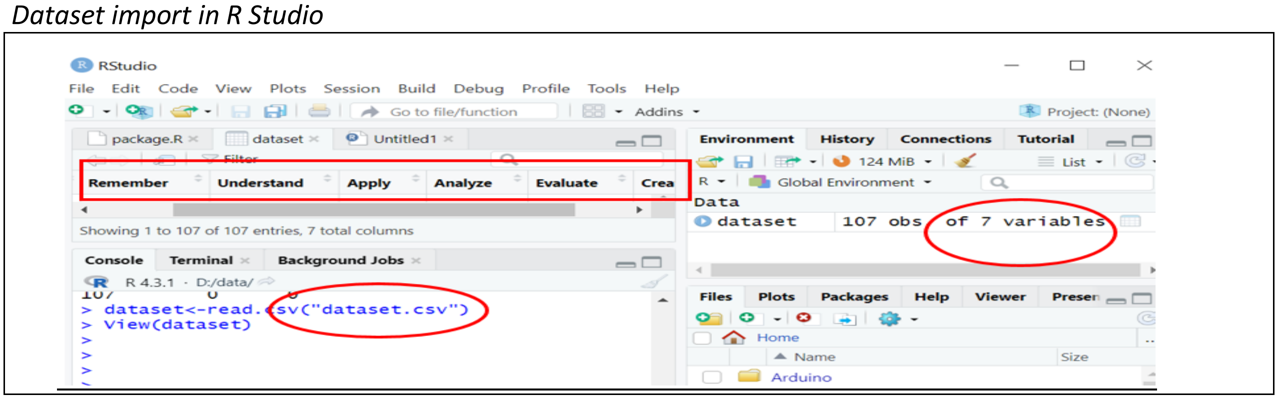
This research study examines higher education learners' data to evaluate performance. Dataset prepared with the OBE-based learning outcome. Higher education learning outcomes are set as pedagogy instruction in the curriculum and justify learners' knowledge improvement, including cognitive skills. R programming is designed for research models and model results, learning skill progress, and those who are strictly following the pedagogy design in the curriculum. R Studio was freely accessed and downloaded from cran project, and R-4.3.1 latest version of R IDE programming applied for experimental work.

2.2. Dataset design

A specific dataset was constructed for the model. Results from the implementation of pedagogical learning were recorded for learners who completed summative assessments at the end of the term. Cognitive skill development was more pronounced compared with learner performance at the initial term. The dataset comprised seven variables corresponding to Bloom's taxonomy classifications, including remembering, understanding, applying, analyzing, evaluating, and creating, along with primary indexing. Each learner's performance was assigned a unique primary identifier to ensure individual data integrity. Registration numbers functioned as auto incremented IDs. Initially, the dataset was imported into R Studio, with the read dataset command enabling display of all data within the environment panel. Figure 5 illustrates the dataset import procedure and its variables. Term results were collected from 120 learners, and after revision, 107 sample sets were finalized for the experimental model. Outcome based education and pedagogy-driven teaching and learning strategies modified instructional approaches through continuous quality improvement, resulting in learner progression toward higher-order cognitive skills, namely applying, analyzing, evaluating, and creating, rather than solely understanding and remembering. Final term results reflected the effectiveness of pedagogical approaches in developing higher cognitive skills as measured by assessments. For comparison with traditional educational methods, pretest assessment data were also collected for the same learners. All datasets were provided in CSV format for R code data import.

