

INTELLIGENT AGENTS IN EDUCATION: ARCHITECTURE OF A MULTI-AGENT SYSTEM FOR LEARNING

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***Abstract:** The rapid development of artificial intelligence technologies has significantly influenced modern educational systems. Intelligent agents are increasingly used to support personalized learning, automate assessment, and provide adaptive educational content. This paper explores the role of intelligent agents in education and analyzes their application in intelligent tutoring systems and adaptive learning environments. A conceptual architecture of an AI-powered multi-agent learning system for mathematics education is proposed. The architecture integrates intelligent agents, machine learning models, learning management systems, and educational databases to create a scalable and adaptive learning environment. The proposed system demonstrates how multiple agents can cooperate to provide personalized feedback, generate exercises, evaluate student performance, and recommend learning materials. The paper also discusses the benefits, limitations, and future research directions of intelligent agent technologies in education.*

***Keywords:** intelligent agents, multi-agent systems, artificial intelligence in education, intelligent tutoring systems, adaptive learning*

1. Introduction

Artificial intelligence technologies have become an important part of modern educational environments. With the increasing availability of digital learning platforms, there is a growing need for intelligent systems capable of supporting students in the learning process.[5] Intelligent agents represent autonomous software entities that can perceive their environment, process information, and perform actions in order to achieve specific goals.[8]

In education, special computer programs are used to create learning environments that adapt to each student's needs. These programs can watch how students learn, check what they know, and change the learning material on the fly. This means students get a learning experience that's just right for them, and they're more likely to stay engaged and interested.[2]

One of the most significant applications of intelligent agents in education is the development of intelligent tutoring systems (ITS). These systems simulate the behavior of human tutors by providing explanations, hints, and feedback during the learning process. Intelligent tutoring systems rely on artificial intelligence techniques to analyze student performance and determine appropriate instructional strategies.[5]

Adaptive learning is another key idea that changes how learning materials are presented based on how well each student is doing. It's like having a personal teacher who adjusts the lessons to fit each student's needs. Intelligent agents, which are like computer programs, help make this happen by keeping an eye on how students are performing and suggesting activities that will help them learn better. This way, students can learn at their own pace and focus on the things they need to work on. It's a more personalized way of learning that can be really effective.

Recent research has also focused on multi-agent systems (MAS), where several intelligent agents cooperate to perform complex tasks. In educational platforms, multi-agent systems can coordinate different learning functions such as problem generation, student modeling, assessment, and recommendation of learning materials.[6]

This study looks at how intelligent agents can be used in education and suggests a basic plan for a system that uses multiple agents to help teach math. The plan shows how different agents and artificial intelligence models can work together on an educational platform to make learning better.

2. Intelligent Agents in Education

Intelligent agents are like computers that can think for themselves. They can look around, make choices, and do things to get what they want. In schools, these agents help students learn by watching what they do and giving them help that's just right for them. [1]

One of the main benefits of using intelligent agents in education is that they can change the learning material to fit the needs of each student. To do this, they look at things like how well the student does on tests, how long it takes them to answer questions, and what kinds of mistakes they make. This helps the intelligent agent figure out how well the student understands the material and gives them the right lessons to help them learn better.

Intelligent agents can play a big role in helping students work with complicated educational software. They can act like a guide, showing users how to get around the system, answering their questions, and giving them suggestions on what to do next. From what we've learned before, these agents can look at how a user is behaving and then give them help that makes sense for what they're doing at the time. [2]

Intelligent agents have another key use in learning management systems. They can keep an eye on what students are doing and spot potential issues, like when someone misses an assignment or isn't very engaged. If that happens, the system can automatically send reminders or offer tips on how to do better in school.

