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Personalized adaptive e-learning application based on learning styles

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ABSTRACT

This study presents the development of an adaptive e-learning system designed to deliver personalized content according to students' learning styles. The system analyzes individual learner profiles through a profiling module, structures learning resources via a content management module, and supports the process with instant feedback mechanisms. By dynamically adapting the flow of content, the system creates distinct learning journeys for students. The study presents the system's architecture, design-based research methodology, and its intended contributions to learner-centered education. It is anticipated that the developed framework will support future research in adaptive e-learning. Thus, the study is expected to provide useful insights into personalized learning processes at both the national and international level.

Keywords: Personalized e-learning, adaptive learning, learning styles, learner-centered education, educational technologies, design-based research, educational data mining s

INTRODUCTION

Digitalization in education has accelerated significantly in recent years, making student-centered teaching approaches increasingly important. Traditional e-learning systems are mostly based on standardized content delivery and fail to adequately consider students' individual learning differences. However, each student possesses a distinct learning style, motivation, and cognitive approach. This situation necessitates that e-learning platforms become more flexible, personalized, and adaptive (Ruman, 2022).

In this context, the system designed in this study aims to provide a personalized adaptive learning environment tailored to students' learning styles. By employing learner profiling techniques, the system collects data on individuals' learning preferences and processes this data to automatically adapt content delivery. For instance, visual learners are provided with diagrams, auditory learners with audio-based content, and kinesthetic learners with interactive applications.

The primary motivation of this research is to integrate the fact that the learning process differs for every student into the system infrastructure, thereby enabling more effective, lasting, and meaningful learning experiences. Furthermore, personalization based on learning styles enhances student engagement, strengthens learning outcomes, and increases motivation during the teaching process (Graf & Kinshuk, 2009).

THEORETICAL FRAMEWORK

Learning Styles

These styles refer to the individual differences in the ways people perceive, process, and recall information. In this study, the VARK model was adopted as the main reference for adaptation, due to its practicality and broad use in adaptive e-learning research. One of the most widely used models is the VARK model (visual, auditory, reading/writing, kinesthetic). According to this model:

- Visual learners prefer to learn through visual materials such as charts, graphs, and diagrams.
- Auditory learners learn by listening to lectures, participating in discussions, and following verbal instructions.
- Reading/writing learners benefit from text-based resources.
- Kinesthetic learners learn through hands-on activities, simulations, and experiential practices.

The model developed by Dunn and Dunn (1992) adopts a more comprehensive perspective by considering environmental, emotional, social, and psychological factors as well. Such models form the foundation of learner-centered systems.

Personalized Learning

The personalized learning approach aims to provide differentiated content pathways based on the individual characteristics of each student. In this approach, the system organizes the course flow according to the learner's current knowledge level, interests, and learning styles. Thus, a student may experience a distinct learning journey even within the same course.

Personalization strategies include learner profiling, content adaptation, dynamic assessment, and instant feedback.

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Particularly, artificial intelligence-based algorithms play a key role in optimizing the learner's pathway in real time (Romero & Ventura, 2020).

Adaptive E-Learning Systems

Adaptive systems are system structures that monitor learners' behaviors and adjust content, methods, or difficulty levels accordingly. The primary goal of such systems is to automatically select the most appropriate learning pathway for each individual learner.

In the literature, adaptive systems are defined by certain common features (Brusilovsky & Millán, 2007):

- User modeling (analyzing the learner's knowledge, skills, and interests)
- Content adaptation (selecting suitable materials for the learner)
- Task adaptation (assigning exercises and activities according to the learner's level)
- Navigation support (intelligent modules that guide learners)

The system developed in this research was designed on the basis of an adaptive architecture, with a specific focus on personalizing content delivery according to students' learning styles.

METHODS

An adaptive e-learning system was developed by redesigning all modules on an open-source learning management infrastructure with personalization and adaptivity at the core.

The system was primarily based on the VARK model, which is one of the most widely recognized frameworks in educational research. This model was selected because it provides clear categorization and supports multiple modalities of learning content. Thus, it allows the system to adapt resources to diverse learner preferences.

The VARK model was chosen because it is widely recognized in adaptive learning research, provides a clear categorization of learner preferences, and supports multiple modalities (visual, auditory, reading/writing, kinesthetic). This alignment ensures that the system can flexibly adapt content to diverse learning needs.

