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INTELLIGENT TUTORING SYSTEMS AND ADAPTIVE LEARNING ENVIRONMENTS: TEACHER-CENTRIC METHOD IN AI-AUGMENTED CLASSROOMS

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Abstract

The Redesigning Education around the Intelligent Tutoring Systems (ITS) and Adaptive Learning Environments (ALE) are integrated into AI-augmented classrooms, teachers have been returned as central figures in a personalized learning ecosystem. It processes real-time feedback and customizes instructions to meet students' individual demands and understanding paces. The ALE takes this even further by analysing individual student data on an ongoing basis in order to tailor learning paths to each and every student. The technology in these tools can easily shift to a teacher-centric model teaching needs with higher value-add, allowing educators to teach critical and creative thinking rather than assessment routine assessments or personalized content. When students are using technology, teachers are able to monitor much easier so that interventions can occur early and supports put into place right away. This improves the relationship between teacher and student during lessons, creating a more give-and-take learning dynamic.

Keywords: ITS, Adaptive Learning Environment, AI Augmented Classrooms, Teacher-Centric Framework, Personalized Learning and Instructions

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Introduction

Personalized learning and instruction are gaining a lot of attention, as Intelligent Tutoring Systems (ITSs) have become ideal tools for providing these adapting environments. Using artificial intelligence (AI) systems, they create personalized learning experiences customized for each student. Adapting content, feedback and guidance for each student's level of progress and personal preferences is intended to make ITSs more effective and engaging than traditional one-size-fits-all approaches (Zint et al., 2024). The design of ITSs adapted learning environments in classrooms could benefit from a closer look at the crucial role teachers play. This used to be created with an accent on student-facing functionality whereas the needs and choices of teachers were thought-about second. This sometimes results in diminished adoption, as teachers may feel like they are quite far from being solo-ed and that the technology forces them off their island or is not tailored to how they currently teach. To deal with this problem, the teacher-centric approach needs to be applied in ITS and adaptive learning environment design and implementation. This role will allow teachers to remain the focal point of development and have a voice in it, which we believe can ensure AI-augmented classrooms are human-focused tools that actually strengthen educators' instructional capacity. This process understands that who better than the teachers themselves, are knowledgeable in their subject matter as well as proficient to deal with such chaos of classroom. When we work together with teachers using AI to develop tools that stand by and extend existing teaching practices instead of replacing them. Engage teachers in every facet of the ITS and adaptive learning environment development lifecycle — from requirements gathering, to iterative user feedback (and refinement) (Raaj, 2024). It means understanding the pedagogical philosophy of (and preferred instructional strategies used by) each teacher, and what they grapple with in their classroom that is essentially beyond your control. Building AI-augmented classrooms, as opposed to solely teacher-controlled or automated systems, elicits student engagement while allowing teachers the freedom to adjust any new system according to their teaching habits and environment in a way that is not too rigid. It finds that a teacher-centric approach gives importance to transparency and control. Teachers need to understand what those AI changes are and how the data justifies any automation. They should also be able to contradict or modify the system recommendations when warranted according to his/her professional opinion and knowledge of their students. Improving the effectiveness of teachers and AI-based systems, respectively by supporting trust and collaboration on both sides.

Teacher-Centric Framework for Integration

Thus, a teacher-centric framework is required to well integrate Intelligent Tutoring Systems (ITSs) and adaptive learning environments to properly support teachers. Overarching this framework are a number of key principles designed to ensure the expertise and needs of teachers is central as design occurs (Romero et al., 2017).

Design Principles for Teacher-Centric ITSs

Co-design with Educators: Involve teachers as co-designers of ITSs so that their inspiration and richness accompany the development perspective. Co-Creation through focus groups, surveys, and workshops where educators discuss their needs, preferences or challenges. A complex system that has user-friendly graphical interfaces (Agbo et al., 2019). An intelligent tutor should provide a design focusing on usability for the teachers. Easy-to-use interfaces that you can master in a few minutes will help educators focus on teaching, rather than learning how to navigate complex new systems (Apiola & Sutinen, 2021). The offering should also include ready access to data analytics and reporting tools that allow educators to easily monitor student progress (Pollock et al., 2019).

Professional Development and Support: Teachers must receive training on an ongoing basis. Again, that means more than just initial training about how the systems work but also

ongoing professional development as a way to help educators enrolled at home "to adapt new updates and methods (Lee et al., 2020).

Engagement of Teachers in Every Phase of System Development

Including teachers in every phase of the systems' development (from idea to solution) makes their voices central. This collaboration can ensure that problems are caught early and interventions are manageable and properly contextualized in the classroom (Psycharis et al., 2018).

Flexibility and Customization Support

Finally, any teacher-centered framework must emphasize flexibility and above all personalization. Teachers need the flexibility to make it their own, based on how they teach and the makeup of their classes. It gives them choices in how content is adjusted, pacing changed and what instructional strategies to use that are aligned with their pedagogical philosophies. If we design ITSs and adaptive learning environments to be flexible, then it could result in proper tools that will contribute positively towards teaching or learning (Liu et al., 2017).

