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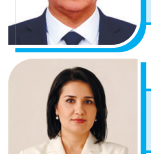

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DEVELOPING AN AI-BASED CONTINUING MEDICAL EDUCATION SYSTEM: A COMPARATIVE ANALYSIS OF NATIONAL AND INTERNATIONAL SCHOLARLY APPROACHES

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Abstract: This article presents a systematic comparative analysis of national and international research on integrating artificial intelligence into continuing professional development for mid-level medical and pharmaceutical personnel. Documentary analysis, content coding, and criterion-based comparison were applied to nine dissertations and scholarly works. The findings reveal insufficient integration between predicting individual competency needs and optimizing training resources and costs. Accordingly, an integrated conceptual model linking a digital profile, needs prediction, an individual learning pathway, resource optimization, and economic efficiency is proposed, together with a set of evaluation indicators.

Keywords: artificial intelligence, continuing professional development, mid-level medical personnel, pharmaceutical personnel, digital profile, competency gap, forecasting, individual learning pathway, resource optimization, return on investment (ROI).

Аннотация: В статье представлен систематический и сравнительный анализ отечественных и зарубежных исследований по внедрению искусственного интеллекта в систему повышения квалификации парамедицинских и фармацевтических работников. Цель исследования – определить границы существующих научных результатов и сформировать теоретическую основу непрерывного контура «цифровой профиль, прогнозирование потребностей, индивидуальная образовательная траектория, оптимизация ресурсов, экономическая эффективность». С помощью методов документального анализа, контент-кодирования и бенчмаркинга были оценены девять диссертаций и научных работ по критериям объекта исследования, технологического решения, прогнозирования, индивидуализации и экономической эффективности. В статье предложена интегрированная концептуальная модель для парамедицинских и фармацевтических работников и показатели ее оценки.

Ключевые слова: искусственный интеллект, повышение квалификации, парамедицинские работники, фармацевтические работники, цифровой профиль, разрыв в компетенциях, прогнозирование, индивидуальная образовательная траектория, оптимизация ресурсов, ROI.

INTRODUCTION

In the digital economy, the effectiveness of the healthcare system is determined not only by medical technologies but also by the knowledge and competencies of personnel capable of applying these technologies in practice. The rapid renewal of clinical protocols, electronic health information systems, telemedicine, AI-based diagnostics, and pharmaceutical management tools requires mid-level medical and pharmaceutical personnel to engage in continuous learning. Continuing professional development must therefore be reconsidered not as a periodic course, but as a management system that regularly identifies changes in an employee's professional activity and produces an appropriate educational decision.

Traditional continuing professional development often assigns learners to a uniform program, identifies needs through subjective surveys or periodic certification, and limits course evaluation to a final test. This approach is insufficient where knowledge and skills become obsolete rapidly, regional workforce needs differ, and educational resources are constrained. Artificial intelligence and machine-learning technologies can integrate heterogeneous data, detect latent patterns, anticipate needs, and recommend appropriate learning content.

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The scholarly literature contains significant findings on distance-learning architecture, predictive management, andragogical education, individual development pathways, AI-enabled Learning and Development, and the economic return on technological investment. However, how these areas should be integrated into the continuing professional development system for mid-level medical and pharmaceutical personnel remains insufficiently specified. In particular, predicting an employee's individual competency gap, recommending learning modules, planning learner flows and resources, and assessing economic efficiency within a single model remain unresolved research problems.

The purpose of this study is to develop the theoretical foundations of an AI-driven integrated conceptual model for the continuing professional development of mid-level medical and pharmaceutical personnel through a comparison of national and international scholarly approaches. To achieve this purpose, prior scientific contributions were systematized, their boundaries in terms of research object, technology, forecasting, individualization, and economic evaluation were determined, the research gap was identified, and an integrated model and outcome indicators were proposed.

