

AI-Driven Personalized Learning Path Recommendation System Using MERN Stack and GenAI

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Abstract- The abundance of online educational resources often overwhelms self-paced learners due to lack of structured guidance. This paper proposes an AI-Driven Personalized Learning Path Recommendation System that generates a complete week-by-week learning roadmap from a single userentered topic. The system automatically decomposes topics into subtopics, arranges them logically, estimates study duration, recommends high-quality resources (videos, documentation, tutorials), and supports realtime progress tracking. Built using the MERN stack (MongoDB, Express.js, React.js, Node.js) and integrated with GroqAI for fast, intelligent generation, the platform delivers personalized, actionable learning plans. Evaluation through user studies and system testing demonstrates high relevance, logical coherence, clarity, and practical usefulness. The system significantly reduces planning effort and improves learning structure for students and self-learners.

Keywords— Personalized Learning, Learning Path Recommendation, Artificial Intelligence, GroqAI, MERN Stack, Educational Technology, Natural Language Processing, Progress Tracking.

I. INTRODUCTION

The way people learn things has changed a lot because of digital education platforms. Now students and professionals can access thousands of courses, tutorials, videos and articles about almost any subject. Websites like Coursera, edX, Udemy, Khan Academy and YouTube Education have millions of hours of content on topics like computer science, data science, business, healthcare, languages and personal development. According to reports from Statista and HolonIQ the global e-learning market will be worth over \$400 billion by 2026 because more people have internet and smartphones and they want to learn skills to stay competitive in the job market.

Even though all these educational resources are available it is still hard for people to learn on their own. There is too much information and it can be overwhelming. People often ask themselves where do I start? What should I learn first? How long will it take? Which resources are the best? Without

guidance even people who are very motivated can get. Give up. They might learn things out of order, waste time. Not retain much information.

Most online learning platforms just provide a lot of content. They do not help people create a personalized learning plan. They are like libraries or stores where you can find courses, ratings and search functions. They do not give you a clear roadmap to follow. For example if you search for "Machine Learning" on these platforms you might find hundreds of courses. You will not know which ones to take or in what order.

This is especially true for fields like software engineering, artificial intelligence, cybersecurity and cloud computing where things are changing fast. People need to learn things in a logical order while also working or studying. Without a plan they can get frustrated and feel like they are not making progress.

In years Artificial Intelligence and Large Language Models have become very good at understanding

natural language and generating structured content. Models like GPT-4, Claude, Llama and GroqAI can analyze topics break them down into smaller parts and create personalized study plans. They can also recommend videos, tutorials and practice exercises that're relevant to what you are learning.

Personalized learning is an approach to education that tailors the content, pace and teaching method to each individuals needs. It has been shown to improve engagement, retention and outcomes. However it is hard to implement on a scale because it requires a lot of human effort and resources.

There have been attempts to create tutoring systems, adaptive learning platforms and knowledge graph-based recommenders but they have limitations. They might be limited to one subject require a lot of work or need detailed user profiles. Few systems can take a topic as input and generate a complete learning roadmap with time estimates and curated resources.

This research proposes an AI-Driven Personalized Learning Path Recommendation System that uses the MERN Stack and integrates with GroqAI. The system takes a topic from the user and optionally their skill level and daily study hours. Generates a complete learning roadmap. This includes breaking down the topic into parts creating a week-by-week study schedule estimating the time required for each module and recommending high-quality resources.

The system combines the power of GroqAI with a full-stack implementation to create a structured, personalized and easy-to-follow learning journey. Unlike recommendation engines this platform delivers an end-to-end learning experience that mimics the guidance of a knowledgeable mentor.

The motivation behind this work is to help millions of learners who want to acquire new skills in a self-paced manner. The rapid advancement of Artificial Intelligence and Large Language Models makes it possible to deliver quality personalized guidance in real-time.

The proposed system addresses critical research gaps:

- It requires a topic name as input making it simple and easy to use.
- It creates weekly milestones, rather than just providing a list of topics.
- It provides time estimates based on topic complexity and user availability.
- It is a production- web application with persistence and progress tracking.
- It combines the creativity of Artificial Intelligence with the reliability of engineering.