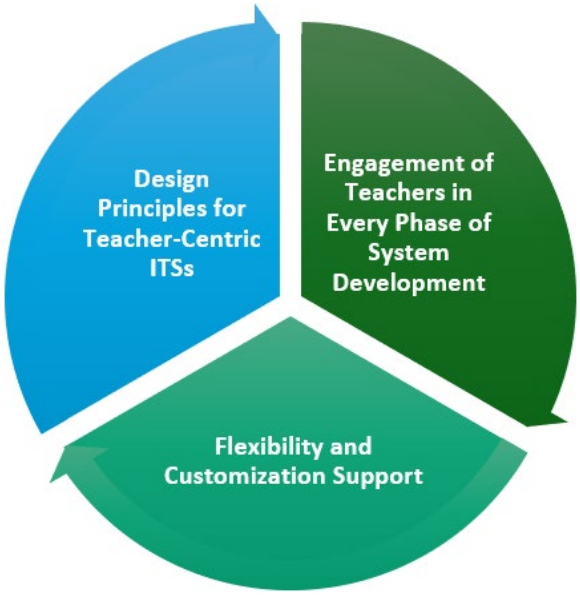

Figure 1 Teacher-Centric Framework

Key Components of Teacher-Centric System

These elements operate from the premise that a teacher-centric system for AI-based classrooms must have certain features to make it responsive to teachers and at the same time use artificial intelligence on its full potential. Adaptive lesson planning, real-time monitoring and feedback, and collaborative learning support all of these add up to the efficacy behind a potent technology-based platform (Pulimood et al., 2016).

Adaptive Lesson Planning

Among the more powerful features a teacher-centric approach can bring to bear is its capacity for helping educators design lesson plans that are adapted based on student data (Weintrop et al., 2016). These AI-powered tools help schools analyze student performance and provide resources to further learning based on what works best for each learner. Without having to moderate data analysis manually these tools wind up thus providing the academics a breather also with insights that are actionable subsequent lesson plans of whoever is partnered (Montiel & Gomez-Zermeño, 2021). But it is critical that these AI powered tools are built to be flexible. Teachers must also be able to modify the system's recommendations with their professional judgement and understanding of what they know about strengths, weaknesses,

desires etc., of every student Options for faculty to include their own lesson materials and teaching methods in the system ensure that these personalized plans are consistent with individual pedagogical philosophies as well of classroom dynamics (Qin, 2009).

Monitoring Delivery in Real Time and Feedback

Real-time progress monitoring, early intervention capabilities deliver insights that can only be accessed through a traditional teacher-centric worldview. AI-driven dashboards and visualization can alert teachers to areas of concern (or even little miracles) so that they have the ability to take appropriate measures as necessary. The tools can also offer suggestions for appropriate next steps (e.g. more practice problems or support) both in general and specifically according to the individual needs of each student, autonomously saving teachers time by optimizing classroom workflows (Barcelos & Silveira, 2012). These systems can provide teachers with data in real-time and through their formative daily use, give teachers actionable insight to inform practice so every student starts on or near grade-level every day. But being able to display data clearly and simply is of the essence, since teachers who are intuitive if not skilled in their use of software might have little patience or time for complex analytics packages. A system also should enable teachers to tailor the data they receive and how it is displayed, so that the information will be delivered in a manner consistent with their routines for tracking student performance (Gross et al., 2014).

Support for Collaborative Learning

Last but not least, features that will make group work and peer learning highly available in AI-augmented classes need to be a part of the teacher-centric system. Among the many advantages of collaborative learning are better problem-solving, higher student engagement and increased social-emotional development (García-Peñalvo & Mendes, 2018). Online collaborative learning with the help of AI-based tools - Using virtual breakout rooms, multiplayer gaming in jeopardy style or even dynamic cute and cuddly whiteboarding alongside peer-driven illustration CF-based comment communities. In this way, by bundling these features into a teacher-centric system, educators can use AI to craft active and productive peer learning outcomes (Psycharis, 2018). One lick before I go This kind of collaboration is great in the sense that it allows teachers to drive these collaborative activities, ensuring they coincide with what we want from our lessons and management. The system should further allow teachers to set the collaborative features in any way they like, depending on their students' needs/preference (Bati et al., 2018).

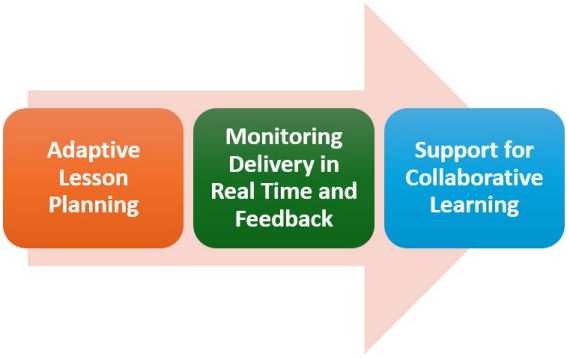

Figure 2 Key Components of a Teacher-Centric System

Challenges in Integrating ITSs and Adaptive Learning Environments

Lack of Teacher Involvement in System Design and Implementation

While intelligent tutoring systems (ITSs) and adaptive learning environments have the potential to offer significant benefits, there are several key challenges faced in integrating such technologies within classrooms. A big challenge is the fact that teachers are rarely

involved in designing or deploying these systems. Generally, ITS have been established from a student perspective rather than the teachers that will be using it. However, this neglect can result in a mismatch between the system's functionalities and how classrooms work on-the-ground, prohibiting teachers from integrating said technology seamlessly into their instructional strategies. The biggest challenges are that it has been very difficult to fit ITSs and adaptive learning environments into all kinds of teaching styles or preferences. Each teacher has their own way, based on subject matter expertise, pedagogical philosophy and the dynamics of a classroom. Building system to support this diversity requires both a keen understanding of what teachers require and the responsiveness to adapt these systems according teacher preferences. If it cannot adapt, educators feel the technology is not meeting them where they are and may impose on their autonomy or teaching philosophies.