The development process followed the design-based research (DBR) methodology, which includes the following five systematic phases:

Analysis: Identification of the educational problem and justification of personalization based on learning styles.

Design: Planning of the learner profiling, content management, and feedback modules.

Development: Technical creation and integration of the modules.

Implementation: Pilot application of the system and collection of user feedback.

Evaluation: Continuous improvement of the system based on collected data.

This structured approach ensures the translation of theory into practice and enables iterative system refinement.

Components of the System

The developed system consists of three main modules:

- **Learner profiling module:** Analyzes the student's learning style, past performance, and preferences.
- **Content management module:** Structures materials provided by instructors and ensures that the most suitable resources are presented according to the learner's individual characteristics.
- **Assessment and feedback module:** Tracks learners' progress, provides instant feedback, and updates the content flow.

A continuous data flow is maintained among these modules, enabling the system to dynamically optimize the student's learning process.

SYSTEM ARCHITECTURE

In this study, an adaptive e-learning system was developed that takes into account students' learning styles. While the developed system is based on an open-source learning management infrastructure, all modules were redesigned to place personalized and adaptive learning processes at the core. Specifically, the system was developed on a Drupal-based open-source framework. Drupal was selected due to its modular architecture, extensive plugin support, customizable user roles, scalability, and integrated reporting features. These characteristics provided the flexibility required to implement adaptive and personalized functionalities.

The development process was carried out using the DBR methodology. This approach aims to translate.

This diagram shows the basic components of the developed adaptive e-learning system and the data flow between these components. The architectural structure consists of three main layers:

- **User layer:** Learners and instructors interact with the system, generating activity data.
- **Application layer:** Personalization engine, content management, task assignment, and reporting units analyze learner profiles and adapt the learning flow.
- **Data layer:** Stores learner profiles, performance data, and activity results to feed the application layer for ongoing adaptation.

Student interactions are first recorded in the user interface, then processed in the application layer to adapt content delivery and transfer it to reporting screens. Thus, the system personalizes the student's learning path and provides the teacher with detailed monitoring capabilities. The flow diagram of this structure is shown in Figure 1 below.

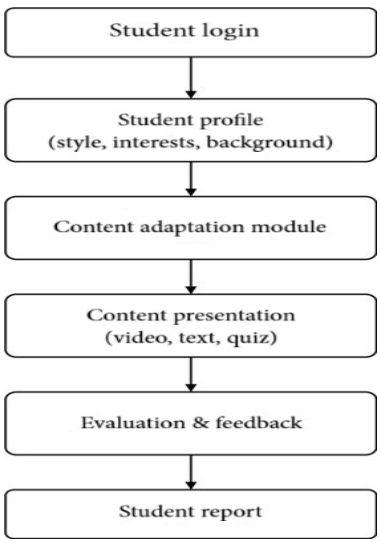

Figure 1. General system architecture (Karay & Erdal & Ergüzen, 2025)

The process of adaptive e-learning system is explained step by step, starting from the student's login to the system, through their interaction with the content, to the evaluation of learning outcomes:

- **Login and profile definition:** After the student logs into the system with their username/password, the system activates the student's profile (pre-test, learning style questionnaire, previous achievement data).
- **Learning style analysis:** The student's individual learning style (e.g., visual, auditory, kinesthetic) and current knowledge level are analyzed. This analysis serves as the starting point for content presentation.
- **Content selection and adaptation:** The most suitable content path is determined based on the student's profile data. For example, students with a visual learning style are presented with content heavy on graphics, diagrams, and videos, while those with an auditory style are prioritized with audio narrations.
- **Activity and task assignment:** The system automatically assigns activities and tasks appropriate to the student's level. The difficulty level is dynamically adjusted according to the student's performance.
- **Progress tracking and feedback:** The student's activity completion status, success rate, and learning time are tracked. The system provides instant feedback and guidance to the student.
- **Reporting and continuous adaptation:** The student's progress data is reflected in the teacher's dashboard. The student's progress is continuously analyzed, and new content and activities are adapted accordingly.

Figure 2 below illustrates the system 's personalization mechanism and concretizes the system's dynamic, student-centered operation.