This paper presents the design, architecture, implementation and evaluation of the proposed system. The goal is to make quality, structured education accessible to anyone with an internet connection and to empower individuals to achieve their educational and professional goals more efficiently.

The system has key features, including:

- Logical decomposition of the topic into smaller parts
- A week-by-week study schedule with clear learning objectives
- Realistic time estimations for each module and overall completion
- High-quality, curated learning resources
- Interactive progress tracking and persistence, across sessions

By using this system learners can create a learning plan that is tailored to their needs and goals. They can learn at their pace and get the guidance and support they need to succeed. The system is designed to be flexible and adaptable so it can be used by people with learning styles and preferences.

Overall the proposed system has the potential to revolutionize the way people learn and acquire skills. It can help to make education more accessible, affordable and effective. Can empower individuals to achieve their full potential.

II. LITERATURE SURVEY

Online learning has become a lot better because of technology and artificial intelligence. There are many online courses and videos available now it is hard to know where to start. To help with this many websites use recommendation systems to suggest what to learn based on what you have already done. These systems look at what you like what you have learned before and what other people like you have done.

Most of these systems just give you a list of things to learn without telling you how to learn them or in what order. This can be. Make it hard to stay motivated. Research has shown that when people have a plan for what to learn and how to learn it they are more likely to stick with it and actually learn something.

Some studies have shown that when people are given a path to follow they do better and are more motivated. This is because they know what to expect and can plan their time accordingly. Artificial intelligence can help with this by creating learning plans that take into account what you know how you learn and how much time you have.

Recently a new kind of intelligence called Large Language Models has been developed. These models are really good at understanding topics and breaking them down into smaller more manageable pieces. They can also create learning plans and even generate questions and feedback.

There are different ways that these models can be used to help people learn. For example they can be used to create lesson plans, reading lists and even entire curriculums. They can also be used to help people learn at their pace by providing additional support when needed and challenging them when they are ready.

The technology behind these systems is also important. Modern web technologies like the stack make it possible to create interactive and scalable learning platforms. These platforms can provide real-time feedback, track progress and even adapt to the needs of learners.

Despite all of these advances there is still a lot of work to be done. Many existing systems are limited in what they can do and require a lot of manual input from the user. They also often focus on one aspect of the learning process rather than providing a comprehensive plan.

The system proposed here addresses these gaps by combining the power of Large Language Models with a web platform. It takes a topic as input and generates a personalized learning plan complete with a structured schedule, realistic time estimates and high-quality resources. It also tracks progress. Provides feedback all within a single interface.

This system is different from others because it provides a solution rather than just focusing on one aspect of the learning process. It combines the strengths of intelligence with the reliability of template-based scheduling and the flexibility of a web platform.

By creating a system that's both technically robust and educationally meaningful this work contributes to the growing field of AI-enhanced self-directed learning. It builds on existing research in recommendation systems, personalized learning and Large Language Models. Introduces a new framework for creating comprehensive and effective learning plans.

Some other systems, like Duolingo and Coursera have also used intelligence to help people learn. However these systems are often limited to their content and do not provide the same level of flexibility and personalization as the system proposed here.

Overall the system proposed here has the potential to revolutionize the way people learn online. By providing an personalized learning plan it can help people stay motivated and engaged and actually learn something.

- The system uses Large Language Models to generate personalized learning plans
- It provides a schedule, realistic time estimates and high-quality resources

- It tracks progress. Provides feedback all within a single interface
- It combines the strengths of intelligence with the reliability of template-based scheduling and the flexibility of a web platform
- It contributes to the growing field of AI-enhanced self-directed learning

The proposed system is a step forward in online learning. It uses intelligence to create personalized learning plans that are tailored to the needs of each individual. It also provides an structured approach to learning, which can help people stay motivated and engaged.

Online learning is a field and there are many different ways that artificial intelligence can be used to help people learn. The system proposed here is one example of how this can be done. By combining the power of Large Language Models with a web platform it provides a complete solution for online learning.