Difficulty in Adapting to Diverse Teaching Styles and Preferences

The special challenge is in integrating the ITS with adaptive learning environments, where issues of transparency and control over AI-based adaptations are particularly difficult. Teachers should know how the AI-based adaptations function and the data that drives these changes. Teachers should also be able to override/modify the system's recommendations as needed, depending on their professional judgment or knowledge of students. If the system is not so transparent or there may be lack of control, this can potentially lead to teachers that are interested in promoting but reluctant to trust and adopt these systems. These issues emphasize the necessity for a teacher-cantered solution in the design and application of ITSs and adaptive learning environments. For making AI-augmented classrooms that actually empower teachers and enrich their ability to support student learning, the place of teacher in development cycle needs to be central as well honouring their voices (Wang et al., 2022). This takes account recognizing that teachers are the domain expertise in their subjects as well managing classroom complexities, and is to design AI based tools which augment/extend/deepen teacher practices rather than replace them (Czerkawski & Lyman, 2015).

Case Studies and Examples

Many successful implementations in different educational settings occur as the integration of teacher-centric Intelligent Tutoring Systems (ITSs) and adaptive learning environments. These case studies point to the strides these systems make in advancing personalized learning, bettering student outcomes and supporting teachers (Papadakis, 2020).

Successful Implementations

Carnegie Learning's Cognitive Tutor: One of the most lauded systems for delivering math instruction. The Cognitive Tutor, an intelligent tutoring system that delivers individualized instruction and adapts to the student's behavior in order to teach complex mathematical concepts. Teachers also commented that the system enabled them to concentrate on meeting individual student requirements, while the software took care of managing adaptive learning. Real-time data analytics implementation allowed teachers to follow student progress and provide guidance beyond the one-size-fits-all learning approach (Yadav et al., 2014).

Adaptive Learning Platform by Knewton: With the aim of personalizing content delivery and making it more student driven. It was tested in a pilot program at a large university, where instructors assessed that the system could increase student engagement and retention because it automatically adjusts to different learning styles. Knewton also provided teachers with data-driven feedback that allowed them to better adjust their teaching strategies for more successful student outcomes (Pollak & Ebner, 2019).

ALEKS (Assessment and Learning in Knowledge Spaces): This is a web-based learning system used to logistic regression which has been access implements via K-12. Adaptive questioning in ALEKS Assessment is supported by reasoned resources and offers an

individualized learning trajectory with the use of flexible assessment. In interviews, educators said that the system improved students' math skills and provided a way for teachers to identify weaknesses in their mathematical knowledge so they could focus on those areas (Saritepeci, 2020).

Learnings and Recommendations

The lessons learned from these implementations offer insights and guidelines in the deployment of teacher-centric ITSs, as well as adaptive learning environments:

Engage Teachers in Development: As is typical for successful systems, teachers should be involved in the design and implementation. They are able to make sure that technology complements real-world teaching practices based on observations of classroom dynamics and pedagogical input (Buitrago-Flórez et al., 2021). The Cognitive Tutor program, for example, was designed with extensive input and advice from teachers a move that probably helped explain why it also proved to be so much more useful and efficient (Gökçe & Yenmez, 2023).

Usability and Training: Proper training goes a long way, as does clear layout design. It is important that teachers are confident in the use of technology to ensure productivity. Continuing education training and support are essential to allow educators themselves the facilities that these system integration gets brought into their methods of teaching smoothly (Lodi & Martini, 2021).

Data Driven Instruction-One of the most powerful features we provide for education institutions today is leverage data to make learning decisions in minutes rather than months! One of the useful aspects for teachers and educators is that they provide actionable insights, which help steer a teacher in making informative decisions about instruction or intervention. The same is true of the tools and analytics built into Knewton's platform, which give teachers invaluable insights into their students' performance patterns that can help them tweak lesson plans in real-time (Tsortanidou et al., 2019).

Encourage Collaborative and Peer Learning: ITSs that enable student interaction with each other in a learning environment will drive higher engagement rates among students and help create an interactive classroom community. Adaptive platforms like ALEKS, which activate group work and peer feedback features for students to learn from one another under teacher guidance (Yilmaz Ince & Koc, 2021).

Flexibility and Customization: Systems must be flexible enough to allow instructors customize the content as well as adapt their own teaching style into it for adoption. This will give the stakeholders room for people to maintain who they are pedagogically by allowing openness in lesson planning/delivery thus being flexible with how technology fits into their personal world (Sırakaya et al., 2020).

Conclusively, the efficient execution of teacher-centred ITSs and adaptive learning situations substantiates its capacity to revolutionize teaching. These systems enable even teachers to achieve data-driven instruction, collaborate more at their own pace and comfort level — better serving students (Hutchins et al., 2020).

Ethical Considerations and Guidelines

As we are increasingly integrating Intelligent Tutoring Systems (ITSs) and becoming habituated to the concept of adaptive learning environments, it is essential that we pay attention also to the ethical peripheries surrounding artificial intelligence in education (Valovičová et al., 2020). Consequently, this blog post calls for a fair and transparent AI-based adaptation ensuring data privacy and security while stressing the importance of ethical implementation guidelines in order to be deliberate about promoting responsible policies towards equitable educational systems (Lockwood & Mooney, 2017).

