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MONITORING THE QUALITY OF STUDENT LEARNING IN VOCATIONAL EDUCATION BASED ON ARTIFICIAL INTELLIGENCE TECHNOLOGIES

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Abstract. The rapid development of artificial intelligence (AI) is transforming vocational education by creating new opportunities for monitoring, assessing, and improving students' learning outcomes. Traditional assessment systems often focus on final examination results and provide limited information about the dynamics of students' learning, practical competencies, individual difficulties, and learning trajectories. This article examines the pedagogical possibilities of using artificial intelligence technologies to monitor the quality of student learning in vocational education. The study analyzes AI-supported diagnostic assessment, learning analytics, adaptive assessment, automated feedback, predictive analytics, digital portfolios, and competency-based monitoring. A conceptual AI-based monitoring model is proposed, consisting of five interconnected stages: initial diagnosis, continuous data collection, AI-based analysis, personalized pedagogical intervention, and repeated assessment. The article argues that AI can support teachers in identifying learning gaps at an early stage, personalizing educational tasks, monitoring competency development, and making evidence-based pedagogical decisions. At the same time, effective implementation requires attention to data privacy, algorithmic bias, transparency, teacher digital competence, and human oversight. The proposed model can contribute to the development of a continuous, data-driven quality management system in vocational education.
Keywords: artificial intelligence, vocational education, learning quality, learning analytics, AI-based assessment, digital monitoring, adaptive learning, competency-based education, personalized learning, predictive analytics, automated feedback, TVET.

Introduction. Technical and Vocational Education and Training (TVET) plays an important role in preparing learners for rapidly changing labour markets. Digital transformation, automation, artificial intelligence, robotics, and intelligent production systems are changing occupational requirements and creating demand for new combinations of technical, digital, cognitive, and problem-solving competencies. In this context, improving the quality of vocational education requires not only modernization of curricula and teaching methods but also the development of effective systems for monitoring students' learning progress. Conventional assessment approaches generally emphasize periodic tests, examinations, grades, and teacher observations. Although these instruments remain important, they may not provide sufficiently detailed information about how students learn, which competencies are developing successfully, where difficulties emerge, and what type of pedagogical intervention is required. Artificial intelligence provides opportunities to transform this situation. AI-based systems can process large amounts of educational data, identify patterns in learner behaviour, detect learning difficulties, generate feedback, recommend learning resources, and support

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individualized learning pathways. UNESCO has identified personalized learning through big data and AI-supported educational systems as one of the strategic directions for modernizing TVET. Such systems can create learner profiles, monitor progress, and support adjustments to educational provision. At the same time, UNESCO's recent practical guidance for TVET institutions emphasizes that AI integration should cover not only teaching and learning but also assessment, competency development, monitoring and evaluation, while maintaining human agency, equity, safety, and responsible governance. Therefore, the development of an AI-based system for monitoring the quality of student learning represents an important direction for improving the management of vocational education. The central research problem is the insufficient integration of continuous learning monitoring, competency assessment, educational analytics, and personalized pedagogical intervention within a single vocational education management system. The objective of this study is to develop a conceptual methodology for monitoring and managing the quality of student learning in vocational education using artificial intelligence technologies.

Literature Review. The development of AI in education has generated new possibilities for continuous assessment and personalized learning. UNESCO emphasizes that learning assessment should provide information not only about what learners know but also about what they can do with their knowledge and how different factors influence learning outcomes. Earlier approaches to AI-supported assessment focused primarily on automated testing and examination technologies. However, contemporary AI systems increasingly support continuous monitoring, targeted feedback, adaptive learning, and analysis of learning behaviour. UNESCO's guidance on AI and education has discussed the possibility of AI-enabled continuous assessment in which learner progress can be monitored over time and feedback can be targeted according to identified learning needs. In the context of TVET, AI has particular significance because vocational learning involves both theoretical knowledge and practical competencies. A learner may achieve a satisfactory score on a theoretical examination while experiencing difficulties in performing practical tasks. Consequently, an effective monitoring system should combine cognitive, practical, behavioural, and digital indicators. Recent UNESCO-UNEVOC initiatives indicate that AI is increasingly being integrated into TVET curricula and learning environments. The content-integrated AI learning model, for example, is designed to integrate AI into existing vocational programmes so that learners develop competencies for an AI-driven economy.

UNESCO-UNEVOC materials also identify AI, adaptive learning platforms, virtual reality, intelligent tutoring systems, automated assessment feedback, and progress tracking as important technologies for transforming TVET.

The literature suggests several major directions for AI application in vocational education: automated and adaptive assessment, learning analytics, individualized learning pathways, intelligent tutoring systems, predictive identification of learning difficulties, automated feedback, competency tracking, digital portfolio analysis, simulation-based assessment. However, technological implementation alone does not guarantee educational improvement. Recent UNESCO guidance stresses the importance of responsible AI governance, human agency, equity, safety, and awareness of AI limitations. Thus, the research gap can be formulated as follows: although AI technologies are increasingly discussed in relation to vocational education, there remains a need for integrated pedagogical models that connect continuous monitoring, AI-based analysis, competency assessment, personalized intervention, and repeated assessment within one quality-management cycle.

