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# Developing a Collaborative Learning Environment For ITS: A New Model Based on IMS-Learning Design

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**Abstract** Intelligent Tutoring Systems (ITS) represent a significant advancement in educational technology, evolving from computer-assisted teaching to more adaptive and interactive learning environments. This paper aims to delve into the methodological aspects of collaborative ITS, with a particular focus on the integration of IMS Learning Design (IMS-LD). The objective is to explore how IMS-LD is instrumental in designing and managing ITS and addressing the challenges of modern education systems. The proposed model addresses these challenges through three foundational principles: categorizing learning activities, clearly defining roles, and designating specific spaces for diverse activities. By integrating the learner model and IMS-LD, the model aims to enhance personalization and effectiveness, creating a more efficient, learner-centric system. The paper also discusses the development of meta-models for collaborative ITS, their correspondence with IMS-LD, and the challenges and benefits of model transformation techniques. The findings highlight the potential of ITS in providing adaptive and personalized learning experiences, fostering effective communication and collaboration among participants, and enhancing the overall quality of education through innovative technological integration.

**Keywords** Intelligent Tutoring Systems, Collaborative learning, IMS Learning Design, Modeling, learner model, pedagogical strategies

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## 1. Introduction

*In 1980,* the advent of Intelligent Tutoring Systems (ITS) marked a significant evolution from computer-assisted teaching (CAT), heralding a new era in educational technology. ITS represents an interdisciplinary amalgamation of artificial intelligence, education, and cognitive psychology, aiming to create more adaptive and interactive learning environments [1]. These systems are distinctively characterized by their focus on the learner, tailoring educational resources to individual needs, learning styles, and cognitive abilities. Equipped with artificial intelligence, ITS can dynamically interact with users, offering personalized instruction and proposing content in the most effective learning modality [2]. Recent advances in ITS reflect a growing emphasis on sustainable education, as highlighted by Lin, Huang, and Lu (2023) and others. These developments showcase the potential of AI in enhancing access to quality education and creating personalized learning experiences. It now encompasses a broad range of applications, from language and law to mathematics, medicine, physics, and reading comprehension, significantly expanding its scope and impact on various educational fields [3, 4].

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In this study, we propose a thorough exploration of the methodological aspects that pertain to collaborative intelligent tutoring systems (ITS), looking at the use of IMS Learning Design (IMS-LD). The main objective of this research is to identify how IMS-LD can be applied for the meaningful creation and deployment of ITS processes, as well as to address those challenges with which today´s educational systems are faced. In particular, we are going to show that IMS-LD allows relating advanced pedagogical strategies making easier the implementation of adaptive learning environments, and concurrently increasing quality and efficiency in education.

The paper is structured as follows: The first section provides an in-depth review of the architecture of intelligent tutoring systems (ITS), shedding light on their foundational components and operational mechanisms, including the meta-model of the collaborative group system and its mapping to IMS Learning Design (IMS-LD). The second section focuses on the development of Collaborative Intelligent Tutoring System meta-models, and their correspondence with the IMS-LD model, This includes the modeling of collaboration spaces in web-based collaborative ITS and the detailed class diagram for collaborative group systems, illustrating the properties and relationships of each class. Finally, the paper concludes with a summary of key findings and implications for future research and practice in the field of intelligent tutoring systems.

## 2. INTELLIGENT TUTORING SYSTEM ARCHITECTURE

This section classifies the selected intelligent tutoring systems that we use in this study, into three classes: architectures of three models of four models, and the new generations of ITS [5].

### *2.1. Three-model architecture*

The Three-Model Architecture of an Intelligent Tutoring System (ITS) is a design framework that comprises three core models to facilitate effective tutoring and personalized learning experiences. These models work together to provide comprehensive support to learners. Here are the three primary models in the architecture of a three-model ITS [6]:

**Student Model:** The student model in this architecture focuses on understanding and representing the learner's characteristics, knowledge, skills, preferences, and progress. It collects data about the student's interactions with the system, such as answers to questions, response times, and areas of difficulty. The student model is used to tailor the tutoring experience to the individual learner, providing customized feedback, remediation, and challenges [7].

**Domain Model:** The domain model represents the knowledge domain or subject matter of the ITS. It includes the curriculum, learning objectives, and the structure of the content. This model defines the concepts, rules, and relationships within the domain. It serves as the foundation for generating learning materials and assessing the learner's progress [8].

**Tutoring Model:** The tutoring model is responsible for determining how the ITS interacts with the learner. It includes pedagogical strategies, instructional methods, and sequencing of content. The tutoring model decides when and how to provide feedback, present new material, and adapt to the learner's needs. It aims to provide effective guidance and support throughout the learning process [8].
While the Three-Model Architecture does not include an explicit interface model, it assumes that the interaction between the learner and the ITS is mediated through user interfaces or platforms. The focus of this architecture is on the essential components of learner modeling, domain representation, and pedagogical decision-making to create a personalized and adaptive learning environment.