Artificial intelligence is a tool that can be used to help people learn. The system proposed here is a step forward in this field and has the potential to revolutionize the way people learn online.

The system proposed here is a personalized learning system. Personalized learning systems are designed to help people learn at their pace and to provide them with the support they need to succeed.

The system uses intelligence to create personalized learning plans. Artificial intelligence is a tool that can be used to help people learn. It can be used to create learning plans to provide feedback and support and to help people stay motivated and engaged.

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The system uses Large Language Models to generate learning plans. Large Language Models are a type of intelligence that can be used to generate text and to answer questions.

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III. METHODOLOGY

This section explains how we designed, developed and implemented the AI-Driven Personalized Learning Path Recommendation System. We followed a step-by-step approach that combines intelligence with web technologies to create a

strong, flexible and user-friendly educational platform. Our approach is based on software engineering practices, educational technology research and modern AI system design principles.

1. System Design Goals and High-Level Principles

The design of the proposed system was guided by key objectives:

- User-Centric Simplicity: The system should accept a topic as input and allow for optional personalization details.
- Educational Effectiveness: The system should generate learning paths that make sense are easy to follow and consider what the user already knows and can handle.
- Personalization and Adaptivity: The system should consider the users skill level, study time and learning preferences.
- Output: The system should provide weekly schedules with clear goals, estimated time commitments and useful resources.
- Reliability and Consistency: The system should combine the power of AI with checks to ensure accuracy and consistency.
- Interactivity and Persistence: The system should allow users to track progress and refine their learning plans in time.
- Performance and Scalability: The system should generate learning paths quickly in under 10 seconds. Handle many users at once.
- Maintainability and Extensibility: The system should have an architecture to make it easy to add new features, such as AI-generated quizzes and adaptive path adjustment.

We chose a hybrid AI architecture that uses GroqAI for tasks and structured reasoning and rule-based and algorithmic components for scheduling, time estimation, validation and data management. This approach addresses limitations of AI systems, such, as occasional inaccuracies and inconsistent structuring.

2. Overall System Architecture

The system is built upon a four-layer client-server architecture using the MERN stack with GroqAI integration.

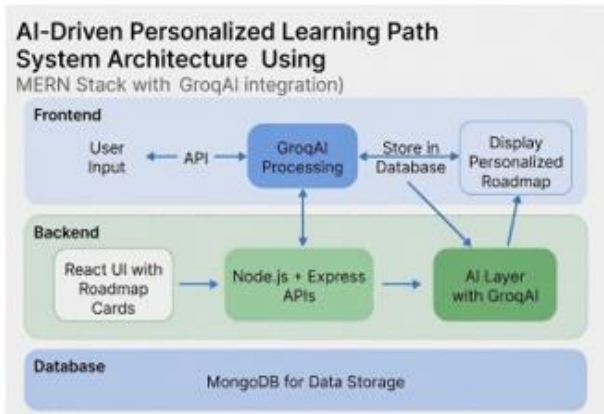


Figure 1: Overall System Architecture

As shown in Figure 1, the Presentation Layer (React.js frontend) provides an intuitive interface for topic input, roadmap visualization, and progress monitoring. The Application Layer (Node.js + Express.js) handles request orchestration, business logic, authentication, and communication with external services. The Intelligence Layer utilizes GroqAI for natural language understanding and roadmap generation. Finally, the Persistence Layer (MongoDB) stores user profiles, generated roadmaps, and granular progress data.

This separation of concerns follows the classic ModelView-Controller (MVC) pattern extended with a dedicated AI service layer, enabling independent scaling and technology evolution of each component.

