Personalized E-Learning Recommendation System Using K-Nearest Neighbor Algorithm

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ABSTRACT

In recent years, the expansion of e-learning platforms has revolutionized the educational landscape, offering learners the flexibility to access educational resources anytime and anywhere. However, the abundance of content often overwhelms students, making it difficult to identify which learning materials best suit their individual needs. To address this challenge, this study proposes the development of a **Personalized E-Learning Recommendation System** that utilizes the **K-Nearest Neighbor (KNN)** algorithm to tailor learning content based on each learner's profile, behavior, and preferences.

The primary objective of this research is to design and implement a data-driven recommendation model that enhances learner engagement and academic performance by providing customized content suggestions. The system collects various types of user data from the e-learning platform, including quiz scores, subject interests, time spent on modules, and interaction history. Each learner is represented as a feature vector encapsulating these attributes. By applying the KNN algorithm, the system identifies students with similar learning patterns and preferences and recommends educational resources that have proven effective for those peers.

The study follows a design and development research methodology, where the system is built, tested, and evaluated through iterative processes. The prototype is developed using Python and its machine learning libraries, while a web-based interface is created using Django and integrated with a backend database to store user data. Evaluation metrics such as recommendation accuracy, user engagement rate, and improvement in quiz performance are used to assess the system's effectiveness. Initial testing shows that learners receiving personalized recommendations spend more time on the platform and demonstrate higher content retention compared to those accessing randomly assigned materials.

This research contributes to the growing field of intelligent e-learning systems by highlighting the effectiveness of simple yet powerful machine learning techniques such as KNN in improving personalization. It also emphasizes the value of learner data in shaping adaptive educational environments that cater to individual learning styles and needs. Future work may include expanding the dataset, incorporating hybrid recommendation models, and exploring deep learning approaches to further improve recommendation quality.

By offering a scalable and adaptable framework, this personalized recommendation system has the potential to significantly enhance the digital learning experience, making online education more targeted, efficient, and impactful.

Keywords: Personalized Learning, E-Learning, Recommendation System, K-Nearest Neighbor (KNN), Machine Learning, Student Engagement, Educational Technology, Learning Analytics, Adaptive Learning, Online Education

INTRODUCTION

The rapid growth of e-learning platforms has transformed education by providing learners with access to a wide range of digital resources. However, the one-size-fits-all approach in most platforms often fails to meet the diverse learning needs and preferences of individual students. As a result, learners may struggle to identify

content that aligns with their skills, interests, and goals. To address this gap, personalized recommendation systems have emerged as a valuable solution. This study proposes the development of a **Personalized E-Learning Recommendation System** using the **K-Nearest Neighbor (KNN)** algorithm. By analyzing user data—such as performance history, content preferences, and interaction patterns—the system identifies similar learners and suggests appropriate learning materials. This personalized approach aims to improve student engagement, learning outcomes, and satisfaction. The study explores the implementation and effectiveness of the KNN-based model in delivering customized educational experiences within an online learning environment.

METHODS

This study employed a design and development research approach to create a personalized e-learning recommendation system using the K-Nearest Neighbor (KNN) algorithm. The system was developed in four phases: data collection, data preprocessing, algorithm implementation, and system evaluation. User data—such as quiz scores, subject preferences, time spent on modules, and interaction history—was collected from a simulated e-learning environment. These attributes were converted into feature vectors representing each learner's profile. The KNN algorithm was applied to identify users with similar learning patterns, enabling the system to recommend relevant educational content. The system was developed using Python and scikit-learn for the machine learning model, Django for the web interface, and SQLite for data storage. Evaluation metrics such as recommendation accuracy, user engagement, and academic performance were used to assess system effectiveness. Feedback from a group of student users was also gathered to measure satisfaction and relevance of the personalized content.

RESULTS & DISCUSSION

The implementation of the personalized e-learning recommendation system using the K-Nearest Neighbor (KNN) algorithm produced promising results in terms of recommendation accuracy, user engagement, and overall learner satisfaction. During the testing phase, the system was evaluated by a sample group of 30 students using simulated user data. The KNN model successfully identified similar learning profiles and generated tailored content suggestions for each student.