### *2.2. Four-model architecture*

The Four-Model Architecture of an Intelligent Tutoring System (ITS) is a design framework that encompasses four distinct models to facilitate effective tutoring and personalized learning experiences. These models work together

to provide comprehensive support to learners. Here are the four primary models in the architecture of an ITS [9]:
Expert model: The domain model deals with the lessons, their arrangement, and a range of elements. Domain model features two fundamental components: Knowledge: It alludes to the material that must be input into the system, including the ideas, queries, tasks, issues, and connections between them [10]. Didactic elements: These are multimedia resources, such as pictures, videos, and audio, that aid in the student's learning throughout the session.
Interface model: Provides support to the student's tasks and the techniques used in carrying out those activities. The GUI should be user friendly, and attractive. The interface model deals with the user interface and user experience aspects of the ITS. It focuses on how the learner interacts with the system, including the design of the interface, navigation, multimedia elements, and accessibility features. A user-friendly and intuitive interface enhances the overall learning experience.
Student model: The student model applied a state-based approach. There are however quite a few criteria for a student's instructional modeling during a learning process. The following elements are composed of the student module: [10] A database with modes of learning is included in the program. A map of the knowledge from the domain module that is updated by the tutor module in response to assessments.
Tutor Model: The Instructional Model provides information for decision-making on instructional strategies. This depends on the learner model's assessment processes to make decisions regarding what, where, and how to present information to a learner. The following sub-modules are composed of: Lesson Planner organizes the contents of the lessons. Profile analyzer, analyzing the attributes of students, choosing the best teaching approach (see Figure 1).

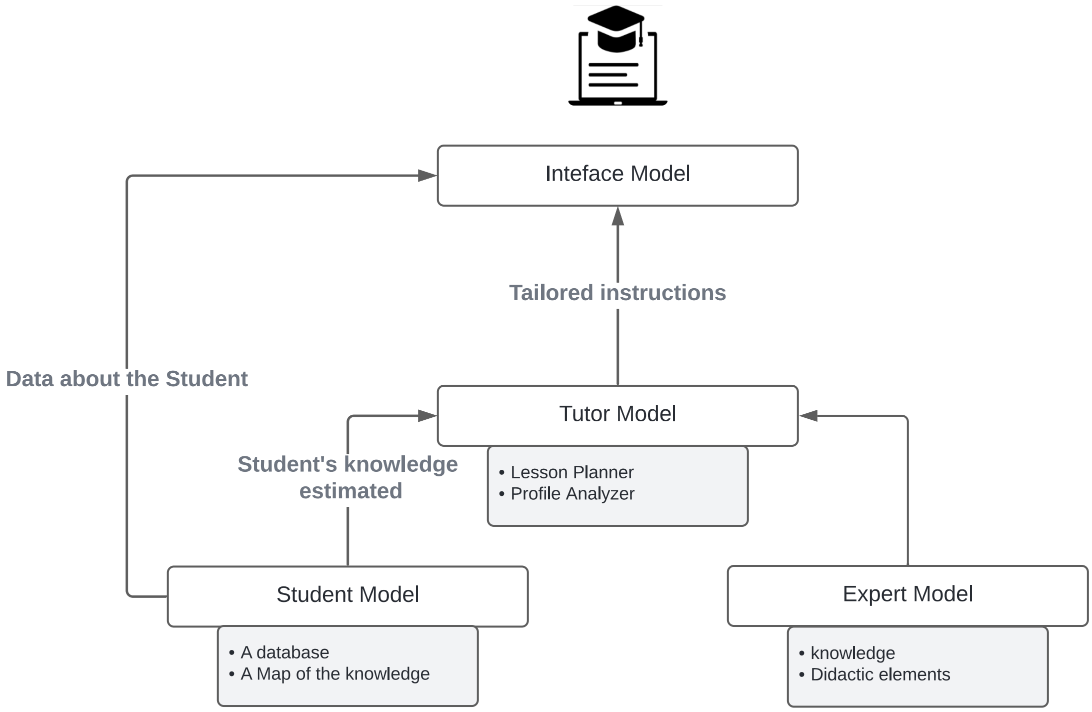


Figure 1. Four-Model Architecture.

The Four-Model Architecture is designed to integrate these models seamlessly, allowing the ITS to provide individualized instruction, adapt to the learner's progress, and create a dynamic and engaging learning environment. This framework enhances the effectiveness of intelligent tutoring systems by combining domain expertise, learner modeling, pedagogical strategies, and user interface design.

### *2.3. New-generation architectures for ITSs*

In summary, the latest generation of Intelligent Tutoring System (ITS) architectures represents a groundbreaking shift in the realm of educational technology. These forward-looking architectures harness cutting-edge technologies and methodologies to deliver learning experiences that are exceptionally personalized, adaptive, and engaging. As a result, they are spearheading a transformative revolution in the way learners access and interact with educational content.

One illustrative example of such an advanced architecture is MATHEMA, a multi-agent framework that serves as the cornerstone for the development of computer-based intelligent learning environments. MATHEMA is composed of six fundamental components, each of which plays a distinctive and pivotal role in the creation of a dynamic and effective learning ecosystem. These components include:

**An External Motivator:** This component serves as a source of motivation for the learner, stimulating their engagement and commitment to the learning process. It can employ various motivational strategies to encourage active participation and progress.

**A Human Learner:** The central figure in the learning environment, the human learner, represents the individual seeking to acquire knowledge and skills. The architecture revolves around catering to the specific needs and preferences of this learner.

**A Micro-Society of Artificial Tutoring Agents (MARTA):** MARTA constitutes a collective of artificial tutoring agents designed to provide guidance, instruction, and support to the human learner. These agents leverage their capabilities to adapt to the learner's progress and deliver personalized assistance.

**A Human Experts Society (HES):** HES acts as a repository of expert knowledge and serves as a valuable resource for MARTA. It provides authoritative information and guidance, ensuring that the tutoring agents have access to accurate and up-to-date subject matter expertise.