Today's educational tools often use special techniques to understand and talk like humans. These tools can have conversations with students and explain things in a way that's similar to how a human teacher would. They can even ask questions and have discussions with learners, making it feel like they're talking to a real person. This makes learning more fun and easier to understand. [3]

For instance, consider the AutoTutor system, it's a great example of how this approach works. This system uses conversations to help students really get a handle on tough ideas. [4] Research has shown that systems like this can make a big difference in how well students learn and understand the material they're studying. By using dialogue to guide them, students can gain a deeper understanding of complex concepts, which is really important for their educational success.

3. Adaptive Learning and Intelligent Tutoring Systems

Adaptive learning systems represent a major development in educational technology. These systems dynamically modify learning content according to the student's performance and learning progress. Intelligent agents play a crucial role in these systems by analyzing learning data and adjusting the difficulty of tasks. [2]

For example, if a student successfully solves a series of mathematical exercises, the system may gradually increase the complexity of subsequent tasks. Conversely, if the student struggles with certain concepts, the system may provide additional explanations or easier exercises.

Adaptive learning platforms use something called learning analytics, which is like looking at a lot of data about how students learn and behave. This helps teachers figure out if a student is going to struggle with something before it happens. It's kind of like having a personal assistant that can spot patterns in the data and say "hey, this student might need some extra help with this". Then, teachers can step in and give that student the support they need, which can make a big difference in how well they learn. By using this kind of technology, educators can get ahead of potential problems and help students succeed.

Intelligent tutoring systems combine several components, including a domain model, a student model, and a pedagogical model. The domain model contains knowledge about the subject being taught, while the student model tracks the learner's knowledge and progress. The pedagogical model determines how the system should respond to the learner's actions.

When all these parts work together, smart teaching systems give students personalized help and feedback as they learn.

4. Multi-Agent Systems in Educational Platforms

Multi-agent systems consist of several intelligent agents that cooperate to achieve a common objective [7]. In educational environments, different agents can perform specialized tasks related to learning management and content delivery.

For instance, one agent might look at how well students are doing, while another agent creates practice problems or checks answers. When these agents work together and share what they know, they can make a learning environment that adjusts really well to each student's needs.[1]

Using systems with multiple agents has a lot of benefits. For one, it makes educational platforms more flexible and able to grow. You can add new agents without having to make big changes to the existing setup. This means you can easily add new features and functions as needed, which is really useful for platforms that need to adapt to different users and situations.

In mathematics education, multi-agent systems can provide automated assistance during problem solving. For instance, an agent may generate practice problems, another agent may evaluate the student's solution, and a tutor agent may provide hints or explanations.

Some new research is looking into using special computer programs, called generative student agents, to mimic how students act and to test different ways of learning in schools.

5. Methodology and Proposed System Design

This research looks at how smart computer systems can help students learn in schools. It uses what we already know about computer programs that teach and adapt to students, as well as systems that have many parts working together. By putting these ideas together, the research suggests a plan for a math learning website that uses artificial intelligence to give each student the help they need. The goal is to create a system that can understand what each student is struggling with and provide the right support to help them learn. This could be a big help for students who need a little extra assistance, and it could also make learning more fun and engaging. The research is trying to figure out how to make this kind of system work, so that students can get the most out of their education.[9]

The main objective is to design an educational platform capable of adapting learning materials and instructional strategies to the individual needs of each learner. To achieve this, the proposed system integrates several intelligent components that work together to monitor student progress, generate appropriate learning tasks, and provide personalized feedback.

The proposed system follows a layered architecture, in which different components interact to support the learning process. The architecture consists of five main layers: the User

Layer, the Learning Management System (LMS) Layer, the Multi-Agent System Layer, the Artificial Intelligence Layer, and the Data Layer. Each layer performs a specific role in managing the interaction between learners, educational content, and intelligent services.[9]

At the core of the system is the multi-agent system, which coordinates the main learning functionalities. The system includes several specialized agents responsible for different tasks within the learning environment. One of the key components is the Student Modeling Agent, which maintains information about the learner's knowledge level, learning progress, and interaction patterns. This information is used to personalize the learning experience and adjust the difficulty of educational materials accordingly.