Quantitative analysis revealed a 78% recommendation accuracy, measured through precision and recall scores. Students who received personalized content showed an average 15% improvement in quiz scores compared to those who accessed general materials. Additionally, user engagement—measured by time spent on learning modules—increased by 25% among those using the system. Qualitative feedback from participants indicated that the majority found the recommendations relevant, helpful, and motivating.

These results suggest that KNN, though a relatively simple algorithm, is highly effective for small to medium-sized e-learning environments. Its ability to quickly match user profiles and generate real-time recommendations makes it suitable for educational platforms that lack large-scale computing infrastructure. However, limitations were also observed, including reduced accuracy when handling sparse or incomplete data. Future improvements may include incorporating hybrid models that combine KNN with content-based filtering or deep learning to improve scalability and adaptability. Overall, the system demonstrates the potential of personalized learning technologies to enhance student experience and academic outcomes in digital education settings.

Results:

Table 1 – Participant Demographics (N = 30)

Variable	Frequency (n)	Percentage (%)
Gender		
Male	12	40%
Female	18	60%

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Age Range		
18–20 years	12	40%
21–23 years	14	46.7%
24+ years	4	13.3%
Academic Level		
1st Year	8	26.7%
2nd Year	7	23.3%
3rd Year	8	26.7%
4th Year	7	23.3%

Table 1 presents the demographic profile of the 30 participants involved in system testing. Female learners were slightly more represented (60%), while males comprised 40%. Most participants were aged 21–23 years (46.7%), and the distribution across academic levels was relatively balanced, ensuring a representative sample for evaluating the personalized e-learning system.

Table 2 – Descriptive Statistics of Learner Data

Variable	**Mean (M)**	**Standard Deviation (SD)**	**n**
Quiz Scores	82	7	30
Time Spent on Modules (minutes)	45	12	30
Engagement Score	3.8	0.6	30
Attention Span	3.4	0.5	30

Table 2 displays descriptive statistics of learner performance and engagement. The mean quiz score was 82, indicating good academic performance, while time spent on modules averaged 45 minutes, reflecting meaningful engagement with the personalized content. Engagement (M = 3.8) and attention span (M = 3.4) suggest that learners effectively interacted with the system, supporting the KNN-based recommendations' positive impact.

Table 3 – Correlation of Key Variables

Variable	**1**	**2**	**3**	**4**
1. Quiz Scores	—			
2. Engagement Score	.65**	—		
3. Time Spent on Modules	.48**	.55**	—	
4. Attention Span	.52**	.60**	.50**	—

Table 3 presents correlations among key learner variables. Quiz scores positively correlated with engagement ($r = .65$, $p < .01$) and attention span ($r = .52$, $p < .01$). Time spent on modules also showed positive relationships with engagement and performance. These results indicate that personalized content increased both engagement and academic outcomes.

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Table 4 – Instrument Reliability

Scale	Number of Items	Cronbach's α
Quiz Scores	10	.88
Engagement Questionnaire	12	.91
Attention Span Checklist	8	.85

Table 4 shows reliability analyses for the instruments. Cronbach's alpha values ranged from .85 to .91, indicating strong internal consistency and confirming that the instruments reliably measured learners' performance and engagement.

Table 5 – System Usability Scale (SUS) Scores

Item	Mean	SD
Ease of Use	4.28	0.61
Functionality	4.10	0.72
Efficiency	4.22	0.67
Overall Usability Score	83.5	—

Table 5 presents SUS scores. High scores across all items and an overall usability score of 83.5 indicate that the system is user-friendly, intuitive, and supports learners' interaction with personalized content.

Table 6 – Dataset Attributes and Description

Data Attribute	Type	Description	Source
Quiz Scores	Numerical	Academic performance	Simulated platform
Subject Preferences	Categorical	Learner interest areas	User profiles
Time Spent on Modules	Numerical	Duration spent on modules	System logs
Interaction History	Mixed	Engagement frequency and type	System logs
Feature Vector	Composite	Combined attributes for KNN	Preprocessed data

Table 6 shows dataset attributes used for KNN-based recommendations. The combination of numerical and categorical data captures both academic performance and engagement behaviors, enabling precise personalization.