**An Interface Agent:** This critical component bridges the interaction between the human learner and MARTA, facilitating seamless communication and understanding. It interprets the learner's needs and conveys them to the tutoring agents, ensuring effective assistance.

**A Communication Agent:** The communication agent plays a pivotal role in connecting MARTA with HES. It serves as the conduit for knowledge exchange, coordination, and maintenance of the tutoring agents. This agent ensures that MARTA has access to the latest insights and expertise from HES.

Together, these six components within the MATHEMA architecture create a dynamic and collaborative intelligent learning environment. They harmonize to deliver an educational experience that not only leverages cutting-edge technologies but also fosters personalization, adaptability, and engagement, ultimately redefining the way learners interact with and access educational content [11].

Intelligent Tutoring Systems (ITS) are conceived to provide personalized and effective education, but they face several major and significant challenges [12] in their ability to provide personalized learning experiences, manage the increasing complexity of educational content, and integrate seamlessly with other educational systems. Firstly, personalization and adaptability represent a major challenge [13], as it must respond dynamically to the specific needs of each learner, adjusting content and teaching strategies in real-time. Secondly, scalability and the management of complexity also pose major challenges [14]. ITS must integrate a wide range of content and learning levels while maintaining pedagogical coherence, particularly when it comes to implementing advanced pedagogical strategies such as collaborative learning. Interoperability and standardization are therefore another major challenge [15, 16]. ITS must be able to integrate effectively with other educational systems and databases, which requires common standards to facilitate the exchange and integration of educational resources.

Integrating IMS Learning Design (IMS-LD) into ITS provides effective solutions to these challenges. IMS-LD enables increased customization through adaptive learning scenarios[17], improves scalability and complexity management through its modular structure, and promotes interoperability by adhering to open standards. As a result, ITSs equipped with IMS-LD become better able to meet the diverse needs of learners, while ensuring the seamless integration of pedagogical strategies and greater compatibility with other educational systems.

## 3. Design of a web-based Intelligent Tutoring System that Considers Collaboration Aspects

Intelligent Tutoring Systems (ITS) face various pedagogical and technical challenges that necessitate innovative solutions tailored to learners' needs. This proposed model addresses these challenges through three foundational principles while integrating the learner model and IMS Learning Design (IMS LD) to enhance personalization and effectiveness[18].
The first principle involves categorizing learning activities into types such as unrestricted, sequential, and conditional, creating a coherent and structured framework that enhances learners' ability to navigate and understand course content effectively. By establishing clear structures, ITS can ensure that learners follow a logical progression in their studies, aiding retention and comprehension. The second principle emphasizes identifying and differentiating roles within the ITS environment based on their responsibilities. Clearly defining these roles ensures that all participants, including instructors, learners, and administrators, understand their functions, fostering efficient communication and collaboration. IMS LD contributes to this by providing detailed descriptions of roles and interactions, facilitating a structured and coherent management of pedagogical processes. The third principle involves designating specific spaces for diverse activities within the ITS, such as multimedia documents, discussion forums, wikis, video conferencing, mind maps, and interactive exercises. This variety empowers learners to engage with content in multiple ways, promoting active learning and exploration. The learner model and IMS LD enable the customization of these spaces according to learner profiles, adjusting available resources and tools to maximize engagement and learning efficiency. Integrating these principles into ITS development aims to create a more efficient, learner-centric system that addresses both the pedagogical and technical challenges inherent in traditional learning management systems. This approach offers a tailored and immersive learning experience while enhancing communication and collaboration among all participants in the learning process. Effective collaboration in ITS involves joint efforts toward common goals, requiring leadership, which can manifest as social leadership in decentralized and egalitarian group settings. Technological advancements have significantly facilitated collaboration among teachers, tutors, and learners through interactive tools and platforms that enable seamless communication and cooperative learning experiences.

The learner model is used to adapt these functions to the needs of each student. Knowledge diagnosis accurately measures the current state of the student's knowledge. Strategic functions involve selecting overall teaching plans or strategies. Predictive functions cover the learning path and behavior of the student, while evaluation functions encompass student assessments and ITS evaluations. Knowledge development, error remediation, and exploration space control are described in more detail in the subsections below. To assist a student in knowledge development, an ITS follows four steps: what to teach, when to teach, how to teach, and implementing teaching actions [19].

### *3.1. Knowledge Development*

The main contribution of this paper is a very simple and fast algorithm, called RecPK, proposed by alternating direction method(ADM), takes advantage of problem structures and thus has an extremely low per-iteration cost.

### *3.2. Organization*

In the context of the evolution of intelligent learning systems, knowledge development plays a central role in optimizing the acquisition and application of knowledge. This section explores how advances in adaptive pedagogy and learning technologies can enrich and deepen the process of knowledge development, focusing on mechanisms that promote deeper understanding and more effective application of educational content.
**What to Teach:** At this point, the learner model provides insights into the learner's current state of knowledge. The system primarily addresses the gaps in the learner's understanding. Based on this information, the tutoring module can determine the most suitable sequence of curriculum, offer targeted assistance and feedback during problem-solving, or provide on-demand support. The curriculum sequence is designed to guide the learner through the most effective learning path, comprising knowledge units to be mastered and associated tasks such as examples, questions, and problem-solving exercises. This sequencing ensures that the learner progresses efficiently through the educational material. There are two types of curriculum sequencing: high-level and low-level. High-level

sequencing, or knowledge sequencing, leverages the learner model and domain knowledge to determine the next teaching concept or topic. In contrast, low-level sequencing focuses solely on the learner model to decide the subsequent learning task (e.g., an example, a test, or questions) [20]. By analyzing recorded learner behaviors, the system can offer active assistance and feedback. Providing intelligent feedback on the student's work, such as highlighting errors or comparing their solution with an ideal model, can significantly improve their grasp of the subject. Furthermore, additional hints or reminders can support learners during the problem-solving process. When learners seek assistance with ongoing tasks, the system delivers passive support, such as hints, answers to queries, or further explanations, all tailored to the learner's knowledge as reflected in the learner model.