Fairness, Transparency and Accountability

The primary ethical issue regarding the use of AI in education is that there might be bias in algorithms (Denning & Tedre, 2021). If trained on biased data sets or if not designed with diversity in mind, AI systems can fuel these very inequalities. It is important to remain vigilant in auditing AI algorithms for bias regularly and getting a broad variety of educators and stakeholders involved in the development process (Hsu & Liang, 2021). Taking an approach that is inclusive of everyone can help to identify and manage biases, which could ultimately influence student results. Another very important thing in using AI ethically is transparency. Both Educators and Students must understand the decision-making process AI systems go through and how this affects learning (Tedre & Denning, 2016). Accessible explanations and details about the algorithms that are used in these systems can provide volumes of trust between users. Also, educators must be able to assess and question AI-generated suggestions, safeguarding their autonomy over teaching practices. Penalties would also need to be applied as a form of accountability in case things go wrong with the AI system or if its effects are unintended. The performance and potential issues from the tools should be monitored, and educational institutions need to have clear policies in place for these guidelines. One way of doing this is through setting up feedback channels for teachers and students to give input on what they feel should be changed or improved (Agbo et al., 2021).

Keeping Data Private and Secure

In education, data privacy is a big concern with deploying AI systems given the dependency of many of these systems on collecting and analyzing mass quantities student behavioral information (Ulger, 2018). Due to student privacy and other legal, FERPA (Family Educational Rights and Privacy Act) restrictions in the US require not only that this data be secured but also audited with a full audit trail. Educational institutions should use end-to-end data security, and protect this highly sensitive information as they do medical records with encryption, access controls and secure storage from unauthorized users (Li et al., 2020). Finally, setting clear data usage policies is key about how information will be collected and used or shared with students. These policies must be shared with parents/guardians, who should have the opportunity to consent about data collection practices. Moreover, data privacy and responsible use of data is a must. Artificial intelligence systems should only take data they needed to work, and educators need training in what is at stake with their use of the comedian. These also contribute to prevent any misuse of the data and drives a culture where handling with Data is ethical (Leonard et al., 2016).

Creating an Ethical Framework for the Application of AI in Education

Given the complexity of AI in education, it is critical too that we create a comprehensive set of ethical guidelines to address both challenges as well as opportunities associated with these technologies (Hava & Koyunlu Unlu, 2021). Those guidelines should be based on fairness, transparency, accountability and privacy centered principles to help frame and guide educators, developers and policymakers alike. This is part of what the guidelines should seek to do: reinforce that educators will be involved in designing and implementing AI systems, such their views and can shape how a tool may develop. They should also promote continuous teacher training to impart them with the necessary skills of how-to combine AI tools in their classrooms while being compliant with ethical considerations (González-Pérez & Ramírez-Montoya, 2022). Ultimately, sustained and active collaboration between stakeholders such as- educators, technologists, policymakers and researchers is necessary in order to develop a common understanding of ethical AI use within Ed Tech. Through open dialogue and collaboration, we can create a set of best practices that supports the ethical use of AI and improves learning for all students (Iversen et al., 2018). In short, understanding the AI education problem together with addressing ethical concerns in its deployment are key to

ensuring that these AIs will be used responsibly and fairly (Miller et al., 2013). These critical pillars fairness, transparency, accountability and data privacy as well as the creation of ethical guidelines by all stakeholders can inform a learning environment that unleashes AI's potential to benefit students while ensuring their rights are protected (Bocconi et al., 2022).

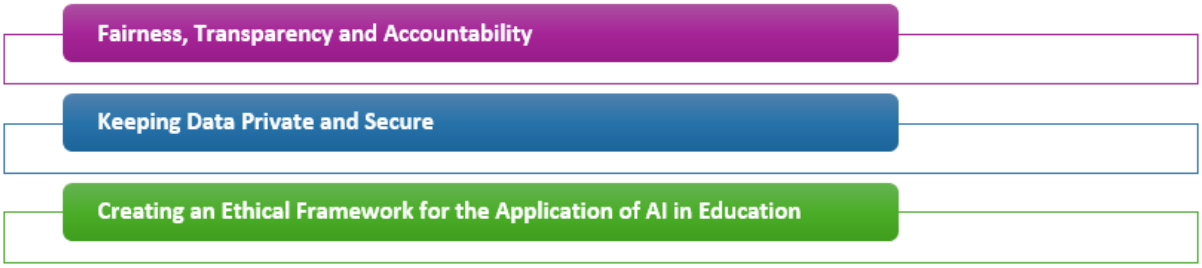

Figure 3 Ethical Considerations and Guidelines

Future Directions and Research Agenda

The education system is changing rapidly, especially in relation to new type of e-learning environments called Intelligent Tutoring System (ITS) and adaptive learning environment. These ongoing initiatives bring to the surface a number of seismic trends and new directions for research as these technologies mature. Its potential as well its need for continued investigation and re-working is evident in these trends.

Trending Technologies and Paradigm Developing

Personalized and Adaptable: Personalisation is one of the most important trends in ITSs. With advancements in AI and machine learning, these systems can process huge amounts of data about how students learn to ensure the content is adapted on-the-fly; hence ensuring effective pacing. This trend speaks to the various ways in which people learn best, and addresses individual needs based on their style of learning making it more interesting overall.

NLP (Natural Language Processing): It includes the variety of NLP technologies to improve how ITSs interact with students in more natural ways. In this way, ITSs can give more comprehensible feedback and support to students because it is able parse natural language that allows the student in engage with a dialogue with the system. This will open the way for a much richer learning and critical thinking.

Collaborative Learning Environments (CLEs): With a move in education toward collaborative learning models, ITS are being created to promote and model group work and peer interactions. This system can maintain the collaborative experience and group project-based learning with a shared responsibility yet continuing to allow personal support which they need. This trend signals a greater shift towards student-centered learning, which is also heavily focused on the importance of collaborative teamwork in education.