REVIEW OF LITERATURE ON THE SUBJECT

K.A. Karimov modeled the distance-based professional development process for managers and teaching staff in the vocational education system. The study developed a distance-learning architecture integrating Learner Information, Learning Content, Management Systems, and Assessment, together with a networked methodological model comprising goal-oriented, content, process, and diagnostic-outcome blocks. This contribution systematizes the pedagogical and information infrastructure of distance learning. However, predicting an individual employee's future competency gap through machine learning and optimizing training costs were not central research objectives.[1]

V.A. Karimova proposed predictive modeling, mechanisms for accounting for social and technological risks, AI-assisted data reliability assessment, and cluster analysis of electronic portfolio data in managing the quality of professional development for higher-education leaders. This study is particularly significant because it introduces AI and forecasting into professional-development quality management. Nevertheless, its research population consists of higher-education managers, while clinical-practical competency gaps, regional demand for healthcare personnel, and individual training duration are not treated as separate prediction targets.[2]

H.X. Xakimjonova developed professional competence through an andragogical approach and substantiated a development pathway based on autonomy, experience, need, equality, and collaboration. This approach demonstrates the importance of accounting for adult learners' motivation and prior experience. These factors may serve as important explanatory variables in an AI model, however, the andragogical model itself does not perform algorithmic needs prediction.[3]

M.T. Jumaniyozova linked a personal and professional learning pathway in continuous professional development with digital transformation and tools for identifying professional needs. This approach strengthens the pedagogical basis of an individualized learning plan. However, a recommendation algorithm that automatically recalculates the pathway as new data arrive, together with an economic model assessing its cost-effectiveness, was not developed separately.[4]

T. Reitgruber compared an AI-driven Learning and Development system with conventional automated learning and applied a PLS-SEM model to data from 144 respondents. The results showed that AI-driven learning explained 65.3% of the variance in learning motivation and that perceived competence was the principal mediating factor. The study empirically substantiates the psychological and behavioral effects of AI personalization, but it does not predict the timing of individual needs, regional workforce flows, or training costs.[5]

S.C. Riley examined strategies used by business leaders to obtain financial benefits from AI and identified themes including strategic leadership, cost and benefit strategies, implementation challenges, mitigation

1 Karimov, K.A. Modeling the Distance-Based Professional Development Process for Managers and Teaching Staff in the Vocational Education System: Abstract of a DSc Dissertation. Tashkent, 2023. 75 pp. Cited page: 10.

2 Karimova, V.A. Improving the Theory and Practice of Quality Management in the Professional Development of Higher-Education Leaders: Abstract of a DSc Dissertation. Tashkent, 2025. 66 pp. Cited page: 10.

3 Xakimjonova, H.X. Developing the Professional Competence of Managers and Teaching Staff in the Vocational Education System through an Andragogical Approach: Abstract of a PhD Dissertation. Tashkent, 2024. 54 pp. Cited page: 8.

4 Jumaniyozova, M.T. Improving the Creative Competence of Social-Sciences and Humanities Teachers in Continuous Professional Development: Abstract of a DSc Dissertation. Tashkent, 2023. 77 pp. Cited pages: 9–10.

5 Reitgruber, T. Transforming Learning and Development: The Impact of Artificial Intelligence and Automation on Employees' Motivation to Learn. Master's dissertation. Universidade Católica Portuguesa, 2023. 111 pp. Cited pages: 45, 51 (PDF pp. 53, 59).

measures, performance measurement, and institutionalization of AI. Employee training and reskilling are presented as essential conditions for increasing the return on AI investment. However, the study does not propose a cost-outcome function for an individual learner or course.[6]

J.T. Sop demonstrated that integrating AI into healthcare organizations' business models requires the coordinated management of data governance, interoperability, ethics, privacy, reskilling, and organizational change. Although this study is directly related to the healthcare sector, its unit of analysis is the organization rather than the competency profile of an individual mid-level medical or pharmaceutical employee.[7]

D.A. Henry analyzed the effects of AI on human labor, occupational roles, and skill composition and recommended accounting for differences among groups by age, job tenure, and technological literacy. These findings support the inclusion of demographic and occupational factors as model features.[8]

D. Marchetti and R. Scardovi classified AI solutions in human-resource processes across the Attraction, Learning and Development, and Well-Being macro-processes. Within Learning and Development, they identified Career Growth, Feedback Management, and Training. Their analytical framework maps the AI-solutions market but does not test an individual prediction algorithm or a specialized ROI function for healthcare personnel.[9]

The literature review yields three general conclusions. First, individualization is well grounded pedagogically, but mechanisms for its automatic and dynamic formation remain limited. Second, although AI-enabled clustering, personalization, and organizational efficiency have been studied, jointly predicting the type and timing of need is uncommon. Third, economic effects are generally described as overall benefits or cost reductions, while quantitative optimization at the learner, course, and resource levels remains underdeveloped. Developing an integrated model is therefore justified both theoretically and practically.