Figure 5

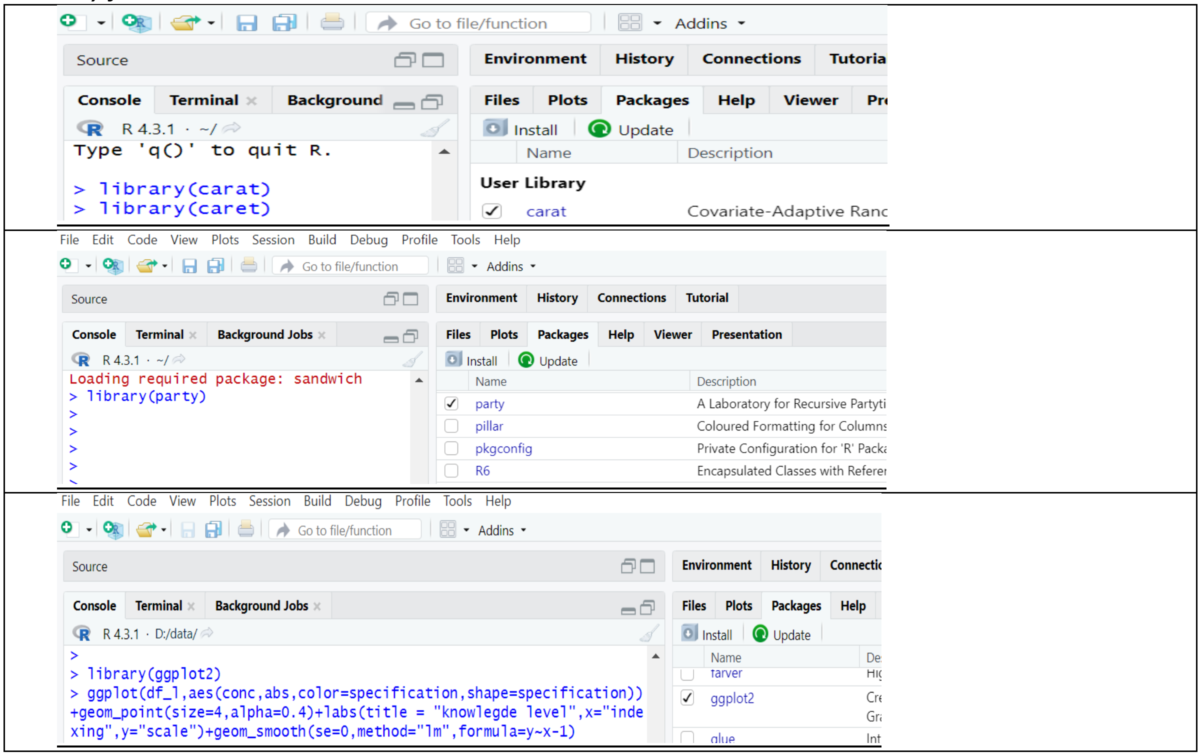
Dataset import in R Studio



The R Studio integrated development environment requires the attachment of specific library files to execute programming tasks. Libraries provide access to R features and resources necessary for data analysis. For the experimental tasks, several libraries were installed. Initial library commands returned FALSE in the R console when packages were not yet installed. Successful installation of library packages is indicated by TRUE results. In the experiment, the libraries, caret, party, and ggplot2 were utilized to support data analysis and visualization of results. Figure 6 presents a graphical representation of the library files displayed in the package console.

Figure 6

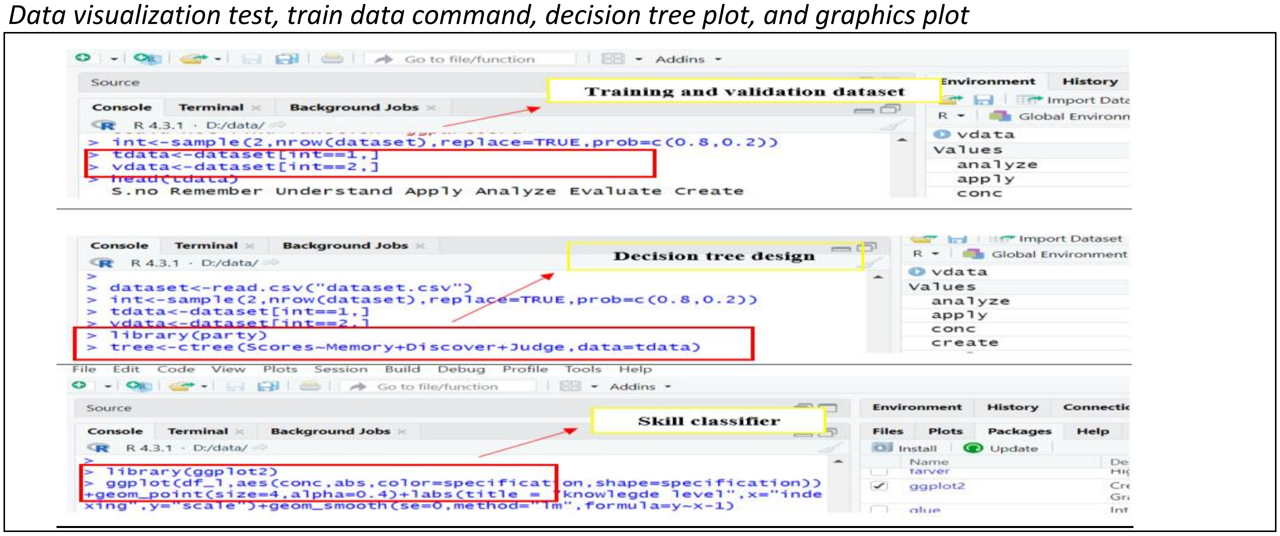
Library files are installed



The dataset was divided into two subsets: training and testing datasets. Training and testing datasets play a critical role in model development and evaluation. The training dataset is used to build and optimize the model, which subsequently functions as a predictor when applied to the testing dataset. In the programming process, variables were defined using the tdata() and vdata() functions to assess model performance, as illustrated in Figure 7. Experimental results were visualized through a decision tree. Decision trees organize dataset values into root and leaf nodes, categorizing data based on similarity and dissimilarity. The tree() function was implemented to plot the decision tree, representing the second phase of analysis shown in Figure 7. To display graphical outputs and model structure, the ggplot() function was employed, depicting the final phase of the experiment.