**When to Teach:** The appropriate timing for knowledge development is calculated using the learner model. This is important for providing active assistance during problem-solving. How to Teach: Appropriate pedagogical actions such as explanations, tests, examples, or problems are chosen using the learner model. These teaching actions are influenced by the learning style or preferences stored in the learner model.

### *3.3. Implementing Teaching Actions*

At this point, specific instructional actions can be adjusted based on the learner model. For instance, if a learner demonstrates advanced knowledge in a particular area, the system may offer only a brief explanation to assist in solving a problem.

### *3.4. Error Remediation*

According to Self, eight remediation methods can be identified: error definition, explicit remediation, implicit remediation, counterexamples, demonstrating a solution method, accessing previous experiences, repeated attempts, and tactical retreat [21]. Error definition provides a textual description of the error and a recommendation for correction. Explicit remediation presents the correct knowledge, while implicit remediation prompts the correct knowledge or actions and shows notes to the learner. Counterexamples are situations or problems generated by the system. Access to previous experiences is given through the user model, where these experiences are stored.

### *3.5. Control of the Exploration Space*

The ITS automatically controls the exploration space as the learner navigates through the domain space. This control involves limiting information resources, the number of pathways and search tools, and the amount of information presented. This concept is used to reduce the learner's cognitive load, as too much information or too many options can reduce the learner's attention and lead to distraction. The control of the exploration space is based on the learner's skill level, experience, and other factors[22].

## 4. Modeling a Collaboration Space in a Collaborative Intelligent Tutoring System

IMS Learning Design (IMS-LD) is a pedagogical modeling language that provides a metalanguage for modeling learning units, accommodating a wide variety of pedagogical models. Published in 2003 by the IMS/GLC Consortium for Global Learning Management Systems, IMS-LD emerged from the European Committee for Standardization's (CEN) evaluation, which deemed the proposed language source (EML) the best suited for meeting LMS criteria due to its focus on reusability and interoperability [23]. IMS-LD, inspired by EML developed by the Open University of the Netherlands, offers a conceptual framework for modeling learning units, balancing flexibility to implement diverse pedagogical approaches with the precision needed for detailed unit descriptions [24]. It allows for the representation and encoding of learning structures for individual learners or groups, defining roles, learning activities, services, and other elements to construct comprehensive learning units. The syllabus, modeled and built with resources assembled into a compressed Zip file, is managed by an executable player that coordinates teachers, students, and activities throughout the learning process [25]. By defining roles and activities, IMS-LD creates a learning scenario executable within compatible systems. Unlike previous e-learning

specifications that maintained pedagogical neutrality, IMS-LD emphasizes the need for a flexible approach, enabling its use with various pedagogical scenarios and models, hence often referred to as a meta-pedagogical model [26].
In this research, we aim to adapt the IMS-LD model using meta-models that support Collaborative Intelligent Tutoring System. This adaptation involves three steps: first, the development of LMS meta-models; second, the study of the correspondence between these meta-models and the IMS-LD model; and third, their transformation into IMS-LD meta-models, reducing the MDA approach to a rule-based transformation implemented in the ATL language. However, we will discuss the design of our LMS meta-models without using the rule-based transformation implemented in the ATL language, as we have identified issues similar to those found in the work of El-Moudden. In IMS-LD, we cannot construct a project comprising multiple sub-projects, leading to semantic loss. Indeed, there are significant semantic loss issues when transforming our meta-models into an IMS-LD model using the ATL language.

Therefore, we have chosen to develop our proposed meta-model along the lines of a schema, where we identify the characteristics of the constituent entities of the activity spaces of our collaborative intelligent tutorial system [27]. This schema allows us to better capture the nuances and specific requirements of CITS [28], ensuring that the metadata associated with each entity is carefully designed to reflect the complexities and dynamic interactions in collaborative learning environments [29]. The metadata includes elements such as participant role descriptions, learning prerequisites, pedagogical objectives, and associated resources, enabling fine-grained structuring and precise execution of complex pedagogical scenarios in a collaborative setting. This choice enables us to overcome the limitations of the standard IMS-LD model [30] and offer a solution better adapted to the specific needs of collaborative learning in an intelligent tutorial environment.

### *4.1. Roles and Functions in a Web-Based Collaborative Intelligent Tutoring System*

In an Intelligent Tutoring System, various actors have specific roles and functions designed to facilitate the learning process effectively. Learners can view projects and their objectives at any time, initiate collaboration, read uploaded documents, download documents, and upload documents. Tutors are responsible for managing groups by adding, modifying, or deleting them, assigning students to groups, initiating collaboration, defining project phases and tasks, assigning tasks to learners, and monitoring and supporting learners. Teachers create courses and projects, define project objectives, import and export documents, and plan educational resources. Administrators set up class groups, manage courses, and handle access rights for teachers and learners. Coordinators manage teachers by adding, modifying, or deleting them, monitor teacher activities, and assign courses to tutors based on their specialties. This structured approach ensures that each actor contributes effectively to the overall learning environment, promoting a collaborative and efficient educational experience(see Figure 2).