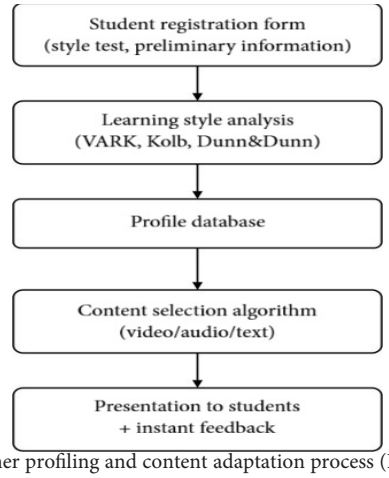

Figure 2. Learner profiling and content adaptation process (Karay & Erdal & Ergüzen, 2025)

SYSTEM FEATURES

Create New Account

A registration form is provided for new users, allowing them to easily create login credentials with basic information (first name, last name, and e-mail). A screenshot is shared in Figure 3.

Login Screen

Users logging into the system are authenticated with a username and password. For security purposes, a "Request New Password" option is also available on this screen. A screenshot is shared in Figure 4.

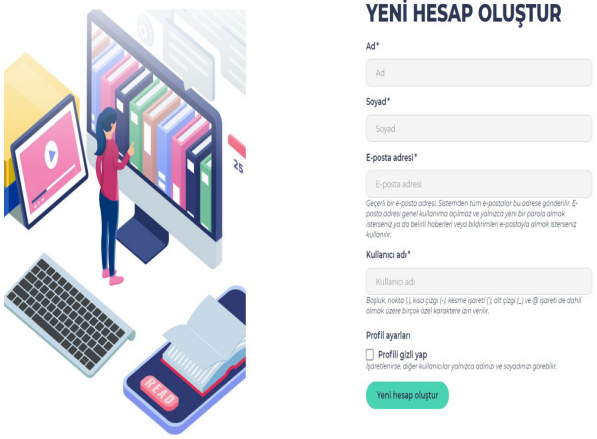

Figure 3. Create new account screenshot (Karay & Erdal & Ergüzen, 2025)

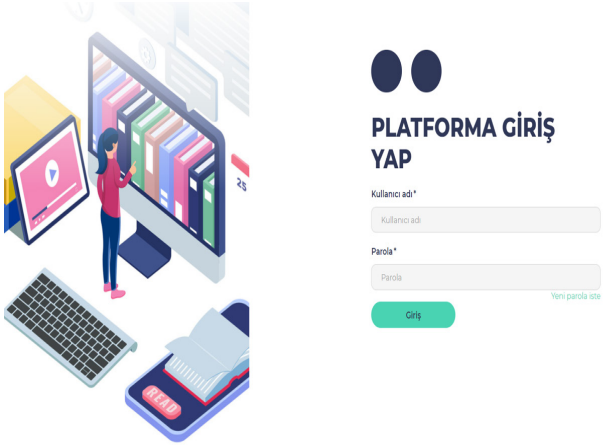

Figure 4. Login screen account screenshot (Karay & Erdal & Ergüzen, 2025)

Student Homepage

This screen displays students' current activities, calendar events, messages, and statistics within a single panel. In particular, social interaction features (comments, likes) enhance motivation in the learning process.

The interface of the system is designed to be simple, accessible, and mobile-friendly. After logging in, students are presented with a personalized main dashboard.

The system provides customizable dashboard blocks for each role (student/instructor/administrator); "my courses," "ongoing modules," "recent activities," "upcoming tasks," "achievement badges/certificates," "my reports." This approach offers users a task-oriented entry experience. A screenshot is shared in Figure 5.

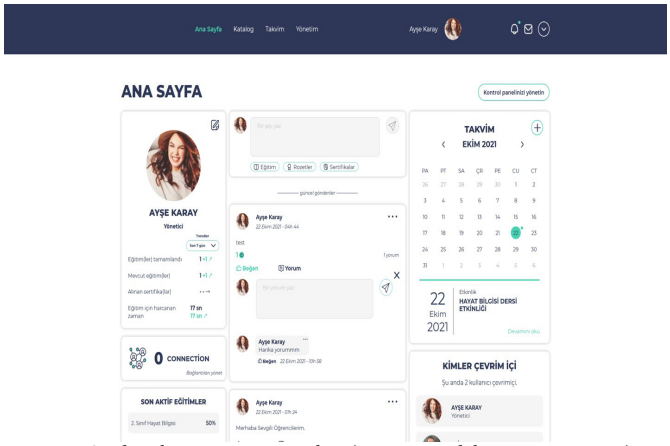

Figure 5. Student homepage screenshot (Karay & Erdal & Ergüzen, 2025)

Course Catalog Page

This screen allows students to view the courses they are enrolled in and monitor their progress. For each course, a visual, description, completion percentage, and a "continue learning" option are provided. In this way, students can quickly track how much of each course they have completed. A screenshot is shared in **Figure 6**.