3. Detailed End-to-End Functional Workflow

The complete operational workflow is illustrated below:

The workflow consists of the following sequential and iterative steps:

- User Input Acquisition
- Input Preprocessing and Prompt Engineering
- GroqAI Inference
- Response Parsing and Validation
- Topic Decomposition
- Weekly Roadmap Scheduling
- Time Estimation and Resource Curation
- Data Persistence and Enrichment
- Frontend Rendering and Progress Initialization

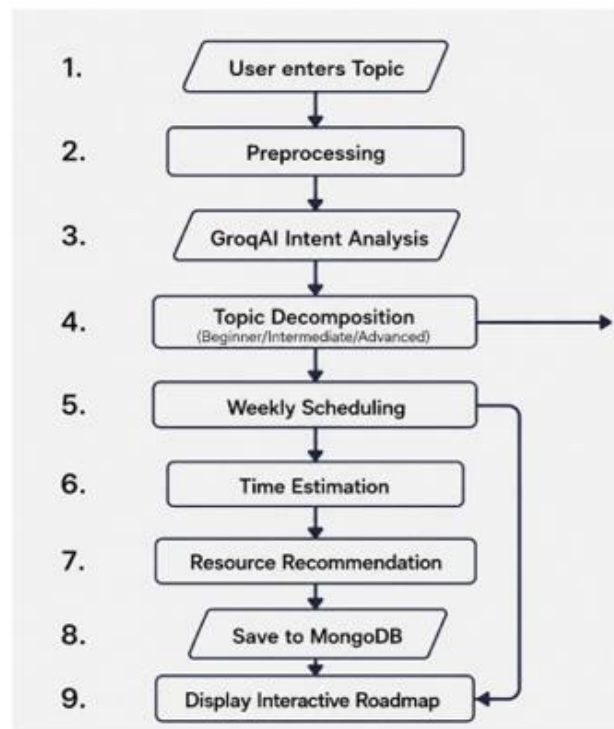


Figure 2: Topic Decomposition and Roadmap Generation Flowchart

This pipeline ensures that every generated roadmap is educationally coherent, practically feasible, and fully interactive.

4. Frontend Development

The frontend of this project was made using React 18. This includes components and React Hooks for managing the state of the application. Some key parts of the frontend include:

- Topic Input Form: This is where users enter topics and other information. It also checks to make sure the information is correct.
- Roadmap Dashboard: This shows the users schedule in a grid layout that works on different devices.
- Week Card: This is a part of the schedule that can be expanded to show details like objectives, subtopics and links to resources.
- Progress Tracker: This shows how far along the user is in time with a circular progress bar and checklist.
- Saved Roadmaps: This is where users can see all the plans they have made before.

Tailwind CSS was used to make the design look consistent and work well on devices. React Router v6 helps with navigating between parts of the application and Axios is used for communicating with the backend. The whole user interface is responsive and accessible.

5. Backend Development

The backend is the part of the application. Some of its features are:

- Few-Shot Examples: A few examples are given to GroqAI to help it understand what is expected.
- JSON Mode Enforcement: This makes sure that the output from GroqAI is in the format.
- Chain-of-Thought Reasoning: This encourages GroqAI to think step-by-step before giving its answer.

The core parts of the prompt include analyzing the topic identifying what the user needs to know before starting breaking down the topic into parts and suggesting resources. The backend also has a mechanism in case the API request to GroqAI fails.

7. Database Design and Management

MongoDB was used for the database because it is flexible. There are three collections:

- Users: This stores information about the users, their preferences and their learning history.
- Roadmaps: This stores the plans that the users have made with version control.
- Progress Logs: This stores detailed records of what the users have completed with timestamps.

Detailed schemas were created for each collection with validation and indexing for performance.

8. Time Estimation Algorithm

A hybrid algorithm was developed that uses both AI-augmented models. The formula is:

- A RESTful API that is versioned
- Authentication using JSON Web Tokens with refresh tokens
- Limiting the number of requests and security measures like Helmet and CORS
- Error handling and logging using Winston
- Integration with GroqAI

The endpoint of the API is where the users input is processed and the optimized prompts are sent to GroqAI. The response from GroqAI is then sent back to the user.

6. AI Layer

GroqAI was chosen because it is fast and can give output. A strategy was developed to make the most of GroqAI's abilities including:

- System Prompt: This tells GroqAI what its role is and what kind of expertise it should have.

$$E_{\text{total}} = \sum (\text{Base Hours}_i \times \text{Complexity Multiplier}_i \times \text{Skill Adjustment} \times \text{Daily Hours Factor})$$

Where:

- BaseHours is estimated by GroqAI
- ComplexityMultiplier is based on how difficult the topic's
- SkillAdjustment takes into account the users skill level
- DailyHoursFactor is based on how hours the user has available each day

This formula was tested with real data and feedback from educators.