Data Analysis and Learning Analytics: Data analytics is become prevalent as increasingly sophisticated capabilities in education. Educators can use ITSs to gather and analyze data from student task performance, engagement, as well as learning behavior suggesting ways that educators might improve their teaching according to collected information. This evidence-based methodology, in turn, leads to better decisions and improved performance of students.

Future Research and Development Areas

Longitudinal Effective Studies: Comprehensive longitudinal studies to evaluate lasting effectiveness on student learning outcomes are necessary for ITSs. Studies are needed to examine this question in different educational contexts (e.g., k12, higher education) and observe student performance over time.

Equity and Access: Future research needs to examine issues related to equity and access in the deployment of ITSs. We need to know how that those technologies could be provided to every student, especially the historically underserved. Understanding access barriers and how to address them is paramount if the societal benefits promised by ITSs are to be made available for socially just reasons.
Teacher Training and Professional Development: As ITSs become more prominent features in the classroom, research should turn towards effective teacher training programs. It will be important to recognize how educators can most effectively receive support in utilizing these new technologies. This may involve investigating potential strategies for ITSs to be included in the current curricula and overcome possible obstacles of teachers.
Questions/attitudes As AI technologies become increasingly common in education, what are the key ethical considerations and how should they be guiding future developments? These studies must deal with the substantial technical obstacles remaining in achieving equity, transparency, accountability — and they will certainly also need to find constructive ways forward balancing very real but counterposed anxieties of data privacy vs. pubic security for instance. Designing a system for the proper use of AI that maintains ethical standards will build trust with educators, students and stakeholders (Sharma & Singh, 2022).

Consequences for Teacher Preparation and Professional Development

Therefore, ITS-integration with adaptive learning environments would require a complete overhaul of the teacher training and professional development programs (Diaz, 2024). This should not be the case and educators at all levels of practice ought to have access to professional learning that equips them with skills on how they can use such technologies in their classroom (Norman & Zoncita, 2024). This involves training on cyber-physical systems and real-time data interpretation, knowing what capabilities ITSs are capable of providing also given other input available to the teachers when they teach their subjects along with some actual strategies for integrating personalized learning into their delivery (Albuquerque et al., 2024). Professional development is further important in understanding educator-researcher-technology developer roles. This will also ensure that the development of ITSs is consonant with what educators and students need as a result (Zahra et al., 2024). Finally, with emerging trends and research areas, the future of ITSs & adaptive learning environment presents optimistic picture about the reshaping education. Through the lens of individualization, inclusivity and collaboration we can create a more personalized educational scene which will serve each learner. Based on that constantly changing landscape, ongoing exploration and innovation will be necessary to have the backs of educators as they use these tools with their students.

New Trends and Technologies

The major trends in ITSs are Personalisation and Adaptivity: Powered by a growing number of AI and machine learning data analysis-driven algorithms, these systems are capable to analyze extensive student datasets, and in turn can adjust the instructional content as well as pacing on real-time basis. By tailoring to the individual learning style, preferences and needs this in engaging learners that provides a better environment on how students can learn more effectively. Natural Language Processing (NLP): The incorporation of NLP technologies in ITSs is making the systems more responsive and interactive than before with students. More specifically, intelligent tutoring systems (ITSs) enable students to have a conversation-like interaction with the system that delivers more meaningful feedback and support by understanding natural language. This capability will help students learn more deeply and challenge them to become critical thinkers.

Collaborative Learning Environments (CLEs): As education moves more and more from a teacher-focused model of learning to collaborative models, ITS are also structuring themselves around supporting group work/pair-interactions. Such systems facilitate a collaborative work and problem solving, based on projects, which enables your students to work together but helps them still have personal support. This tendency also mirrors a larger wave passing through education in the form of student-centred learning and collaborative work.

Data vs Learning Analytics: right now, educational data analytics is just starting to mature as a field. By doing so, ITSs can track their performance data related to student interaction and learning behaviours that helps educators understand how effective has been their approach towards teaching. Enabling data-driven decision-making and targeted interventions, leading to better student outcomes.

Multimodal learning experiences: The use of text, Annotations, audio, video digest will make a JIT and enhanced with capabilities provided by the new emerging technologies ITS that are able to integrate multimodal. These systems can better cater to different types of learning preferences with varied content delivery, improving engagement. Multimodal learning also has the potential to improve knowledge retention and transfer too, as students can consume information through multiple sensory pathways.

Longitudinal Studies on Efficacy: To the best of our knowledge, there are no long-term evaluations (i.e., competence exams) about the efficacy of ITSs like ours in favor or opposed to student performance. Examine different contexts of education (eg, K-12 and higher education) to understand what the educational systems are doing well or failing in regard to promoting student success over time.

Equity and Access: Future research could further consider equity and access in the deployment of ITSs. The author said it is important to know how these new technologies can be available for everyone, especially more unprivileged students. Exploring what prevents access and how these impediments may be surmounted will help ensure that the benefits of ITSs benefit everyone in an equal manner.

Support for teacher training and professional development: Recommendations on ensuring that teachers have the support they need to create educational environments in which ITS can be successfully integrated. It will be crucial to understand how we can best support educators in utilizing these technologies toward their potential. This involves exploring the best ways teachers can introduce ITSs in their class and overcome whatever barriers they encounter.