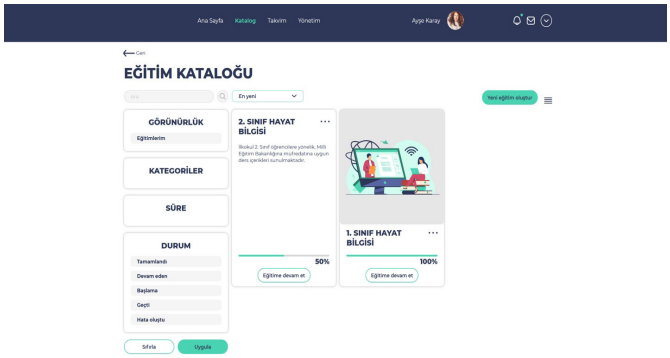

Figure 6. Course catalog page screenshot (Karay & Erdal & Ergüzen, 2025)

Course Detail Page-1

This screen allows students to view the courses they are enrolled in and monitor their progress. For each course, a visual, description, completion percentage, and a "continue learning" option are provided. In this way, students can quickly track how much of each course they have completed. A screenshot is shared in **Figure 7**.

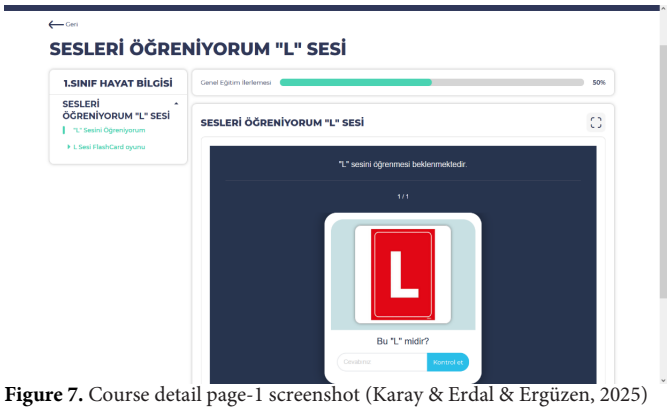

Figure 7. Course detail page-1 screenshot (Karay & Erdal & Ergüzen, 2025)

Course Detail Page-2

In the second course detail screen, a personalized feedback area and detailed information about completed activities are displayed. Students have the opportunity to evaluate their own performance and identify their areas of weakness. A screenshot is shared in **Figure 8**.

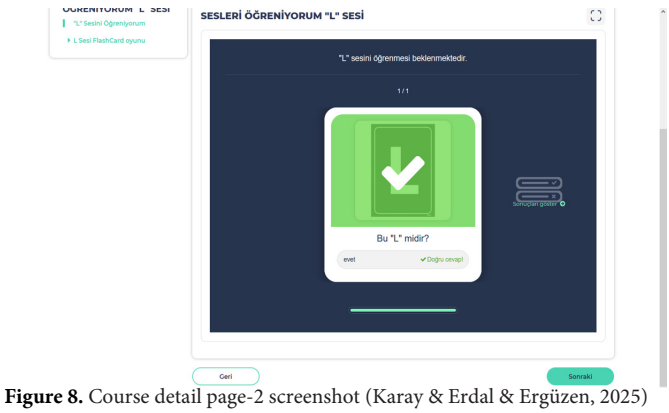

Figure 8. Course detail page-2 screenshot (Karay & Erdal & Ergüzen, 2025)

Course Detail Page-3

This screen contains the results section, which specifically summarizes the student's correct and incorrect answers. In this way, students can see not only their overall success rates but also identify in which activities they made mistakes. A screenshot is shared in **Figure 9**.