Table 7 – KNN Algorithm Configuration

Parameter	Description	Value
K	Number of nearest neighbors	5
Distance Metric	Similarity measure	Euclidean
Feature Normalization	Scaling	Min–Max
Training Method	Model approach	Instance-based
Dataset Size	Number of learners	30

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Table 7 describes KNN settings. K = 5 and Euclidean distance ensured accurate detection of similar learners. Feature normalization prevented attribute bias, and the instance-based method allowed dynamic updates as new learners were added.

Table 8 – System Development Tools

Component	Technology	Purpose
Backend	Python	ML logic
ML Library	Scikit-learn	KNN model
Web Framework	Django	UI development
Database	SQLite	Data storage
Front-End	HTML/CSS/JS	Interactive interface

Table 8 summarizes development tools. The combination of Python, Django, SQLite, and front-end technologies created a responsive, reliable system capable of real-time personalized recommendations.

Table 9 – System Evaluation Metrics

Metric	Description	Result
Recommendation Accuracy	Precision and recall	78%
User Engagement	Time spent on modules	+25%
Academic Performance	Quiz score improvement	+15%
User Satisfaction	Feedback ratings	High
System Efficiency	Real-time recommendation	Achieved

Table 9 shows system evaluation. Personalized recommendations increased engagement and improved academic outcomes, with the KNN algorithm achieving 78% accuracy, validating its effectiveness.

Table 10 – User Satisfaction Survey

Indicator	Mean	SD
Ease of Use	4.28	0.61
Functionality	4.10	0.72
Efficiency	4.22	0.67
Overall Usability Score	83.5	—

Table 10 demonstrates participants' perceptions. High usability scores indicate that the system effectively supports learners in navigating and utilizing personalized recommendations.

Table 11 – Performance Outcomes of the Personalized Recommendation System

Performance Indicator	Result	Description
Recommendation Accuracy	78%	Accuracy measured through precision and recall analysis.
Improvement in Quiz Scores	15% increase	Average score improvement among students who received personalized content compared to those who used general materials.
User Engagement	25% increase	Increase in time spent on learning modules by users of the personalized system.
Qualitative Feedback	Positive	Majority of participants reported that recommendations were relevant, helpful, and motivating.

Table 11 shows the performance outcomes of the personalized recommendation system. The results show a 78% recommendation accuracy, a 15% increase in quiz scores, and a 25% rise in user engagement. Qualitative feedback also indicates that users found the recommendations relevant and helpful.

CONCLUSIONS & RECOMMENDATIONS

This study successfully developed and evaluated a personalized e-learning recommendation system utilizing the K-Nearest Neighbor (KNN) algorithm. The system effectively tailored learning content based on users' academic performance, preferences, and behavioral data, resulting in improved learner engagement and academic outcomes. Results demonstrated that the system provided accurate and relevant content recommendations, contributing to a more meaningful and efficient e-learning experience. The increase in quiz performance and time spent on recommended materials confirmed the effectiveness of the personalized approach.

The use of KNN proved to be a practical solution for small to medium-scale educational platforms due to its simplicity, interpretability, and minimal computational requirements. However, challenges such as handling sparse data and cold-start problems suggest the need for more adaptive models in the future.

It is recommended that educational institutions and e-learning developers adopt and expand this system to enhance digital learning environments. For broader application, future research may consider integrating hybrid recommendation method combining collaborative and content-based filtering or leveraging deep learning to improve scalability and personalization. Additionally, expanding the dataset to include real-time user behavior, emotional response tracking, and learning styles could further refine the recommendation accuracy.

Ultimately, this personalized e-learning system offers a valuable contribution to improving online education by addressing learners' individual needs, promoting self-directed learning, and enhancing the overall quality of digital instruction.

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DESCRIPTION

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