RESEARCH METHODOLOGY

The study employed a qualitative comparative design. The unit of analysis was a dissertation or scholarly work addressing continuing professional development, AI, personalization, forecasting, or economic efficiency. Three inclusion criteria were applied: first, professional development or employee development had to occupy a central place in the study, second, the study had to include a digital-technology or AI component, and third, its scientific contribution or practical result had to be stated explicitly. On this basis, four national and five international studies were included in the comparative corpus.

Five coding criteria were established for the content analysis: (1) research object, (2) principal technological or pedagogical solution, (3) level of forecasting, (4) individualization mechanism, and (5) method for evaluating economic efficiency. The scientific-contribution and results sections of each source were reviewed using these codes. The categories "present," "partially present," and "absent" were applied only to mechanisms explicitly described in the text.

The comparative synthesis was conducted in two stages. First, the independent scientific contribution of each study was identified and its distinction from the author's approach was described. Second, recurring and complementary elements were consolidated into a single logical cycle. The proposed cycle consists of input data, an analytical core, a management decision, and an outcome-evaluation block.

A limitation of the study is that the comparison draws on works from different fields, levels, and methodological traditions, therefore, their results were not directly meta-analyzed by effect size. The findings are interpreted as a conceptual synthesis. The model should subsequently be tested empirically using real medical-education data.

ANALYSIS AND RESULTS

The results of the comparative analysis are summarized in Table 1. The table highlights the specific strengths of previous studies and the integrative nature of the model proposed in this study (Table 1).

6 Riley, S.C. Successful Strategies Business Leaders Use to Implement Artificial Intelligence for Achieving Financial Benefits. DBA dissertation. Walden University, 2026. 97 pp. Cited pages: 21, 36 (PDF pp. 32, 47).

7 Sop, J.T. Effective Strategies for Artificial Intelligence Adoption in the Healthcare Industry. DBA dissertation. Walden University, 2025. 98 pp. Cited pages: 14–15, 56 (PDF pp. 26–27, 68).

8 Henry, D.A. Impacts of Artificial Intelligence on the Human Workforce. Doctoral dissertation. Pepperdine University, 2025. 49 pp. Cited page: 38 (PDF p. 45).

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Table 1. Comparative Analysis of Previous Studies on AI-Driven Continuing Professional Development[10]

Study	Research object	Principal approach	Forecasting and individualization	Economic evaluation
K.A. Karimov	Vocational education personnel	Networked distance-learning model	Learner-centered approach, no AI forecasting	No specialized optimization
V.A. Karimova	Higher-education leaders	AI, predictive model, clustering	Quality forecasting and electronic portfolio	Specialized ROI assessment is limited
H.X. Xakimjonova	Vocational education personnel	Andragogical model	Pathway based on needs and experience	Pedagogical effect
M.T. Jumaniyozova	Teachers	Personal and professional pathway	Individual plan, no automatic recalculation	Not a principal research object
T. Reitgruber	Employees across sectors	AI-driven L&D	Motivation and personalization	No cost model
S.C. Riley	Business organizations	AI implementation strategy	Organizational monitoring and reskilling	Financial-benefit strategy
J.T. Sop	Healthcare organizations	AI and the business model	Organizational planning and AI literacy	Operational efficiency
D.A. Henry	Employees from different generations	Qualitative analysis of AI impacts	Occupational roles and reskilling	Description of benefits
Marchetti & Scardovi	HR and start-ups	Map of AI solutions	Career growth, feedback, and training	Classification of benefits and barriers
Proposed model	Mid-level medical and pharmaceutical personnel	Digital profile, ML, and recommender system	Forecasting of needs, timing, modules, flows, and resources	Cost-outcome and ROI optimization

The comparative findings show that five functions remain fragmented across existing studies. The distance-learning model organizes the learning environment, the andragogical model accounts for learners' experience and motivation, predictive management assesses quality stability, AI personalization adapts content and feedback, and economic studies reveal the organizational conditions of investment returns. Yet these functions have not been connected into a unified decision chain extending from the individual employee to system-level resources.

The first block of the proposed model is the digital profile. It integrates an employee's position, specialty, length of service, region, certification results, competency tests, previous courses, digital activity, and job-performance indicators. The digital profile is not a static questionnaire; it is an analytical object that is updated whenever new data become available.

The second block is needs prediction. A classification algorithm estimates the competency area in which professional development is required, while a regression or time-to-event model estimates when the need will arise. The output is not limited to a binary "training required/not required" decision, it also accounts for the priority of the need and the expected cost of an incorrect decision.