Figure 7

Data visualization test, train data command, decision tree plot, and graphics plot



Ethical Considerations

This study complies with internationally accepted ethical standards for research involving human participants. The dataset was derived from academic performance records collected within a higher education context. All data were fully anonymized before analysis, and no personal identifiers were retained. The study utilized secondary data obtained from institutional educational processes; therefore, no direct interaction with participants was required. The use of the data for research purposes was permitted within institutional regulations, and all procedures ensured the confidentiality, privacy, and protection of participants. The findings are reported in aggregate form to prevent identification of individuals.

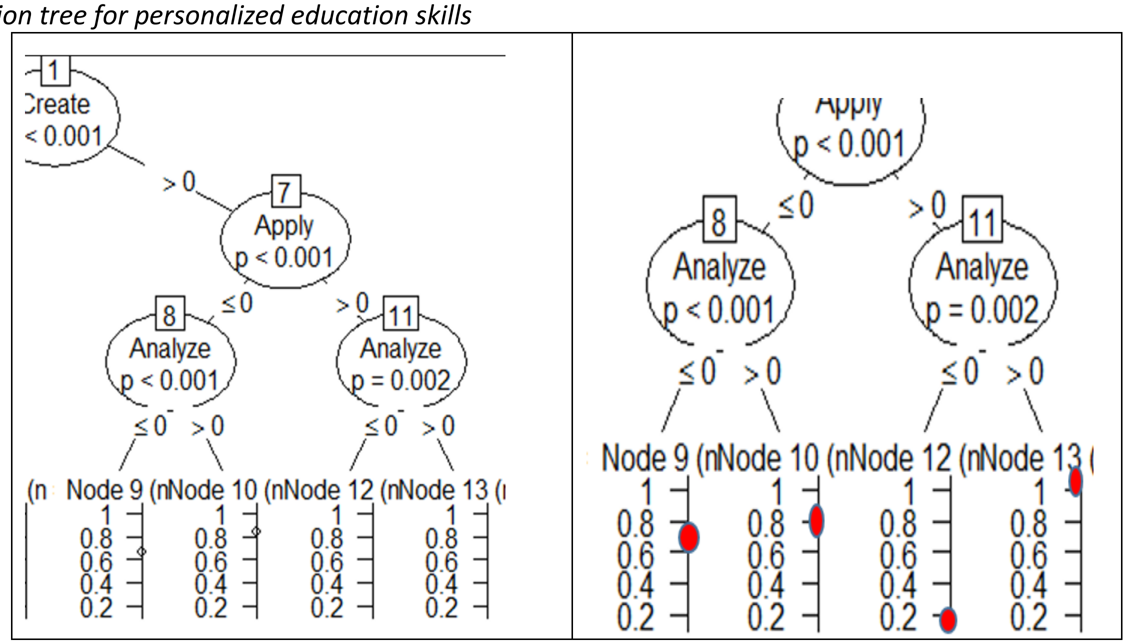
3. RESULTS

Advanced higher education emphasizes personalized skill development within the framework of education 4.0. Outcome based education design is maintained to monitor and trace cognitive skill improvements among learners. Learners are expected to progressively develop cognitive skills guided by instructors through pedagogical learning design embedded in the curriculum. Programming model results provide measurable indicators of personalized learning progress. Instructors facilitate gradual skill development, while learners may exhibit challenges in acquiring or applying knowledge for decision making. The decision tree generated from the programming model, presented in the result summary, enables both instructors and learners to identify personalized learning progress and detect skill gaps within the educational system. This process increases awareness of specific skill areas necessary to achieve expected learning outcomes.

Education 4.0 incorporates unique mechanisms for fostering personalized education skills. Cognitive skills are categorized according to Bloom's six classifications: remembering, understanding, applying, analyzing, evaluating, and creating. Figure 8 illustrates cognitive skill development derived from learners' anticipated performance using a decision tree visualization. Consequently, education 4.0 enhances educational quality by transparently revealing cognitive skill gaps, providing actionable insights for both instructors and learners.