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Discussion. The findings of the study indicate that artificial intelligence technologies can significantly expand the methodological possibilities for monitoring the quality of student learning in vocational education. Unlike traditional assessment models, which frequently concentrate on periodic examinations and final grades, AI-supported monitoring makes it possible to collect and analyze learning evidence continuously. This creates conditions for shifting from predominantly summative assessment toward a more dynamic system of diagnosis, feedback, intervention, and reassessment. One of the most important findings is that AI-based monitoring can provide a more comprehensive representation of students' learning quality. In vocational education, learning outcomes cannot be adequately measured through theoretical knowledge alone. Professional competence also includes practical accuracy, independence, problem-solving ability, occupational safety, digital competence, communication, and the ability to apply theoretical knowledge in real or simulated professional situations. Therefore, an AI-supported monitoring system should integrate different sources of evidence rather than rely on a single test score. This finding is consistent with recent UNESCO approaches to TVET digital transformation. UNESCO identifies personalized learning through big data, AI-supported learner profiles, and data-informed educational decision-making as important opportunities for modernizing vocational education.

AI-Based Monitoring and Personalized Learning. A particularly important pedagogical implication concerns personalization. Students entering vocational education have different levels of prior knowledge, practical experience, learning speed, and digital competence. A uniform instructional and assessment strategy may therefore produce different results for different learners. AI-based monitoring can help identify these differences by continuously analyzing students' performance. For example, a learner who demonstrates strong theoretical knowledge but repeatedly makes errors during practical tasks may require additional simulation-based training rather than additional theoretical instruction. Conversely, a learner who performs practical procedures successfully but demonstrates insufficient conceptual understanding may benefit from targeted theoretical activities.

Thus, AI can contribute to the development of individualized learning trajectories:

Diagnosis → Learner Profile → Personalized Task → Monitoring → Feedback → Intervention → Reassessment.

Such a model changes the function of assessment. Assessment becomes not only a mechanism for determining achievement but also a mechanism for improving learning. UNESCO-UNEVOC has reported the use of adaptive learning platforms, intelligent tutoring systems, automated assessment feedback, and progress tracking as emerging opportunities for personalized TVET learning.

Continuous Monitoring versus Periodic Assessment. The findings also demonstrate an important distinction between periodic assessment and continuous AI-supported monitoring.

In a traditional model, the learning process can be represented as:

Teaching → Test → Grade.

In an AI-supported model, the process becomes:

Diagnosis → Learning Activity → Data Collection → AI Analysis → Feedback → Pedagogical Intervention → Reassessment.

The second model provides information about learning dynamics rather than only final achievement. This is particularly important when students experience temporary difficulties, gradual improvement, or declining performance. For example, a student may obtain an acceptable final examination score but demonstrate a gradual decline in learning activity during the preceding weeks. Continuous

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monitoring can identify such a pattern earlier and enable the teacher to investigate the underlying causes. Consequently, the pedagogical value of AI monitoring lies not simply in predicting performance but in providing timely information for intervention.

AI and Practical Competence Assessment. An important issue in vocational education is the assessment of practical competence. Traditional computer-based testing is particularly limited when the intended learning outcome involves performing a professional task. AI technologies can potentially extend assessment beyond conventional multiple-choice testing. Simulations, digital portfolios, interactive practical tasks, computer vision, and intelligent tutoring systems can provide additional evidence about students' practical performance. For example, in automotive training, an AI-supported simulation may record whether the learner correctly follows diagnostic procedures, identifies a fault, selects an appropriate tool, and completes the task within a reasonable period. In electrical training, the system may analyze the sequence of operations and identify deviations from the prescribed procedure. However, AI-generated assessments of practical skills should not automatically replace expert observation. Professional competence often involves contextual judgement, safety considerations, communication, and decision-making that may be difficult to capture through automated indicators. Therefore, the most appropriate approach is a hybrid assessment model in which AI provides analytical evidence while teachers and vocational experts retain responsibility for professional judgement.

Learning Analytics and Evidence-Based Pedagogical Decisions. Another important finding concerns the role of learning analytics. The collection of educational data has limited value if the data are not transformed into meaningful pedagogical decisions.

The proposed model therefore emphasizes the sequence:

Data → Analysis → Interpretation → Decision → Intervention → New Data.

AI can identify patterns such as repeated errors, declining performance, incomplete assignments, excessive response time, or differences between theoretical and practical performance. The teacher can then interpret these patterns and determine an appropriate intervention. This approach can also support institutional quality management. Aggregated data may reveal that a large proportion of students experience difficulties with a particular module, competency, or practical procedure. Such information may indicate the need to revise instructional materials, practical assignments, assessment criteria, or curriculum content. UNESCO's recent practical guide for TVET institutions recommends an institution-wide approach to AI that includes pedagogy, assessment, competency development, monitoring and evaluation, while emphasizing educational purpose, human agency, equity, and safety.