The third block is the individual learning pathway. A recommender system selects the module, delivery mode, duration, difficulty level, and sequence appropriate to the employee. Andragogical principles function as constraints and preferences at this stage: the learner's experience, motivation, time availability, and learning style are incorporated into the recommendation function.

The fourth block is resource optimization. Based on the aggregate of individual recommendations, learner flows are forecast by region, specialty, and time period. An optimal course portfolio is then developed subject to constraints on instructor workload, classrooms, simulators, platform capacity, budget, and continuity of service.

The fifth block is economic efficiency. Outcomes are assessed through cost per learner, savings in learning and working time, reductions in repeated courses, competency gains, the cost of prediction errors, net economic benefit, and ROI. Pedagogical effectiveness is thereby connected with economic and system-level outcomes (Table 2).

10 Source: Compiled by the author based on the cited sources.

Table 2. Integrated AI-Driven Model for Continuing Professional Development[11]

Model block	Input data	Principal method	Outcome indicator
Digital profile	Position, tenure, region, tests, certification, learning history	Data integration and cleaning	Profile completeness and data quality
Needs prediction	Competency gap and performance features	Classification, regression, and time-to-event model	F1, ROC-AUC, MAE/RMSE
Individual pathway	Prediction, preferences, and module catalog	Recommender system	Relevance, completion, and competency growth
Resource optimization	Flows, budget, instructor and platform constraints	Constrained optimization	Utilization, coverage, and unit cost
Economic evaluation	Cost, time, repeated courses, and outcomes	Cost-benefit analysis and ROI	Net benefit, ROI, and payback period

The proposed model does not contradict previous scholarly works, rather, it integrates their strengths into a unified management architecture. Karimov's networked model provides the organizational foundation for a digital learning environment, Karimova's predictive and cluster-based approach strengthens the analytical layer, and the studies by Xakimjonova and Jumaniyozova define the pedagogical conditions of an individual pathway. Reitgruber explains the motivational mechanism of personalization, whereas Riley and Sop reveal the economic and institutional conditions of implementation.

The model's theoretical novelty lies in linking levels of analysis. At the micro level, the employee's competency profile and individual needs are identified. At the meso level, courses, instructors, and platform resources are coordinated. At the macro level, regional workforce needs, budgets, and the strategic priorities of the healthcare system are taken into account. This linkage transforms an individual recommendation from a standalone pedagogical service into a system-management decision.

Data quality, algorithmic fairness, privacy, explainability, and human oversight are critical to practical implementation. Model recommendations should not completely replace managerial or pedagogical decisions, instead, they should support evidence-based decision-making. Error rates must be examined across groups to ensure that an employee's age, region, or position does not produce discriminatory outcomes.

Assessing economic efficiency solely through a reduction in platform costs would be inappropriate. A lower unit cost accompanied by declining educational quality does not constitute genuine efficiency. Cost indicators should therefore be evaluated together with competency growth, practical outcomes, service continuity, and the risk of error.

A phased design is recommended for future empirical research: first, develop a data dictionary and competency ontology, second, build a baseline model using retrospective data, third, conduct a prospective trial in a pilot institution, and finally, compare conventional and AI-based groups in terms of cost, time, competency growth, and practical outcomes.

CONCLUSIONS AND SUGGESTIONS

The comparative analysis demonstrates that national and international studies have produced important findings on distance learning, predictive quality management, andragogical development, individual pathways, AI personalization, and economic returns. However, for mid-level medical and pharmaceutical personnel, the early identification of individual needs, automatic formation of learning pathways, and simultaneous optimization of resources and costs have not been sufficiently developed as an integrated solution.

To address the identified research gap, a continuous "digital profile – needs prediction – individual learning pathway – resource optimization – economic efficiency" cycle is proposed. This cycle enables a transition from data to individual recommendations and from individual recommendations to system-level resource decisions.

The following practical recommendations are proposed: develop a unified competency classifier for mid-level medical and pharmaceutical personnel, create a digital profile integrating certification, testing, and learning-history data, test the prediction model against explainability and fairness criteria, use the recommender system under pedagogical supervision, and evaluate pilot results in terms of unit cost, time savings, competency growth, repeated courses, and ROI.

11 Source: Developed by the author.

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The findings provide a theoretical basis for transforming continuing professional development in healthcare from a course-planning process into a data-driven mechanism for continuous human-capital management.

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