Ethical implications and policies: With the development of AI technologies, ethical guidelines should be created for its application in education. Research should tackle key challenges related to the fairness, transparency and accountability of AI-driven systems like enhancing data-oriented approaches concerned with privacy and security. Having a system of regulations and guidelines on how AI should be used ethically will create trust between educators, students as well stakeholders.

Teacher Preparation and Professional Development Implications

The integration of intelligent tutoring systems with adaptive learning environments calls for a revision in teacher training and professional development programs. Education outcomes can be positively enhanced by putting the tools and knowledge into educators' hands on how to effectively use these technologies in their classroom. Among these are methods in reading and writing data analyses, an appreciation for the analytic possibilities afforded by ITSs on courseware platforms, as well as how they can embed personalization into their instruction. In addition, the professional development of all three stakeholder groups should highlight collaborative opportunities between educators and researchers or technology developers. Building these kinds of relationships and always having in mind a dialogue on a regular basis,

we keep at the center of ITS deployment an economical construct that is beneficial to educators and favourable to students (Nicolaides et al., 2024).

Conclusion

Challenges and opportunities in the integration of Intelligent Tutoring Systems (ITSs) with adaptive learning environments into educational settings We have seen in this the discussion throughout, a teacher-centric methodology is foremost to unleashing of AI use in education (Raghav et al., 2024). Only through the designing and implementation of systems with educators at the centre can we create a sustainable ecosystem where teaching is supported in practice, not just on paper one that truly supports students

Finally, successful deployment of ITSs and ALE always highlights the teacher's role in its operation. Educators have critical perspectives on what works in our classrooms, with specific students and unique groups of kids. Working with teachers in every phase of system development from ideation to continuous feedback ensures that the tools are authentic, timely solutions consistent with teaching on-the-ground. A teacher-centric system must be flexible (because teachers are) and customizable. To minimise skill division, it is plausible to imagine some boundaries within which educators should be able configure the degree of personalisation they want AI driven recommendations can provide with only few options. This flexibility allows teachers to stay true professionals while using technology as a supplemental learning tool. Real-time monitoring and feedback systems are extremely important to allow for successful integration. These systems deliver formative insights to educators to act upon, including informing timely interventions and instructional decision-making. This data-driven approach not only promotes individual student achievement, but encourages an environment of excellence in the classroom. In addition, ethical aspects related to integrity of access and data privacy should take precedence over the use of AI in education. Trust and fairness: ensuring that AI systems are bias-free, fostering educators' awareness on how this work, handling the data of students in a responsible way. Inversely, as we move into a more technology-dominant educational climate it's all the most important for educators and researchers to promote teacher-centric models in AI-augmented classrooms. This sort of call to action is made up by various key components

Engagement and Collaboration, Educators should be key participants in all stages of AI development. A foundational first step would be to create Collaboratory structures that support sustained dialogue between teachers, developers and researchers in schools and educational institutions. The partnership will also ensure that the AI tools are built by people who have a deep understanding of the classroom.

Professional development Create capacity building opportunities to prepare the teacher with knowledge, skills and competencies required for AI integrated pedagogy. This training should include technical skills in addition to ethical considerations, data interpretation and the like related with AI. Training must be comprehensive regarding all aspects of using any form of technology including how they can be applied within teaching contexts etc. Policymakers should prioritize the creation of formal ethical guidelines and standards for AI use in educational provision. To stay within the bounds of reason, necessary legislative guidelines for fairness, transparency and accountability need to be set up around issues such as data privacy etc., further ensuring that AI deployments in this sector are used primarily keeping best interest of students and educators at priority.

Continued Exploration of the Intersection Between AI and Education, Researchers should investigate how to apply different types of educational innovations aimed at enhancing teaching, learning. These narratives should be the focus of this analyses to continuously change AI development, as it evolves in and for a classroom.

These strands promise to transform education finally and in short, the integration of ITSs with adaptive learning environments is a message home. exercise it, but only when we take a teacher-centric approach that empowers teachers, leads with ethical considerations in the driver's seat and calls for collaboration among all stakeholders. It helps us make AI-augmented classrooms that would serve to not just augment learning but also support the precious role of a teacher for they are facilitators so essential in helping students learn and grow. The future of education looks promising and with joint effort, it is possible that the same will be realized in a more Cost-Effective, convenient as well smooth sailing way.

References

Agbo, F., Oyelere, S., Suhonen, J., & Adewumi, S. (2019). *A systematic review of computational thinking approach for programming education in higher education institutions*. A paper presented at the 19th Koli Calling International Conference on Computing Education Research, Koli, Finland.

Agbo, F., Yigzaw, S., Sanusi, I., Oyelere, S., & Mare, A. (2021). *Examining theoretical and pedagogical foundations of computational thinking in the context of higher education*. A paper presented at the 2021 IEEE Frontiers in Education Conference, Lincoln, USA.

Albuquerque, U., Maroyi, A., Ladio, A., Pieroni, A., Abbasi, A., Toledo, B., & Ferreira Júnior, W. (2024). Advancing ethnobiology for the ecological transition and a more inclusive and just world: a comprehensive framework for the next 20 years. *Journal of Ethnobiology and Ethnomedicine, 20*, 18.

Apiola, M., & Sutinen, E. (2021). Design science research for learning software engineering and computational thinking: Four cases. *Computer Applications in Engineering Education, 29*(1), 83-101.

Barcelos, T., & Silveira, I. (2012). *Teaching computational thinking in initial series an analysis of the confluence among mathematics and computer sciences in elementary education and its implications for higher education*. A paper presented at the 2012 XXXVIII Conferencia Latinoamericana En Informatica, Medellin, Colombia.