So, there's this other key part called the Problem Generation Agent. It makes math exercises that get harder or easier depending on how the learner is doing. When a student turns in their answer, the Assessment Agent checks it out and finds any mistakes or wrong ideas they might have. Then, the Tutor Agent uses that information to give the learner explanations, feedback, or hints to help them understand how to solve the problem better. This way, the learner can get a better grasp of the whole process.

The system also has a Recommendation Agent that helps students by suggesting more learning materials, exercises, or topics based on how well they are doing. At the same time, there's an Analytics Agent that collects and analyzes data on how students interact with the system to find patterns in how they learn and predict any difficulties they might have. This way, the system can give students a more personalized learning experience.

To support adaptive learning behavior, the system integrates several artificial intelligence models. These include natural language processing models for communication with students, adaptive learning algorithms for content personalization, and knowledge tracing models for monitoring student mastery over time. The models rely on data stored in several databases, including a student model database, a learning content database, interaction logs, and a knowledge graph of mathematical concepts.

The idea behind this approach is to make it easy to adapt and grow as new technologies and tools become available. By breaking it down into smaller parts, the system can work well with big education platforms and can be easily updated with new artificial intelligence or machine learning models without having to overhaul the whole thing. This way, the system can keep up with the latest developments and improvements in the field, making it a great foundation for building a strong and flexible learning environment.

So, let's break down how adaptive learning works. It's like a cycle where everything is connected. The student starts by trying to complete a task, and then the system assesses how

they do. After that, the student gets feedback on their performance, and the system suggests new exercises for them to try. This whole process is like a workflow, and it's shown in **Figure 1**. The main idea is that the system is always adapting to the student's needs, so they can learn in the best way possible. It's a pretty straightforward process, but it's really important for making sure students get the most out of their learning experience.