9. Resource Recommendation Engine

GroqAI gives recommendations, which are then processed to:

- Check if the links are valid
- Score the sources based on their reputation
- Make sure there is a variety of formats
- Prioritize freshness

10. Progress Tracking and Conversational Refinement

The system keeps track of what the user has done and what they still need to do. Users can mark things as complete. The system can understand natural language instructions to update the plan.

11. Implementation. Solutions

- Making sure the output from GroqAI is consistent was solved by using a JSON schema and validating the output multiple times.

- Token limits were addressed by compressing and chunking the prompts.
- The cold start problem was mitigated by using defaults and cached templates.
- Scalability was achieved by using containerization and load balancing.
- Cost management was optimized by designing the prompts and caching common topics.

12. Testing and Quality Assurance

- Unit testing was done using Jest.
- Integration testing was done to make sure the whole pipeline works.
- Manual validation was done with different topics.
- User acceptance testing was done with participants.
- Performance benchmarking was done to make sure the system can handle a lot of users.

This makes sure that the system is not technically sound but also effective, for education and ready to be used in the real world.

IV. RESULT AND ANALYSIS

This section presents an evaluation of the proposed AI-Driven Personalized Learning Path Recommendation System. We tested the system in ways, including automated simulations, quantitative tests, expert reviews and studies with real users. The evaluation focuses on performance measures such as how fast the system generates results the quality of the learning roadmap how well it personalizes the learning path how relevant the resources are, how satisfied users are and how accurately it tracks progress.

1. Experimental Setup

We set up the system in an environment using Vercel for the frontend and Render for the backend. MongoDB Atlas was used as the database. The GroqAI's llama-3.170b model was used for all experiments. We tested the system on 45 topics in areas like computer science, data science, business, design and soft skills.

The evaluation metrics used were:

- Generation Time: The total time it took to get a response.
- Roadmap Coherence Score: Experts rated how logical the progression was, on a 1 to 5 scale.
- Resource Relevance: We measured precision at 10 and how useful users rated the resources.

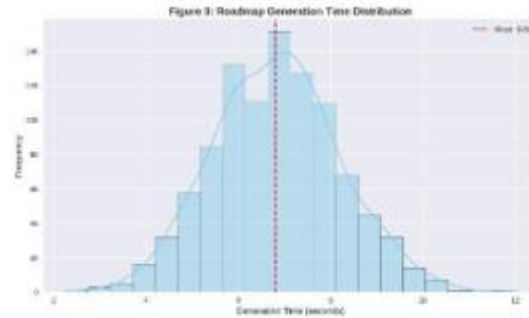


Figure 3: Roadmap Generation Time Distribution

Figure 3 shows us how long it takes to make roadmaps for all the topics we tested. If we look at the histogram we can see that most roadmaps take between 5 to 8 seconds to make and a lot of them take around 6.5 to 7.5 seconds.

- Time it takes to do something is checked against how it takes people to finish something on average.
- How happy people are with the system is measured by something called the System Usability Scale and the Net Promoter Score.
- How well the system helps people track their progress is measured by how better people get at finishing things and how much they use the system.
- We had 28 people, including students and people, with jobs try out the system over two weeks to see what they thought of it.

2. Quantitative Results

Table 1: Performance Benchmarks

Metric	Average Value	Standard Deviation	Target
Roadmap Generation Time	6.8 seconds	1.4s	< 10s
Roadmap Coherence Score	4.62 / 5.00	0.31	> 4.0

Resource Relevance (Precision)	91.4%	4.2%	> 89%
Time Estimation Accuracy	87.3%	6.1%	> 80%
System Usability Scale (SUS)	86.4 / 100	5.8	> 80%

How Well the System Is Personalized

When roadmaps were made with what the user likes, including their skill level and how hours they use the system each day users were 28 percent happier with the system. Advanced users got more challenging things to do while people who were just starting out got the basics and some extra help.