The Role of the Teacher in AI-Based Monitoring. The findings do not support the replacement of teachers by AI. Instead, they indicate a transformation of the teacher's role. In a traditional assessment environment, teachers may spend substantial time collecting, organizing, and calculating student performance data. AI can automate some of these routine analytical processes. This can allow teachers to devote more attention to interpreting results, providing individualized support, designing practical activities, and developing students' professional competencies. UNESCO-UNEVOC has documented initiatives in which AI-supported digital platforms and programmed chatbots are used to reduce trainer workload and provide learners with additional support. Accordingly, the teacher should be viewed as a professional decision-maker supported by AI, rather than as a passive recipient of automated recommendations.

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Ethical and Organizational Challenges. Despite the identified opportunities, the implementation of AI-based monitoring creates several important challenges.

First, student data privacy must be protected. AI monitoring systems may process large amounts of information about students' learning behaviour, performance, and individual characteristics. Institutions therefore need clear rules concerning data collection, storage, access, and use.

Second, algorithmic bias represents a potential risk. If an AI system is trained on incomplete or unrepresentative data, its recommendations may disadvantage certain groups of learners. UNESCO-UNEVOC has specifically highlighted algorithmic bias, data privacy, infrastructure limitations, and unequal access as challenges associated with AI-enabled TVET. Third, AI-generated recommendations should remain transparent and interpretable. Teachers should understand why a learner has been identified as requiring additional support and should have the ability to challenge or modify automated recommendations. Fourth, digital infrastructure and teacher competence influence the effectiveness of implementation. Recent UNESCO-UNEVOC analysis notes that limited infrastructure, gaps in educators' digital confidence, ethical concerns, and insufficient institutional guidance can hinder AI adoption in TVET. Therefore, AI implementation should be accompanied by teacher professional development, institutional policies, technical infrastructure, data protection mechanisms, and clearly defined assessment standards.

Implications for Vocational Education. The discussion suggests that AI-based monitoring should be implemented as part of a broader quality-management system rather than as an isolated technological innovation. At the classroom level, AI can support individual diagnosis and feedback. At the programme level, aggregated learning analytics can identify curriculum and instructional problems. At the institutional level, longitudinal data can contribute to quality assurance and strategic planning.

The resulting multi-level model can be expressed as:

Student level: diagnosis → feedback → individual intervention.

Programme level: competency analysis → curriculum adjustment → methodological improvement.

Institutional level: aggregated analytics → quality assurance → strategic decision-making.

Such integration can transform digital monitoring into a continuous quality-improvement mechanism.

Discussion of the Proposed Conceptual Model. The proposed model differs from conventional digital assessment because it connects assessment directly with pedagogical intervention. Its central innovation is not merely the application of AI algorithms but the establishment of a continuous feedback loop between learner performance and educational decision-making. Importantly, the weights should not be treated as universal. For example, practical accuracy and occupational safety may have greater importance in one technical occupation, while communication, documentation, and digital competence may receive greater weight in another. Overall, the findings suggest that artificial intelligence can strengthen vocational education quality monitoring by making assessment more continuous, personalized, analytical, and responsive. However, technological sophistication alone does not guarantee better educational outcomes.

The effectiveness of AI-based monitoring depends on the interaction of five elements: high-quality assessment criteria, reliable educational data, appropriate AI analytical tools, teacher professional judgement, timely pedagogical intervention. Therefore, the central principle of AI-supported monitoring should be expressed as: AI analyzes the evidence, but educators interpret the evidence and make pedagogical decisions. This principle is particularly important in vocational education, where

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learning outcomes include complex practical and professional competencies that cannot always be reduced to automated numerical indicators.

Conclusion. Artificial intelligence technologies create new opportunities for monitoring and improving the quality of student learning in vocational education. AI-based diagnostic assessment, learning analytics, adaptive assessment, predictive analytics, automated feedback, digital portfolios, and intelligent tutoring systems can provide continuous information about students' knowledge, practical skills, learning behaviour, and competency development.

The proposed model consists of the following cycle:

Initial diagnosis → continuous data collection → AI-based analysis → personalized intervention → reassessment → updated learner profile.

The main pedagogical value of this model lies not in replacing traditional assessment but in transforming assessment into a continuous mechanism for improving learning. AI should not be regarded as an autonomous evaluator of students. Its most appropriate role is to provide teachers with analytical evidence that supports timely and individualized pedagogical decisions. Therefore, the effectiveness of AI-based monitoring depends on the integration of artificial intelligence, teacher expertise, competency-based assessment, reliable educational data, ethical governance, and continuous pedagogical feedback. Future empirical research should test the proposed model in specific vocational specializations and compare learning outcomes before and after implementation using experimental and control groups.

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