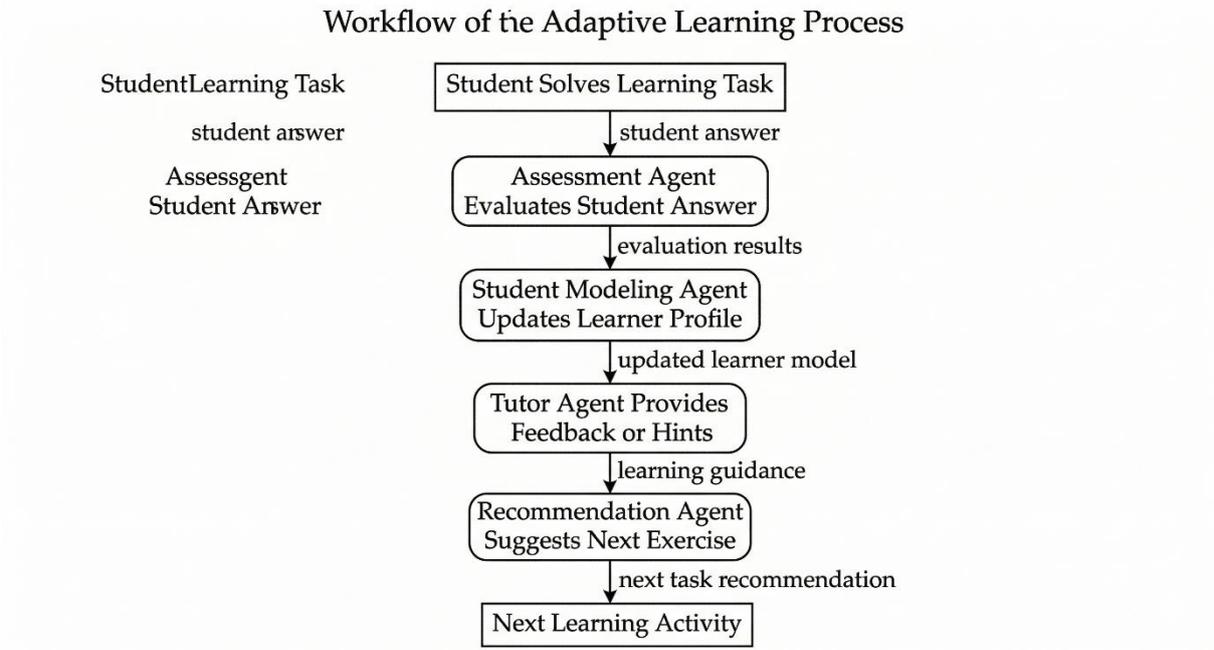


Figure 1. The workflow of the adaptive learning process

6. System Architecture of the Proposed Multi-Agent Learning System

This section presents a conceptual architecture of a multi-agent learning system designed to support mathematics education.

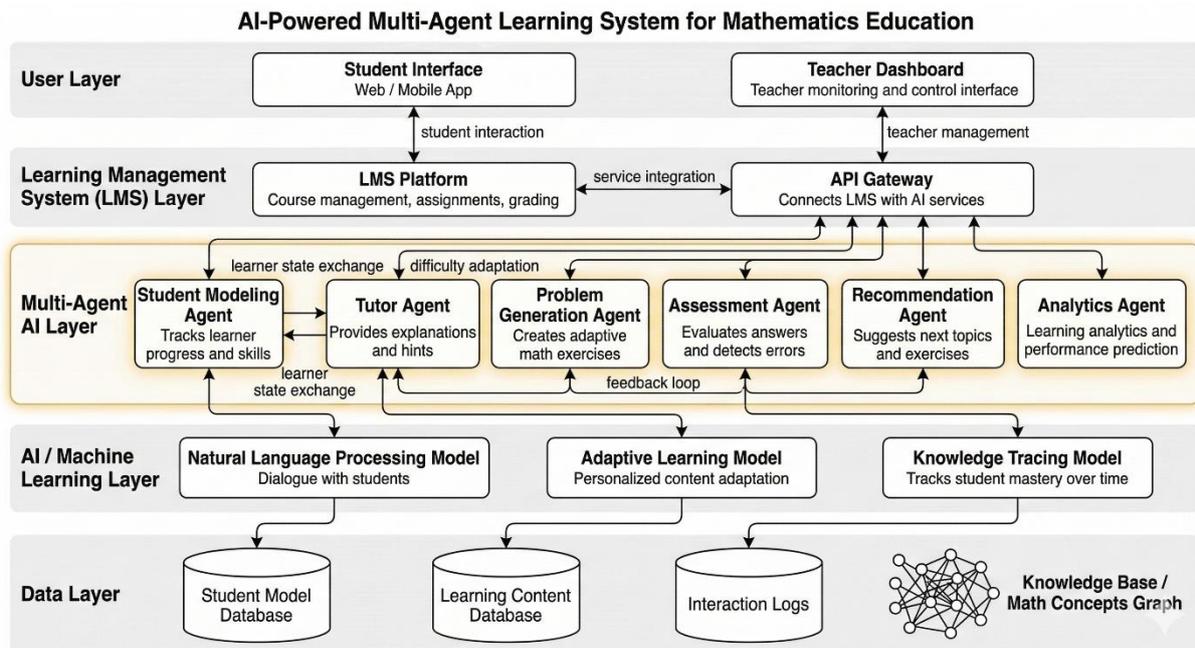


Figure 2 – AI-Powered Multi-Agent Learning System for Mathematics Education

The proposed architecture consists of several layers:

- **User Layer**

This layer represents the interaction between users and the system. It includes the student interface and the teacher dashboard.

- **Learning Management System Layer**

The LMS layer manages course content, assignments, and grading. It communicates with the AI components through an API gateway.

- **Multi-Agent Layer**

This layer represents the core of the intelligent system and includes several specialized agents:

- Student Modeling Agent
- Tutor Agent
- Problem Generation Agent
- Assessment Agent
- Recommendation Agent
- Analytics Agent

- **AI / Machine Learning Layer**

This layer includes artificial intelligence models used to support adaptive learning:

- Natural Language Processing models
- Adaptive learning models

- Knowledge tracing models

- **Data Layer**

The data layer stores student models, learning materials, interaction logs, and knowledge bases.