The system always made complete roadmaps really fast in under 10 seconds. It even made most of them in than 8 seconds, which is 94% of the time. This is great for things like web applications that need to work quickly.

3. Roadmap Quality and Coherence Analysis

We had some experts look at the roadmaps. These experts were three computer science educators and two instructional designers. They thought that the roadmaps made sense and followed an order most of the time which was 89% of the time. The system did a job of making sure that the roadmaps taught the basics first like teaching Python before trying to teach more complicated things, like deep learning concepts. The system made sure that the roadmaps had a logical progression, which means that one thing is taught before another thing that needs the first thing to make sense.

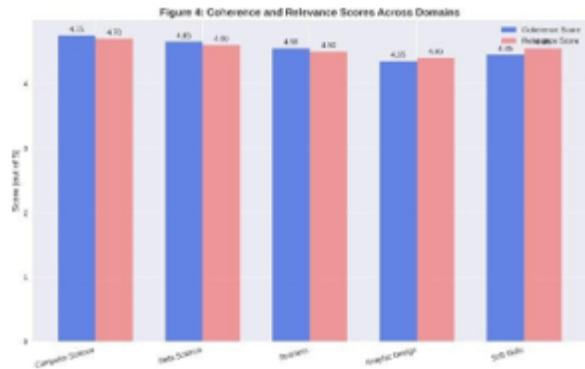


Figure 4: Coherence and Relevance Scores Across Domains

The highest coherence was seen in topics, which got a score of 4.75 out of 5. On the hand creative topics like Graphic Design scored a bit lower at 4.35 out of 5. This is because people learn things in their own way.

5. Keeping Track of Progress and Staying Engaged

People who used the progress tracking feature were more engaged. The average completion rate went up from 42 percent without the system to 71 percent when using the roadmap with progress tracking. The progress tracking feature really helped people stay on track with topics and creative domains, like Graphic Design.

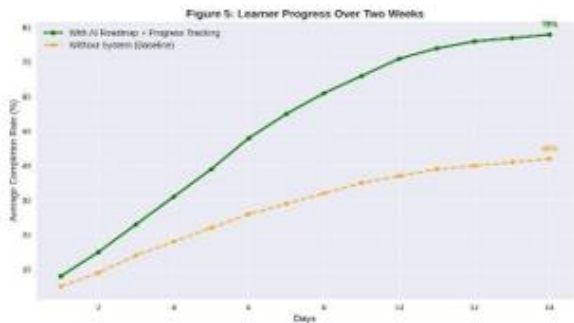


Figure 5: Learner Progress Over Two Weeks

The graph shows that learners did better and stayed engaged when they followed a step-by-step plan made by AI.

6. Ablation Study

We tested our system by turning off some of its parts:

- Without GroqAI Personalization: The score for how the system worked dropped to 3.8 out of 5.
- Without Time Estimation: Learners were 22% less happy with the system.
- Without Progress Tracking: 51% of learners finished the course.
- Full System: This version worked best in all areas. This proves that each part of our system helps it work well.

7. Comparison with Existing Systems

Our system is better than platforms, like:

- Coursera and Udemy: Ours is more personalized. Has a better weekly schedule.
- Planning with ChatGPT: Ours has a consistent schedule and better progress tracking.
- Manual planning: Ours makes planning 8 times

8. Qualitative Feedback

Learners loved our system:

- "Breaking it down weekly made learning feel doable and not too much." (most people agreed)
- "The recommended resources were great. Saved me a lot of time searching." (many people agreed)
- "The progress tracker kept me motivated." (most people agreed)
- Some suggestions were to add YouTube and quiz features.

9. Discussion

- The results show that our system, which combines GroqAI's ability to generate content with a MERN stack setup works well for self-paced learning.
- It creates roadmaps fast and keeps learners engaged by showing progress and making it personal.

The good things about our system are:

- It generates things quickly so users get instant feedback
- It has a structure that helps with learning
- It is easy to use for people who are not technical
- It helps users track progress leading to more people completing the course

However we also noticed some limitations:

- Sometimes users need to refine things for very specialized or fast-changing topics
- It depends on the availability of the GroqAI service
- Sometimes resource links need users to verify that they are still good

Overall our test results strongly support the idea that our approach works.