### *4.2. Meta-Model of the Collaborative Intelligent Tutoring System*

In this subsection we provide a comparative overview of the elements in the meta-model for the collaborative group system and their corresponding elements in the IMS Learning Design (IMS-LD) specification, helping to understand how various components in a Learning Management System (LMS) designed for collaborative learning can be mapped to standardized elements defined by IMS-LD. In this mapping, a Project corresponds to an Activity, representing tasks or a series of tasks. Tasks and subtasks align with Activity structures, defining the organization of activities. A Phase equates to a Play, indicating stages of the learning process. Roles and features in the meta-model match Roles in IMS-LD, detailing the responsibilities of participants. Members and Team correspond to Person, identifying individual or group participants. The Tutor aligns with Staff, supporting learners, while the Learner remains consistent in both models. The Collaboration Space maps to the Environment, providing the context for learning activities. Objective aligns with Learning Objective, defining project goals. Course or Learning Project corresponds to Learning Object, representing educational content, and Tools map to Services, offering functionalities and support for activities. This alignment ensures compatibility and interoperability within educational systems(see Table 1).

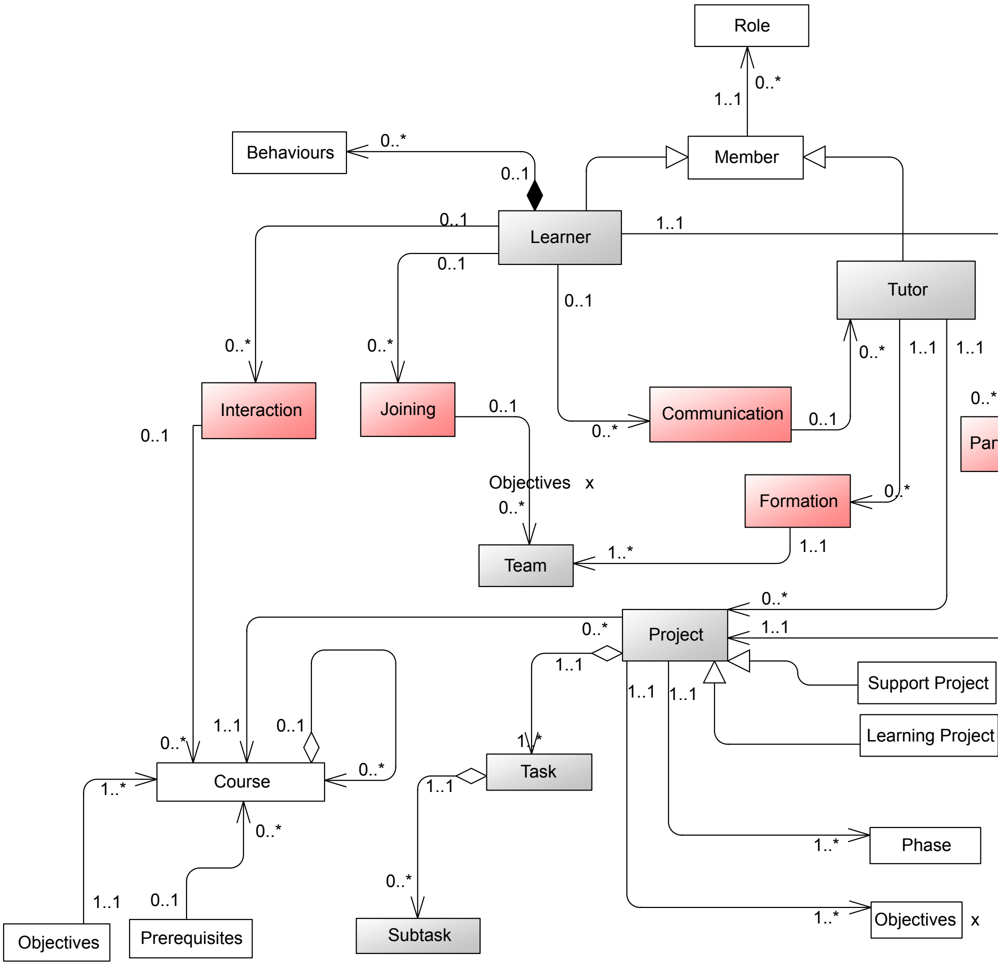


Figure 2. Proposed Conceptual Meta-Model for the Collaborative Group System.

Table 1. Meta-Model of the Collaborative Group System

| Meta-model of the collaborative group system | IMS-LD |
|---|---|
| Project | Activity |
| Task, and subtask | Activity structure |
| Phase | Play |
| Role, and features | Role |
| Members, and Team | Person |
| Tutor | Staff |
| Learner | Learner |
| Espace de collaboration | Environment |
| Objective | Learning Objective |
| Course, Learning Project | Learning Object |
| Tools | Services |

### *4.3. Class Diagram of the Collaborative Intelligent Tutoring System*

In our LMS, we propose a class diagram model for the collaborative group system (see Figure 2) based on our proposed meta-model in Figure 1 In this diagram, we have defined the properties of each class and the relationships between them. Most of the classes designed in our class diagram model correspond perfectly to the meta-model proposed making their transformations possible. Model transformation is a technique aimed at linking models to avoid unnecessary reproductions (see Figure 3).