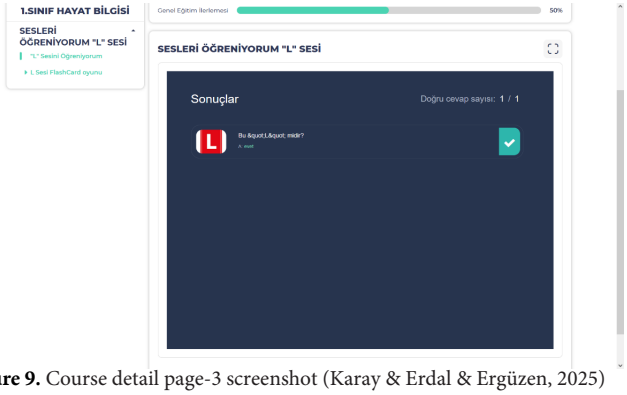

Figure 9. Course detail page-3 screenshot (Karay & Erdal & Ergüzen, 2025)

Learning Path Manager

Trainings are organized with a course → module → activity hierarchy through a drag-and-drop interface. With the tree view, modules within a course are visible, and new modules can be added or existing ones attached within a single screen. A screenshot is shared in **Figure 10**.

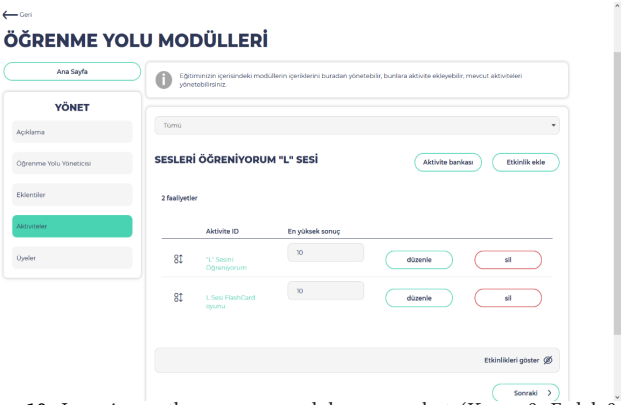

Figure 10. Learning path manager modules screenshot (Karay & Erdal & Ergüzen, 2025)

In designing the student module, the system was conceptually oriented toward elementary-level classes, focusing on basic literacy and numeracy activities. This level was considered appropriate because younger learners benefit strongly from multimodal content delivery (visual, auditory, and kinesthetic). However, this module has not yet been implemented in a live classroom setting; it remains a planned direction for future empirical testing.

Activities and Learning Modules

- **Course:** The pedagogical unit of the program; registration, access, and prerequisites are defined here.
- **Module:** Content packages (video, document, H5P, quiz, assignment, etc.) and sequencing rules.
- **Activity:** The atomic element with which the learner interacts (H5P interaction, SCORM package, quiz questions, file-upload assignments, etc.).

The system provides an enriched learning experience through H5P content types (interactive video, presentation, hotspot, timeline, etc.), and learner interaction data within the content (completion, score, attempts) can be monitored in real time.

Activity List View

Courses are supported with a variety of learning activities (quizzes, forums, SCORM content, video lessons, etc.), which students complete in order to progress.

The activity list presents all activities defined within a course in a tabular format. For each activity, the activity ID, highest score, edit, and delete options are displayed. This structure enables instructors to track learners' progress and update activity content when necessary. A screenshot is shared in **Figure 10**.

Adding Activities from the Activity Bank

This screen allows instructors to select from a variety of learning activities. For example, options such as file upload, long-answer questions, video, audio recording, slide presentation, or drag-and-drop are listed. This diversity supports the use of multiple sensory modalities in the learning process and addresses different learning styles. A screenshot is shared in **Figure 11**.

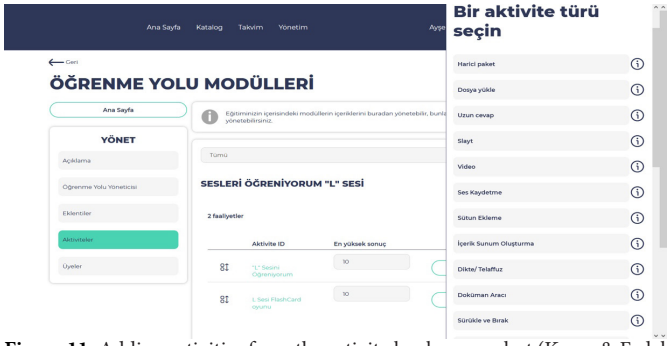

Figure 11. Adding activities from the activity bank screenshot (Karay & Erdal & Ergüzen, 2025)

Activity Type Selection Screen

This section, as a continuation of the previous screen, highlights assessment-focused activities such as fill-in-the-blank, flashcards, multiple-choice tests, timelines, and true/false questions. This module provides students with opportunities for reinforcement at both the cognitive and practical levels. A screenshot is shared in **Figure 12**.