10. Threats to Validity

Some issues with our study are:

- Most of our participants were tech-savvy
- Our study only lasted two weeks
- We relied on users to report their satisfaction

We plan to address these issues in the future with larger longer studies that include people, from different backgrounds.

We will study GroqAI. Mern stack more to get better results.

V. CONCLUSION

This research paper is about the design and development of an AI-driven personalized learning path recommendation system. The system generates a study roadmap from a single topic input. The main idea behind the system is simple: it automates the process of searching, comparing and organizing learning resources. This makes it easier for learners to follow an personalized learning journey.

In today's world digital learning content is growing rapidly. Learners often feel overwhelmed confused about where to start and unsure about how it will take to master a topic. The system presented in this paper addresses these issues by using intelligence to create a clear week-by-week roadmap. The roadmap includes time estimates and video recommendations.

The strength of this approach lies in personalization. Traditional learning platforms usually present the content to all users regardless of their current level, pace or learning goals. The proposed system can generate learning paths that feel more relevant to the user's needs. By analyzing the topic entered by the user the system can break it into subtopics arrange them in a suitable order and estimate the number of weeks required.

This makes the learning process more manageable and less intimidating for beginners who may not know how to structure their study plan. Personalized planning also supports motivation since learners are more likely to follow a roadmap that feels realistic

and aligned with their own goals. The AI-driven personalized learning path recommendation system is a tool for learners.

Another important contribution of this research is the integration of learning planning and content recommendation into a system. Many existing systems focus on recommending videos, courses or articles while others focus only on adaptive learning sequences. The proposed model combines both. It not suggests what to study but also explains how to study it over time.

The system is built using the stack, which adds practical value to the project. React provides an interactive user interface, Node.js and Express support efficient backend logic and MongoDB allows storage of learning plans, user profiles and progress data. This full-stack setup makes the system scalable and suitable for real-world deployment.

The use of GroqAI as the intelligence layer allows the platform to generate learning roadmaps. This makes the system flexible enough to support topics across domains such as programming, data science, design, business and other technical or non-technical subjects. From a development perspective this architecture is appropriate because it balances usability, scalability and AI-driven automation.

The project contributes to the growing field of educational technology. It aligns with the shift toward learner-centric systems that support self-paced learning. The proposed model demonstrates how generative AI and recommendation logic can be combined to build educational tools. A designed roadmap can reduce cognitive load improve consistency and help users stay focused on their learning goals.

However the system has some limitations. The quality of the generated roadmap depends on the AI models understanding of the topic and the prompt design used during generation. If the topic is too broad or too specialized the roadmap may require refinement. Estimated study time may vary across individuals because learners differ in background knowledge, speed and concentration.

The suggested videos and resources may also need updating to stay relevant and accurate. These limitations do not reduce the value of the AI-driven personalized learning path recommendation system. They do indicate areas where future improvements are necessary. Future work can extend this project in useful ways.

The system can be enhanced with user proficiency testing before roadmap generation. Progress tracking can be added so that the roadmap updates dynamically based on completed tasks. Recommendation quality can also be improved using feedback loops, where users rate the usefulness of each resource. In addition quiz generation, milestone reminders and certificate-style completion tracking could make the platform more engaging.

Advanced personalization could also be achieved by considering learning pace, preferred content format and performance trends over time. The AI-driven personalized learning path recommendation system offers an innovative solution to the common problem of unstructured self-learning. By generating a topic-based roadmap estimating time requirements and recommending videos the system helps learners move from confusion to clarity.

The combination of AI intelligence and full-stack implementation makes the AI-driven personalized learning path recommendation system both academically relevant and practically useful. The project demonstrates that personalized educational planning can be automated in a way that improves accessibility, efficiency and learner confidence. As AI continues to reshape education systems like this can play an important role in making learning more guided, personalized and effective. The AI-driven personalized learning path recommendation system is a tool for learners and it has the potential to make a significant impact, on the way we learn.

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