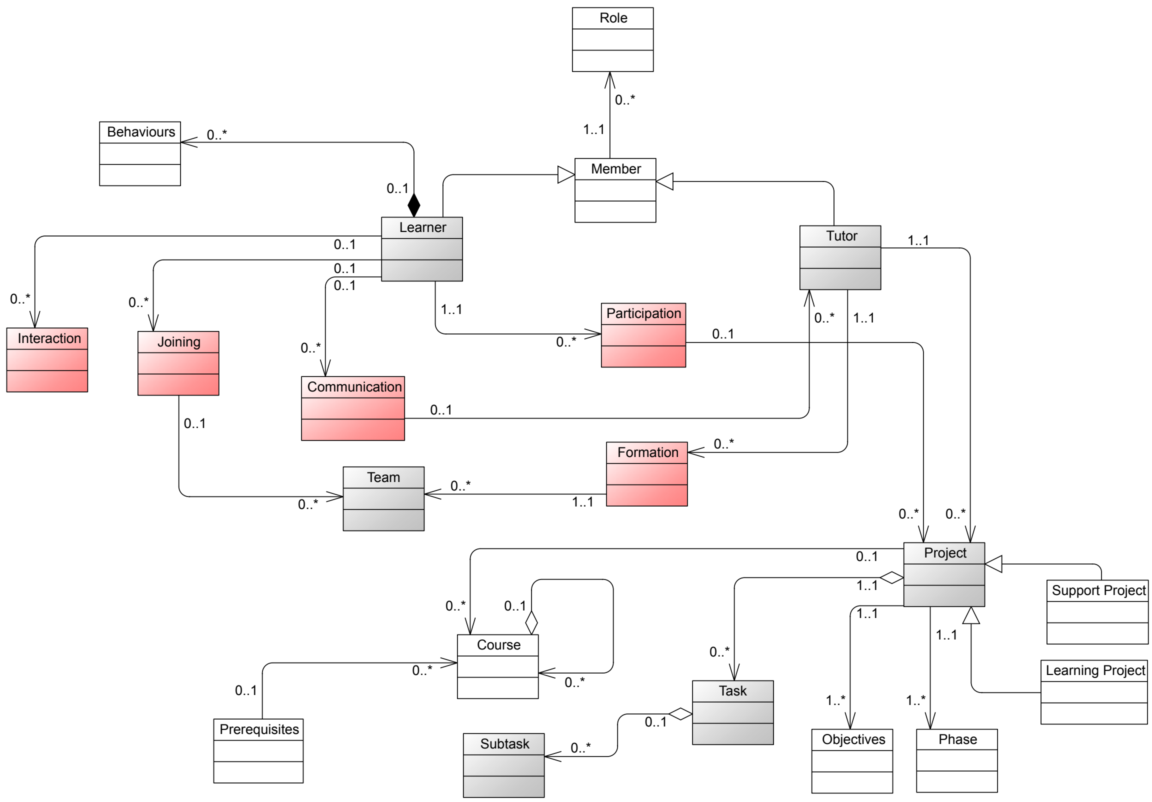


Figure 3. The Class Diagram of the Collaborative Group System.

Each class in the diagram is designed to represent distinct entities such as students, teachers, learning activities, and learning resources. The properties defined for each class capture specific aspects of these entities, such as student skills, teacher roles, and types of learning activities. The relationships established between classes facilitate interaction between these entities, enabling fluid, integrated management of collaborative learning activities.

This modeling contributes not only to the effective management of pedagogical interactions but also to greater personalization of learning experiences. By enabling fine-tuning to the needs and preferences of learners, our model promotes more targeted and relevant learning [31]. In addition, the structuring provided by our model allows for improved interoperability and increased reuse of pedagogical elements, thus meeting the flexibility and integration requirements of modern learning environments. The ability to reuse pedagogical components across different learning scenarios and dynamically adjust interactions according to data collected on learners enhances the relevance and effectiveness of educational processes [32].
By comparing our collaborative group systems model in an LMS with existing intelligent tutoring systems (ITS), several distinct advantages and areas for improvement emerge. Traditional ITS models typically focus on adaptive learning by using student performance data to adjust instructional content and feedback. These systems often use

fixed instructional strategies and predefined rules to guide the learning process, which can limit flexibility and customization.
Our proposed model, on the other hand, offers a more nuanced approach by defining and structuring the relationships between students, teachers, learning activities, and resources in a detailed class diagram. This model not only captures specific properties such as student skills, teacher roles, and activity types but also facilitates the dynamic management of interactions. As opposed to traditional ITSs, which can rely on static rules and constraints, our model enables real-time adjustments based on learner data, promoting a more personalized and adaptive learning experience.
In addition, the improved interoperability and reuse of pedagogical elements in our model addresses some of the limitations of traditional ITS systems. Traditional ITSs often have difficulty integrating diverse pedagogical approaches and adapting to different educational contexts. In contrast, our approach improves flexibility by allowing the reuse of pedagogical components across different learning scenarios and by dynamically adjusting interactions based on learner feedback.
This dynamic adaptability represents a significant advance over traditional ITS models, which generally involve rigid, predefined learning paths.