Figure 8

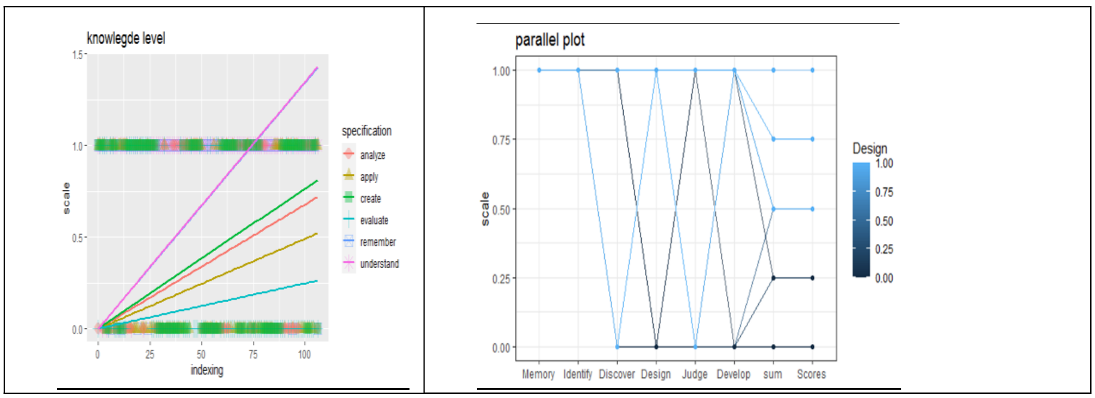
Decision tree for personalized education skills



In the decision tree plot, the "create" skill represents a higher-order cognitive ability according to Bloom's taxonomy. Learners must progress through the "apply" and "analyze" skill levels before reaching the "create" stage. Full knowledge acquisition is achieved when learners complete all learning stages from "remember" to "create." In the presented figure, nodes 9, 10, 12, and 13 were selected and programmed in R, with scaling values representing cognitive skill levels. The "analyze" skill corresponds to the leaf nodes. For node 9, learners achieved an average scale value of 0.6, indicating moderate development in "analyze" knowledge. Node 10 reflects near complete knowledge acquisition in "analyze," with a scale value of 0.8, while a scale value of 1 indicates full mastery. Node 12 represents an initial stage of "analyze" knowledge, with a low scale value of 0.2, suggesting that pedagogical design may need adjustment, increased instructional focus, or targeted assessment interventions. Node 13 demonstrates strong skill development in "analyze," with a scale value approaching 1, indicating effective pedagogical strategies and learner readiness to apply "analyze" knowledge acquired from course materials. Figure 9 illustrates the grammar of the graphical plot for the experimental design.

Figure 9

Grammer of graphics plot for knowledge scaling values



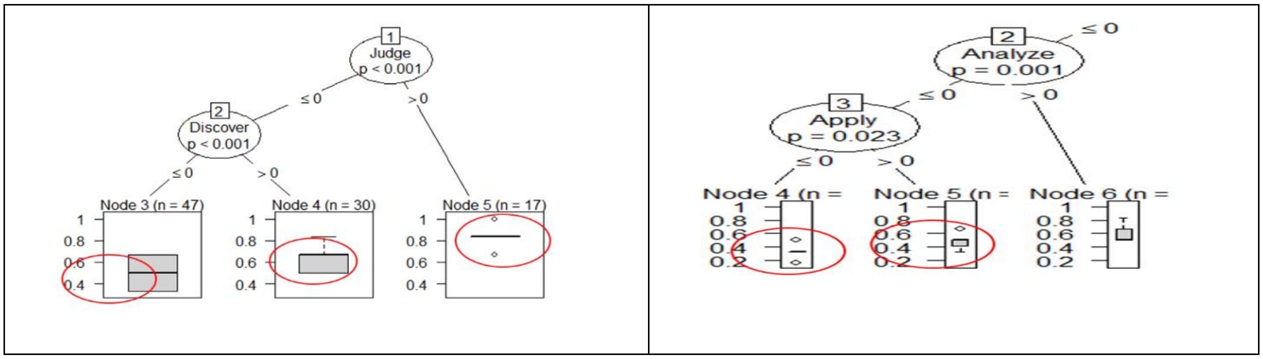
Modern higher education strictly copies OBE and pedagogy learning methods that provide personalized learning. Teachers evaluate teaching strategies to guide learners to meet the knowledge gap, while learners not only learn, but also apply learned knowledge in practical work. Modern education 4.0 applied pedagogy learning outcomes and developed higher-level cognitive skills, including large-scale values.