The interaction between different agents during the learning process is illustrated in **Figure 3**. The diagram demonstrates how the Student Modeling Agent, Problem Generation Agent, Assessment Agent, Tutor Agent, and Recommendation Agent communicate and exchange information in order to support adaptive learning.

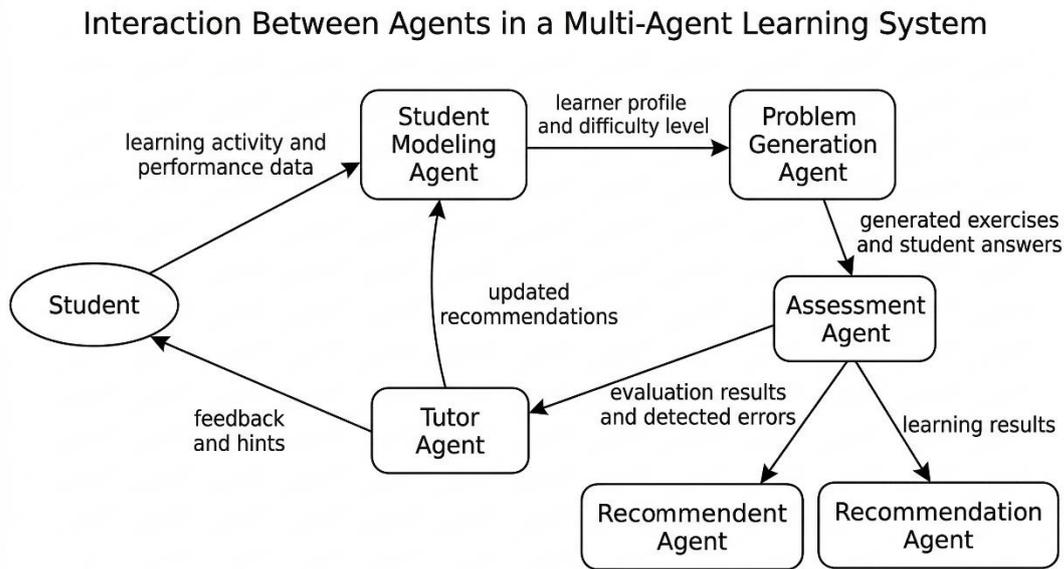


Figure 3. Interaction between agents in the multi-agent learning system.

7. Benefits of the Proposed System

The proposed multi-agent architecture provides several significant advantages for modern educational environments. One of the most important benefits is the ability to support personalized learning experiences. By continuously analyzing student performance, learning behavior, and interaction patterns, the system can dynamically adapt educational content to the individual needs and abilities of each learner. This adaptive approach allows students to progress at their own pace and receive targeted assistance when difficulties arise.

Another important advantage of the proposed architecture is the implementation of automated feedback and assessment mechanisms. Intelligent agents can evaluate student responses, detect common mistakes, and provide immediate feedback. This functionality not only improves the efficiency of the learning process but also reduces the workload of

instructors, allowing them to focus on more complex pedagogical tasks such as mentoring and curriculum development.

The design of the system is also made to be modular and scalable, which is really important for big educational platforms. Each part of the system does a specific job, like understanding the student, creating problems, assessing, or suggesting learning materials. Since these parts work on their own but can talk to each other through set interfaces, new parts or AI models can be added to the system without having to make big changes to what's already there. This modular design makes it flexible and easier to expand the system in the future. It allows for easy updates and additions, which is crucial for keeping up with the changing needs of students and educators. By being able to add new components without disrupting the whole system, it saves time and resources, making it a more efficient and effective way to manage educational platforms.