### *4.4. Limitations of the Collaborative Intelligent Tutoring System*

Despite the advances made by our class diagram model for collaborative group systems in an LMS, several limitations must be acknowledged [33]. Firstly, the complexity of the modeling can create challenges in terms of implementation and integration with existing systems. Creating and managing the detailed relationships between learning entities requires technical expertise and can increase development and maintenance costs. Furthermore, although our model improves adaptability and customization, it relies heavily on the quality of the data collected. Errors or biases in learner data can lead to inappropriate adjustments and negatively affect the learning experience.

Another limitation is the potential reliance on specific tools and technologies to implement the model. LMS systems and analysis tools need to be compatible with our approach to ensure seamless integration. In addition, the reuse of pedagogical components, while advantageous, can sometimes run up against limitations in terms of standardization and compatibility between different learning environments.

## 5. Conclusions

This paper has explored the integration of IMS Learning Design (IMS-LD) into Intelligent Tutoring Systems (ITS), focusing on the methodological aspects and collaborative frameworks. The discussion began with an overview of ITS architecture, detailing the foundational components and operational mechanisms that make up these advanced educational technologies. We examined the development of meta-models for collaborative ITS, their correspondence with IMS-LD, and the challenges and benefits of model transformation techniques.
The proposed model addresses key pedagogical and technical challenges by categorizing learning activities, clearly defining roles, and designating specific spaces for diverse activities. These principles, supported by IMS-LD and the learner model, aim to create a more efficient, learner-centric system that enhances personalization, engagement, and collaborative learning. The inclusion of detailed class diagrams and meta-models for collaborative group systems further demonstrates how these structures can be mapped to IMS-LD, ensuring compatibility and interoperability within educational systems.
By leveraging the capabilities of IMS-LD and advanced pedagogical strategies, ITS can provide adaptive and personalized learning experiences, fostering effective communication and collaboration among all participants. The advancements in ITS reflect a growing emphasis on sustainable and inclusive education, highlighting the potential of AI in enhancing access to quality education across various fields.

To overcome the limitations already identified, several research perspectives are envisaged. It is essential to develop more accessible tools and frameworks to simplify the implementation of our model in different

LMS systems while strengthening data quality assurance mechanisms to improve the accuracy of adaptive adjustments. Increasing the reusability of learning components by establishing universal standards and protocols for compatibility between systems is also essential. Integrating advanced technologies such as artificial intelligence and machine learning could offer finer and more personalized adjustments, optimizing the learning experience according to learners' individual needs and staying at the forefront of educational innovation, providing dynamic and engaging learning environments. The results and implications discussed in this article pave the way for continued improvements and innovations in the field of intelligent tutoring systems, ultimately contributing to a more efficient and equitable educational landscape.