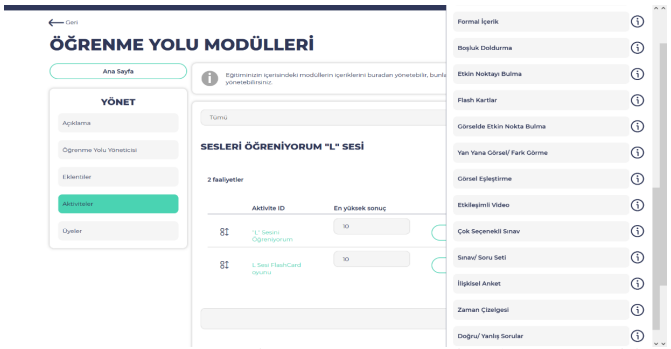

Figure 12. Activity type selection screen screenshot (Karay & Erdal & Ergüzen, 2025)

In-Class Messaging Screen

This screen includes a discussion area that enables real-time communication between instructors and students. Dedicated chat rooms for course groups support information sharing and social interaction among students and instructors. A screenshot is shared in **Figure 13**.

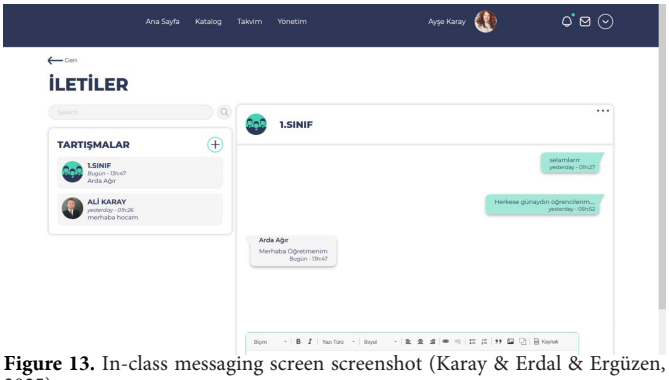

Figure 13. In-class messaging screen screenshot (Karay & Erdal & Ergüzen, 2025)

Student Profile Screen

The student profile displays identity information, enrollment date, last access time, earned badges, and enrolled courses. In addition, the trends section presents graphical data on the number of completed courses, time spent, and activity level within the last seven days. A screenshot is shared in **Figure 14**.

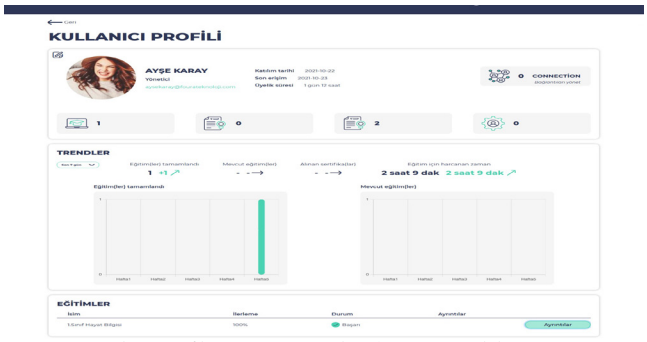

Figure 14. Student profile screen screenshot (Karay & Erdal & Ergüzen, 2025)

Student Achievement Screen

This screen lists the trainings completed by students, along with their success rates and statuses. For each course, details such as completion percentage, date, and results are presented comprehensively. In this way, students can clearly view their individual performance. A screenshot is shared in **Figure 15**.

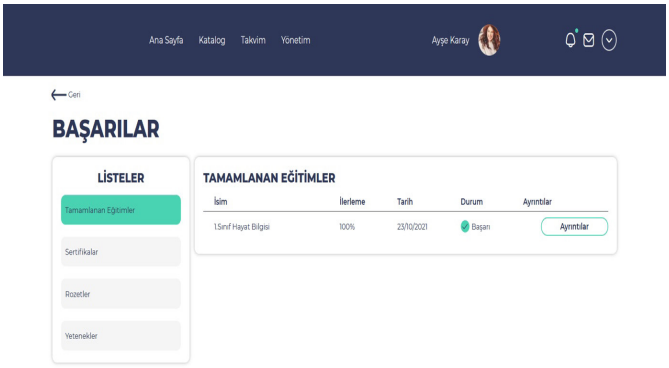

Figure 15. Student achievement screen screenshot (Karay & Erdal & Ergüzen, 2025)

Reporting and Statistic

Multi-layered reporting (global, course-level, user-level) allows monitoring of completion rates, average scores, number of attempts, activity duration, and time-series trends.