Traditional education still lags behind the smart education ecosystem. Learners learn knowledge, but application skill development is not defined by learner performance. Skill development progress is not updated, and tracing learners' skill gaps is quite impossible to guide. The modern education system has created learner opportunities for learners to develop different levels of cognitive skills, such as the discovery of new concepts, and professional skills for judgment. Contrary to traditional education, learners have very low cognitive skill development in the application, case analysis, and innovation of new ideas (Figure 10).

Figure 10

Contrast between education4.0 and traditional learning approaches in higher education

Modern education 4.0outcome	Traditional education outcome



4. DISCUSSION

The results of this study reinforce the transformative role of Education 4.0 in higher education, highlighting the integration of outcome-based education (OBE) and personalized pedagogical design as key mechanisms for enhancing cognitive skill development. The decision tree analysis of learners' cognitive skills, as shown in Figures 8 and 9, illustrates that higher-order skills such as "analyze" and "create" are achieved progressively when learners engage with well-structured pedagogical frameworks. These findings corroborate earlier studies by Killen (2007) and Zawacki-Richter et al. (2019), who emphasized that learner-centered approaches and adaptive technologies facilitate active engagement and measurable skill acquisition. Similarly, the gradual progression observed from "remember" to "create" aligns with Bloom's taxonomy, confirming that systematic scaffolding within Education 4.0 fosters comprehensive learning outcomes, consistent with the pedagogical models described by Patiño et al. (2023) and Chigbu et al. (2023).

Our findings also align with García-Rico et al. (2021) and Tilbury et al. (2002), who argued that sustainable education requires continuous innovation in teaching and learning processes. The implementation of AI-driven and technology-enhanced learning tools, as identified in this study, supports learners' autonomous engagement and real-time assessment, echoing the conclusions of Yang et al. (2021), Liu and Yang (2024), and Schiff (2021). Specifically, the ability to track skill gaps through the decision tree allows instructors to intervene strategically, enhancing learner readiness and practical application, which is consistent with Bates et al.'s (2020) assertion regarding the benefits of AI integration in higher education.

When contrasted with traditional educational approaches, our study highlights significant differences. Education 4.0 emphasizes applied learning, professional judgment, and innovation, whereas traditional education remains focused on memorization and knowledge recall, with limited capacity to trace or address skill gaps. These results resonate with the observations of Srivastava and Agnihotri (2022) and Killen (2007), who noted that traditional pedagogical methods often fail to develop higher-order cognitive skills or support learner autonomy. In particular, learners in traditional settings demonstrate lower proficiency in "apply," "analyze," and "create" levels of Bloom's taxonomy, whereas Education 4.0 approaches facilitate measurable improvement in these domains (Figures 8–10).

However, some nuances emerged in comparison to prior studies. While our results indicate strong skill progression using AI-supported OBE frameworks, He (2023) highlighted potential barriers related to digital security and access, suggesting that technology integration must consider infrastructural and policy challenges. Similarly, Yusuf et al. (2022) noted that pedagogical strategy effectiveness depends on curriculum alignment and soft skills integration; our study confirms this by showing that learners with lower initial "analyze" skill scores (node 12, Figure 9) require targeted instructional adjustments to achieve optimal outcomes.

Overall, the findings corroborate the growing consensus that Education 4.0, through the combination of personalized learning, OBE frameworks, and AI-supported assessment, significantly enhances cognitive skill development compared to traditional methods. The study reinforces the importance of continuous pedagogical innovation and real-time feedback mechanisms, demonstrating that modern higher education can achieve both skill mastery and practical application, a goal that traditional education struggles to accomplish. These results underscore the critical role of smart technologies and outcome-aligned pedagogical design in preparing learners for complex, real-world decision-making and lifelong learning.

5. CONCLUSION

This research investigated personalized learning practices in higher education within the context of education 4.0. Globalization and digitalization have created a demand for modern educational approaches capable of enabling learners to engage in self-directed learning and to solve complex problems. Findings indicate that traditional education is limited in addressing learners' interests and aligning with global learning preferences.

The study demonstrates that personalized learning approaches yield superior educational outcomes compared with traditional learning methods. This approach mitigates monotonous and conventional instructional practices while providing outcome-based, practical learning experiences. Consequently, outcome-based learning content is more relevant, engaging, applicable, and constructive.

Learners at the university level reported satisfaction with the pedagogical curriculum design and personalized learning initiatives. Study limitations include the application of only six cognitive classifiers and a focus on higher education institutions. Future research will expand the scope to incorporate additional classifiers within creative theory and examine implementation across broader national education systems.

Conflict of Interest: The authors declare no conflict of interest.

Ethical Approval: The study adheres to the ethical guidelines for conducting research.

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