Bati, K., Yetişir, M., Çalişkan, I., Güneş, G., & Gül Saçan, E. (2018). Teaching the concept of time: A steam-based program on computational thinking in science education. *Cogent Education, 5*(1), 1507306.

Bocconi, S., Chioccariello, A., Kampylis, P., Dagienė, V., Wastiau, P., Engelhardt, K., & Stupurienė, G. (2022). *Reviewing computational thinking in compulsory education: State of play and practices from computing education*. Luxembourg: Publications Office of the European Union.

Buitrago-Flórez, F., Danies, G., Restrepo, S., & Hernández, C. (2021). Fostering 21st Century Competences through Computational Thinking and Active Learning: A Mixed Method Study. *International Journal of Instruction, 14*(3), 737-754.

Czerkawski, B., & Lyman, E. (2015). Exploring issues about computational thinking in higher education. *TechTrends, 59*, 57-65.

Denning, P., & Tedre, M. (2021). Computational thinking: A disciplinary perspective. *Informatics in Education, 20*(1), 361-390.

Díaz, C. (2024). Wild theory: From Transdisciplinary Concepts to Undisciplined Futures. In J. Ulmer, C. Hughes, M. Salazar Pérez, & C. Taylor. (eds.). *The Routledge International Handbook of Transdisciplinary Feminist Research and Methodological Praxis* (No. 16). London: Routledge.

García-Peñalvo, F., & Mendes, A. (2018). Exploring the computational thinking effects in pre-university education. *Computers in Human Behavior, 80*, 407-411.

Garg, N., & Singh, B. (2022). Sustainable Development-Adopting a Balanced Approach between Development and Development Induced Changes. *ECS Transactions, 107*(1), 15.

Gökçe, S., & Yenmez, A. (2023). Ingenuity of scratch programming on reflective thinking towards problem solving and computational thinking. *Education and Information Technologies, 28*(5), 5493-5517.

González-Pérez, L., & Ramírez-Montoya, M. (2022). Components of Education 4.0 in 21st century skills frameworks: systematic review. *Sustainability, 14*(3), 1493.

Gross, S., Kim, M., Schlosser, J., Mohtadi, C., Lluch, D., & Schneider, D. (2014). *Fostering computational thinking in engineering education: Challenges, examples, and best practices*. A paper presented at the 2014 IEEE Global Engineering Education Conference, Istanbul, Turkey.

Hava, K., & Koyunlu Ünlü, Z. (2021). Investigation of the relationship between middle school students' computational thinking skills and their STEM career interest and attitudes toward inquiry. *Journal of Science Education and Technology, 30*(4), 484-495.

Hsu, T., & Liang, Y. (2021). Simultaneously improving computational thinking and foreign language learning: Interdisciplinary media with plugged and unplugged approaches. *Journal of Educational Computing Research, 59*(6), 1184-1207.

Hutchins, N., Biswas, G., Maróti, M., Lédeczi, Á., Grover, S., Wolf, R., & McElhaney, K. (2020). C2STEM: A system for synergistic learning of physics and computational thinking. *Journal of Science Education and Technology, 29*, 83-100.

Iversen, O., Smith, R., & Dindler, C. (2018). *From computational thinking to computational empowerment: a 21st century PD agenda*. A paper presented at the 15th Participatory Design Conference, Genk, Belgium.

Lee, I., Grover, S., Martin, F., Pillai, S., & Malyn-Smith, J. (2020). Computational thinking from a disciplinary perspective: Integrating computational thinking in K-12 science, technology, engineering, and mathematics education. *Journal of Science Education and Technology, 29*(1), 1-8.

Leonard, J., Buss, A., Gamboa, R., Mitchell, M., Fashola, O., Hubert, T., & Almughyirah, S. (2016). Using robotics and game design to enhance children's self-efficacy, STEM attitudes, and computational thinking skills. *Journal of Science Education and Technology, 25*, 860-876.

Li, Y., Schoenfeld, A., diSessa, A., Graesser, A., Benson, L., English, L., & Duschl, R. (2020). Computational thinking is more about thinking than computing. *Journal for STEM Education Research, 3*, 1-18.

Liu, H., Perera, S., & Klein, J. (2017). Using Model-Based Learning to Promote Computational Thinking Education. In P. Rich, & C. Hodges. (eds.). *Emerging Research, Practice, and Policy on Computational Thinking* (pp. 153-172). Springer, Cham.

Lockwood, J., & Mooney, A. (2017). *Computational Thinking in Education: Where does it fit? A systematic literary review*. Retrieved from https://doi.org/10.48550/arXiv.1703.07659.

Lodi, M., & Martini, S. (2021). Computational thinking, between Papert and Wing. *Science & Education, 30*(4), 883-908.

Miller, L., Soh, L., Chiriacescu, V., Ingraham, E., Shell, D., Ramsay, S., & Hazley, M. (2013). *Improving learning of computational thinking using creative thinking exercises in CS-1 computer science courses*. A paper presented at the 2013 IEEE Frontiers in Education Conference, Oklahoma City, USA.

Montiel, H., & Gomez-Zermeño, M. (2021). Educational challenges for computational thinking in k-12 education: A systematic literature review of "scratch" as an innovative programming tool. *Computers, 10*(6), 69.

Nicolaides, A., Lim, A., Herr, N., & Barefield, T. (eds.). (2024). *Reimagining Adult Education as World Building: Creating Learning Ecologies for Transformation*. New York: Taylor & Francis.