## REFERENCES


1. Miao, Fengchun, Holmes, Wayne, Ronghuai Huang, Hui Zhang, *AI and education: guidance for policy-makers* UNESCO, 2021.
2. Mohamed Benfarha,Mohamed Sefian Lamarti, *Evaluation of a student-centered online one-to-one tutoring system* Global Journal of Engineering and Technology Advances, vol. 15, no. 1,pp. 033–040, doi = 10.30574/gjeta.2023.15.1.0072, 2023.
3. YAYLA ESKİCİ, Gamze, *Sustainability and its Reflection on Education* International e-Journal of Educational Studies, vol. 7, no. 15,pp. 884–894,doi = 10.31458/iejes.1341475, 2023.
4. Lin, Chien Chang and Huang, Anna Y.Q. and Lu, Owen H.T., *Artificial intelligence in intelligent tutoring systems toward sustainable education: a systematic review* Smart Learning Environments, vol. 10, no. 1, 2023.
5. Lazrag, Mohamed and Machkour, Mustapha, *A multi-agent architecture for an intelligent tutoring system* Journal of Advanced Research in Dynamical and Control Systems, vol. 12, 2020.
6. Abu Bakar, Mohamad Ariffin and Ab Ghani, Ahmad Termimi and Abdullah, Mohd Lazim, *An Intelligent Mathematics Problem-Solving Tutoring System Framework: A Conceptual of Merging of Fuzzy Neural Networks and Neuroscience Mechanistic*, International journal of online and biomedical engineering, vol. 20 , no. 5, pp. 44–65, 2024.
7. Rida, Zakaria and Boukachour, Hadhoum and Ennaji, Mourad and MacHkour, Mustapha , *An architecture for the dynamic adaptation of an intelligent multi-tutoring system* Journal of Intelligent and Fuzzy Systems, vol. 45, no. 6,pp. 9899–9913, doi = 10.3233/JIFS-232319, 2023.
8. hongyu Cao , jicheng Li, *Design and implementation of design platform for automatic generated micro-application system based on domain model* Proceedings of SPIE - The International Society for Optical Engineering,pp. 221, doi = 10.1117/12.3004151, 2023.
9. Pijeira-Díaz, Héctor J. and Braumann, Sophia and van de Pol, Janneke and van Gog, Tamara and de Bruin, Anique B.H., *Towards adaptive support for self-regulated learning of causal relations: Evaluating four Dutch word vector models* British Journal of Educational Technology, vol. 55, no. 4,pp. 1354–1375,doi = 10.1111/bjet.13431, 2024.
10. Ahmed, Ghanim Hussein Ali and Alshboul, Jawad and Kovács, László, *Development of Ontology-based Domain Knowledge Model for IT Domain in e-Tutor Systems* International Journal of Advanced Computer Science and Applications, vol. 13, no. 5,pp. 28–34,doi = 10.14569/IJACSA.2022.0130505, 2022.
11. Zhang, Lishan and Pan, Mengqi and Yu, Shengquan and Chen, Ling and Zhang, Jing , *Evaluation of a student-centered online one-to-one tutoring system* Interactive Learning Environments, vol. 31, no. 7,pp. 4251–4269, doi = 10.1080/10494820.2021.1958234, 2023.
12. VanLehn, Kurt, *The Relative Effectiveness of Human Tutoring, Intelligent Tutoring Systems, and Other Tutoring Systems* Educational Psychologist, vol. 46,no. 4,PP. 197–221, 2011.
13. Angela Stott and Annemarie Hattingh, *Conceptual Tutoring Software for Promoting Deep Learning: A Case Study* International Forum of Educational Technology and Society, vol. 18,no. 2, pp. 179-194 , 2015.
14. Paula J Durlach , Alan M. Lesgold, *Adaptive Technologies for Training and Education* Cambridge University Press, 2012.
15. Rob Koper , Bill Olivier, *Representing the Learning Design of Units of Learning* international Forum of Educational Technology and Society, vol. 7,no. 3, pp.97–111, 2004.
16. Smaili, El Miloud and Khoudda, Chaimaa and Sraidi, Soukaina and Azzouzi, Salma and El Hassan Charaf, My, *An Innovative Approach to Prevent Learners Dropout from MOOCs using Optimal Personalized Learning Paths: An Online Learning Case Study* Statistics Optimization and Information Computing, vol. 10,no. 1, pp.45–58, 2022.
17. Daniel Burgos, Colin Tattersall, Rob Koper, *Representing adaptive eLearning strategies in IMS Learning Design* Interactive Learning Environments, pp. 54-60, 2006.
18. Shi, Wenjing and Nie, Zhuming and Shi, Yuhan , *Research on the Design and Implementation of Intelligent Tutoring System Based on AI Big Model* Proceedings of 2023 IEEE International Conference on Unmanned Systems, ICUS 2023, doi = 10.1109/ICUS58632.2023.10318499, 2023.
19. Gan, Wenbin and Sun, Yuan and Sun, Yi, *Knowledge interaction enhanced sequential modeling for interpretable learner knowledge diagnosis in intelligent tutoring systems* Neurocomputing, vol. 488,pp. 36–53, 2022.
20. Brusilovsky, Peter, *Methods and techniques of adaptive hypermedia* User Modeling and User-Adapted Interaction, vol. 6, no. 2-3,pp. 87–129,doi = 10.1007/BF00143964, 1996.
21. Self, J, *Student models: What are they?* IFIP/TC3 FRASCATI, 1987.
22. Kashihara, Akihiro and Oppermann, Reinhard and Rashev, Rossen and Simm, Helmut and Others, *A cognitive load reduction approach to exploratory learning and its application to an interactive simulation-based learning system* Journal of Educational Multimedia and Hypermedia, vol. 9,no. 3, pp.253–276, 2000.
23. El, Fauzi and Mohamed, Prof. and Aammou, Prof., *Designing an IMS-LD Model for Collaborative Learning* Journal of Advanced Computer Science and Applications, vol. 6, no. 12, 2015.

24. Ouadoud, Mohammed and Chkouri, Mohamed Yassin, *Designing an IMS-LD Model for Sharing Space of Learning Management System* Lecture Notes in Intelligent Transportation and Infrastructure, vol. Part F1405,pp. 334–347, 2019.
25. De Oliveira, Francisco Kelsen and Gomes, Alex Sandro , *A developemnt model of units of learning for multiple platforms* 2015 10th Iberian Conference on Information Systems and Technologies, CISTI 2015, doi = 10.1109/CISTI.2015.7170481, 2015.
26. Burgos, and Daniel, *A critical review of ims learning design*, The Art and Science of Learning Design, 9789463001038, pp. 137–153, 2015.
27. Aneesha Bakharia, Shane Dawson, *SNAPP: A bird's-eye view of temporal participant interaction*, Proceedings of the 1st International Conference on Learning Analytics and Knowledge, 9789463001038, pp. 137–153, 2011.
28. Kalogeraki, Eleni Maria and Troussas, Christos and Apostolou, Dimitris and Virvou, Maria and Panayiotopoulos, Themis, *Ontology-based model for learning object metadata* IISA 2016 - 7th International Conference on Information Intelligence Systems and Applications, 2016.
29. Burgos, Daniel and Tattersall, Colin and Koper, Rob, *How to represent adaptation in e-learning with IMS learning design* Interactive Learning Environments, vol. 15,no. 2, pp.161–170, 2007.
30. Magnisalis, Ioannis and Demetriadis, Stavros, *Extending IMS-LD Capabilities: A Review, a Proposed Framework and Implementation Cases* Studies in Computational Intelligence,vol. 408 pp. 85–108, 2012.
31. Koper, Rob and Miao, Yongwu, *Using the IMS LD Standard to Describe Learning Designs* https://services.igi-global.com/resolvedoi/resolve.aspx?, pp. 41–86, 1.
32. Maina, Marcelo Fabián, *Design of pedagogical scenarios : adapting the MISA method to the IMS LD specification* http://hdl.handle.net/10609/6401, 2010.
33. Olsen, Jennifer K. and Aleven, Vincent and Rummel, Nikol, *Toward Combining Individual and Collaborative Learning Within an Intelligent Tutoring System* Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics),Springer, Cham, vol. 9112,pp. 848–851, 2015.