The system also has a feature that helps teachers understand how students are doing. It collects and analyzes lots of information about how students are progressing and how they're using the learning platform. This information can help teachers see how students are learning, find out if they're having trouble, and make their teaching strategies better. By using this data, teachers can make sure they're giving students the best possible education. They can also use it to change their teaching methods to help students who are struggling. This way, teachers can make sure all their students are getting the most out of their education.

The key advantages of the proposed multi-agent architecture can be summarized as follows:

- personalized and adaptive learning experiences
- automated feedback and intelligent assessment
- scalable and modular system architecture
- enhanced learning analytics and performance monitoring
- adaptive generation of educational exercises

Overall, the integration of intelligent agents into educational systems has the potential to significantly enhance the learning process. By providing continuous support, personalized guidance, and adaptive instructional strategies, multi-agent learning systems can create more efficient, flexible, and engaging educational environments.

8. Conclusion

Intelligent agents are becoming an increasingly important component of modern educational technologies. By enabling personalized learning, automating various instructional

processes, and providing adaptive feedback, intelligent agent systems can significantly enhance the effectiveness of digital learning environments. As noted in previous research, intelligent tutoring systems are capable of simulating certain aspects of human tutoring by providing individualized guidance and feedback to learners [4].

This study looked at how intelligent agents can be used in education and came up with a plan for a system that uses multiple agents to help teach math. The idea is to bring together intelligent agents, machine learning, and learning management systems to create a single platform for education. By working together, different agents like those that track student progress, create problems, assess performance, and suggest resources can help students learn better. The system can keep an eye on how students are doing, give them tasks that fit their needs, check how well they're doing, and recommend things that can help them learn more. This can make learning more effective and personalized for each student.

When you bring together multiple agents, the system can change and adjust to what each learner needs. This kind of adaptive learning environment is really important for getting students more engaged and helping them learn better. Like Woolf said, intelligent tutoring technologies can really change the way we learn online by giving students the support they need and using teaching strategies that adapt to them [10].

Despite these advantages, several challenges remain in the implementation of intelligent agent technologies in education. Important issues include the protection of student data, transparency and interpretability of AI algorithms, and the reliability of automatically generated educational content. Addressing these challenges is essential to ensure trust, fairness, and effectiveness in AI-driven educational systems.

To take things to the next level, we need to work on making artificial intelligence models more accurate and reliable. We also need to make it easier to understand how adaptive learning algorithms work. And let's not forget about finding new ways to combine intelligent agents with the latest educational technologies. By doing this, we can create learning environments that are not only smarter but also more accessible and effective for everyone. This will be a big step forward in making education better and more personalized.

9. Future Research

Future research in intelligent agent technologies for education may focus on the integration of advanced machine learning algorithms capable of more accurately analyzing student behavior and predicting potential learning difficulties. Such improvements could

significantly enhance the effectiveness of adaptive learning environments and intelligent tutoring systems by enabling more precise personalization of educational content [2].

Another way to make education better is to use a type of artificial intelligence called generative AI. This can help create educational materials and explanations automatically. These AI systems can make personalized exercises and examples in real time, which can help educational platforms be more flexible and responsive to students' needs.

Researchers are looking into combining intelligent agents with virtual and augmented reality to create immersive learning environments. In these environments, students can interact with virtual objects, simulations, and intelligent tutoring systems. This can make learning more engaging and interactive for students. For example, students can use virtual reality to explore historical sites or participate in simulated labs, which can enhance their understanding and retention of complex concepts. Additionally, intelligent tutoring systems can provide personalized feedback and guidance to students, helping them to learn at their own pace. Overall, the integration of intelligent agents with virtual and augmented reality has the potential to revolutionize the way we learn and teach.

We need to think about the ethical and social issues that come with using artificial intelligence in education. Some key concerns are keeping student data safe, making sure AI algorithms are transparent and accountable, and ensuring everyone has equal access to the latest educational technologies. It's vital that we tackle these challenges to make sure intelligent educational systems are used in a responsible and sustainable way.

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