When certain activities are completed, skill achievements can be automatically linked; the logic of offering an "automatic skill module" based on target competencies is also supported. Certificates are generated once a course or learning path is completed.

User-Based Course Progress

A personalized reporting screen for each student details course-based progress, scoring, time spent, and earned badges. This enables students to monitor their individual development, while instructors can track student performance. A screenshot is shared in Figure 16.

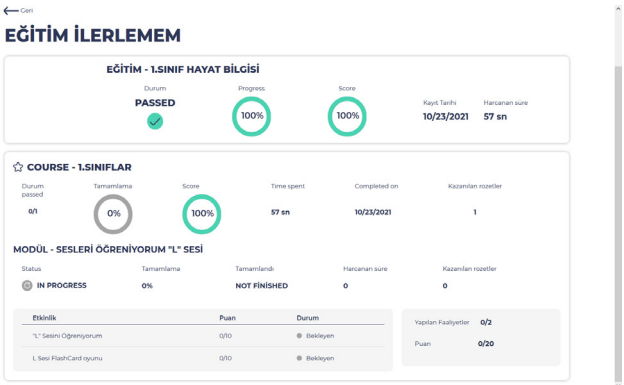

Figure 16. User-based course progress screen screenshot (Karay & Erdal & Ergüzen, 2025)

Training Statistics

This page presents summary statistics about the overall performance of the system in graphical form. Indicators such as learning progress percentage, completion rates, number of new users, and active users enable administrators to make data-driven decisions. A screenshot is shared in Figure 17.

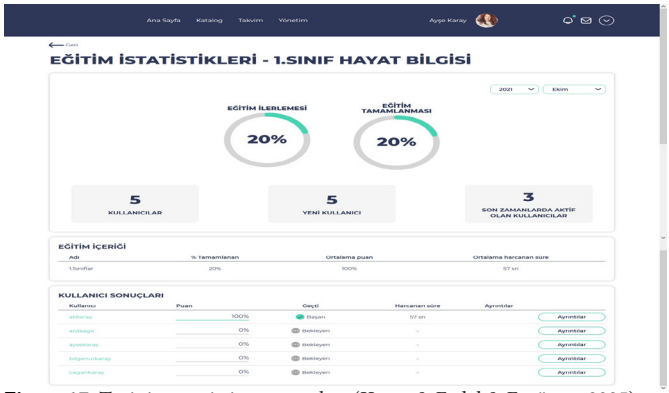

Figure 17. Training statistics screenshot (Karay & Erdal & Ergüzen, 2025)

School-Wide Statistics

These screens present institution-level data such as the number of users, course completion rates, distributions of active users, and overall success averages. Such statistics support decision-making at the administrative level and contribute to the improvement of educational policy. A screenshot is shared in Figure 18.

Event Creation and Calendar Management

The calendar module enables students and instructors to track course events on a date-based basis. Event start and end times, descriptions, and invited users can be displayed. This feature strengthens organization within the online learning process. A screenshot is shared in Figure 19.

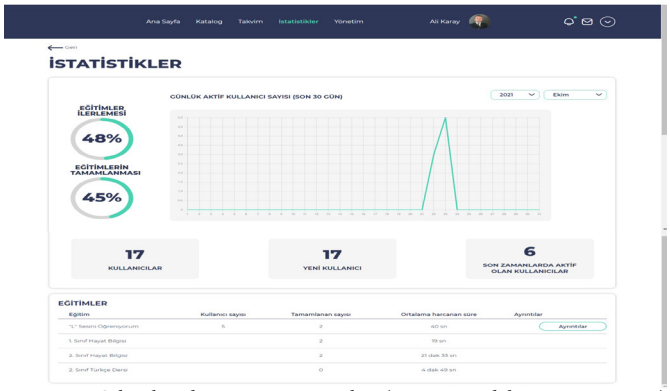

Figure 18. School-wide statistics screenshot (Karay & Erdal & Ergüzen, 2025)