Norman, P., & Zoncita, D. (2024). *Elaborating the Efficacy of Outdoor Arts-based Cooperative Learning Experiences on the Latino Immigrant Students' Engagement, and Academic & Social Success in ESL-STEAM Education*. Doctor of Leadership Studies Thesis, Gonzaga University.

Papadakis, S. (2020). Evaluating a teaching intervention for teaching STEM and programming concepts through the creation of a weather-forecast app for smart mobile devices. In M. Kalogiannakis, & S. Papadakis. (eds.). *Handbook of research on tools for teaching computational thinking in P-12 education* (pp. 31-53). Pennsylvania: IGI Global.

Pollak, M., & Ebner, M. (2019). The missing link to computational thinking. *Future Internet, 11*(12), 263.

Pollock, L., Mouza, C., Guidry, K., & Pusecker, K. (2019). *Infusing computational thinking across disciplines: Reflections & lessons learned*. A paper presented at the 50th ACM Technical Symposium on Computer Science Education, Minneapolis, USA.

Psycharis, S. (2018). STEAM in education: A literature review on the role of computational thinking, engineering epistemology and computational science. computational steam pedagogy (CSP). *Scientific Culture, 4*(2), 51-72.

Psycharis, S., Kalovrektis, K., Sakellaridi, E., Korres, K., & Mastorodimos, D. (2018). Unfolding the curriculum: physical computing, computational thinking and computational experiment in STEM's transdisciplinary approach. *European Journal of Engineering and Technology Research*, (Special Issue), 19-24.

Pulimood, S., Pearson, K., & Bates, D. (2016). *A study on the impact of multidisciplinary collaboration on computational thinking*. A paper presented at the 47th ACM technical symposium on computing science education, Memphis, USA.

Qin, H. (2009). *Teaching computational thinking through bioinformatics to biology students*. A paper presented at the 40th ACM technical symposium on Computer science education, Chattanooga, USA.

Raaj, S. (2024). Education, Research and Innovation in India: The Shifting Paradigms. *Journal of Higher Education Theory and Practice, 24*(1), 75-85.

Raghav, A., Singh, B., Jermsittiparsert, K., Raghav, R., & Yadav, U. (2024). Artificial Intelligence in Environmental and Climate Changes: A Sustainable Future. In B. Singh, C. Kaunert, K. Vig, & S. Dutta. (eds.). *Maintaining a Sustainable World in the Nexus of Environmental Science and AI* (pp. 485-506). Pennsylvania: IGI Global.

Romero, M., Lepage, A., & Lille, B. (2017). Computational thinking development through creative programming in higher education. *International Journal of Educational Technology in Higher Education, 14*(1), 1-15.

Saritepeci, M. (2020). Developing computational thinking skills of high school students: Design-based learning activities and programming tasks. *The Asia-Pacific Education Researcher, 29*(1), 35-54.

Sharma, A., & Singh, B. (2022). Measuring Impact of E-commerce on Small Scale Business: A Systematic Review. *Journal of Corporate Governance and International Business Law, 5*(1), 34-38.

Sırakaya, M., Alsancak Sırakaya, D., & Korkmaz, Ö. (2020). The impact of STEM attitude and thinking style on computational thinking determined via structural equation modeling. *Journal of Science Education and Technology, 29*, 561-572.

Tedre, M., & Denning, P. (2016). *The long quest for computational thinking*. A paper presented at the 16th Koli Calling international conference on computing education research, Koli, Finland.

Tsortanidou, X., Daradoumis, T., & Barberá, E. (2019). Connecting moments of creativity, computational thinking, collaboration and new media literacy skills. *Information and Learning Sciences, 120*(11/12), 704-722.

Ulger, K. (2018). The effect of problem-based learning on the creative thinking and critical thinking disposition of students in visual arts education. *Interdisciplinary Journal of Problem-Based Learning, 12*(1). Article 10.

Valovičová, Ľ., Ondruška, J., Zelenický, Ľ., Chytrý, V., & Medová, J. (2020). Enhancing computational thinking through interdisciplinary STEAM activities using tablets. *Mathematics, 8*(12), 2128.

Wang, C., Shen, J., & Chao, J. (2022). Integrating computational thinking in STEM education: A literature review. *International Journal of Science and Mathematics Education, 20*(8), 1949-1972.

Weintrop, D., Beheshti, E., Horn, M., Orton, K., Jona, K., Trouille, L., & Wilensky, U. (2016). Defining computational thinking for mathematics and science classrooms. *Journal of Science Education and Technology, 25*, 127-147.

Yadav, A., Mayfield, C., Zhou, N., Hambrusch, S., & Korb, J. (2014). Computational thinking in elementary and secondary teacher education. *ACM Transactions on Computing Education, 14*(1), 1-16.

Yilmaz Ince, E., & Koc, M. (2021). The consequences of robotics programming education on computational thinking skills: An intervention of the Young Engineer's Workshop. *Computer Applications in Engineering Education, 29*(1), 191-208.

Zahra, A., Waheed, Z., Fatima, T., & Khong, K. (2024). Leveraging Technology for Environmental Awareness: Insights from Experimental Research with Middle School Students in Malaysia. *RMLE Online, 47*(4), 1-17.

Zint, M., Michel, J., Valentine, T., & Collins, S. (2024). Collaborating with Students to Advance Climate Change Education at the University of Michigan (USA): Insights and Recommendations. In W. Leal Filho, M. Sima, A. Lange Salvia, M. Kovaleva, & E. Manolas. (eds.). *University Initiatives on Climate Change Education and Research* (pp. 1-28). Cham: Springer.

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