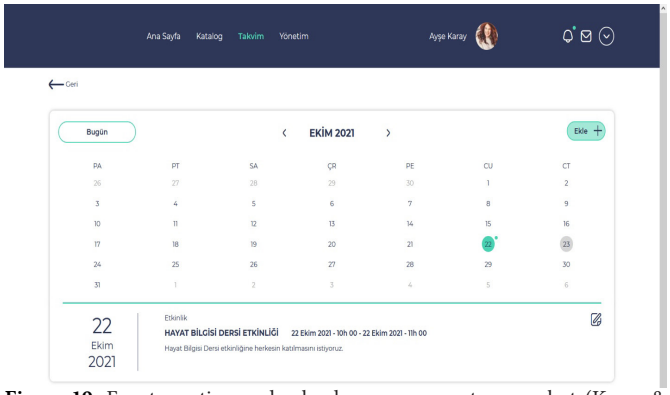

Figure 19. Event creation and calendar management screenshot (Karay & Erdal & Ergüzen, 2025)

Adding and Tracking Students in a Group/Class

Through this screen, education administrators can add new students to course groups, adjust the roles of existing members, and monitor participation dates. Group-based management helps instructors maintain control at the class level. A screenshot is shared in Figure 20.

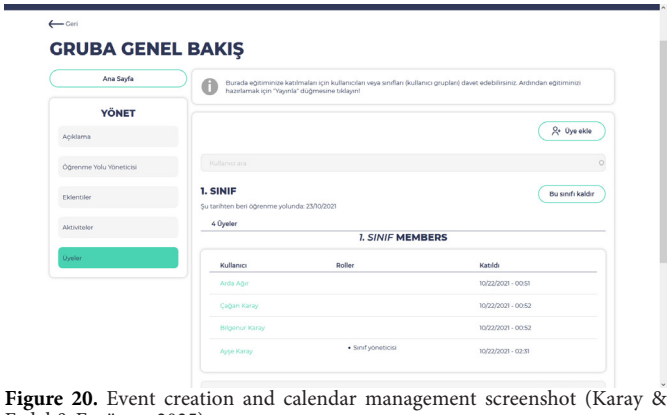

Figure 20. Event creation and calendar management screenshot (Karay & Erdal & Ergüzen, 2025)

DISCUSSION

Comparison with the Literature

Previous research (Romero & Ventura, 2020) emphasizes that adaptive systems improve student achievement, and our findings align with this. However, Graf and Kinshuk (2009) argue that personalization based solely on learning styles is insufficient, highlighting the need to include motivation and contextual factors.

A preliminary pilot study has not yet been conducted. Instead, the current phase of the project focused on the design

and technical development of the adaptive system. Empirical testing with real classroom data is planned for future research, subject to ethical approval and informed consent procedures.

International Contribution

In addition to its relevance for the Turkish context, this study is expected to provide insights into the broader discussion on adaptive learning. The redesigned modules on an open-source LMS may serve as an example of how adaptive personalization could be applied in different cultural and pedagogical settings, potentially offering a useful point of reference for future studies.

Contributions to Educational Technology

This system provides an original contribution to the field of personalized e-learning in Turkiye. While existing systems generally deliver standardized content, this system dynamically modifies content flow in real time through learner profiling algorithms.

Limitations

The system has not yet been tested with a large-scale learner sample, which limits the generalizability of findings. Additionally, the focus was on system development, not on empirical measurement of learning outcomes. These constraints should be addressed in future studies.

CONCLUSION

This study aimed to develop an adaptive e-learning system personalized according to learning styles. The system enhances the learning experience by considering individual differences among students, making it more meaningful and effective. Through learner profiling, content adaptation, and feedback mechanisms, the system enables each student to experience a unique learning journey.

- The system demonstrates that students with different learning profiles can reach the same learning objectives through different pathways. This supports the applicability of the learner-centered approach in digital environments.
- Data security is a critical factor in adaptive systems. The secure storage and anonymization of data collected during learner profiling will become increasingly important in the future.

Recommendations

- **Motivation and context:** Future studies should include not only learning styles but also motivation, learning context, and emotional states in the profiling process.
- **AI-powered recommendation engines:** The system can be enhanced with AI-based recommendation engines to provide learners with more flexible learning pathways.
- **Semi-automatic content generation:** Modules that support instructors in content development may reduce workload.
- Long-term studies should measure the impact of this system on academic achievement, student satisfaction, and learning retention.

In conclusion, this system makes a significant contribution to educational technologies in terms of personalization and adaptability. Such systems, which support learner-centered approaches in the process of digital transformation in education, are expected to become widely adopted in the future.

ETHICAL DECLARATIONS

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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