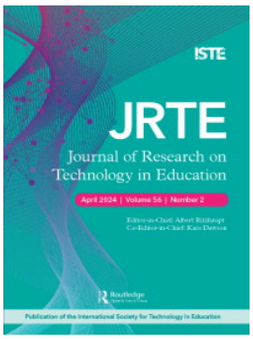

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Augmented teachers: K–12 teachers' needs for artificial intelligence's complementary role in personalized learning

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ABSTRACT

Empowering K-12 teachers for personalized learning using artificial intelligence (AI) is an open challenge. AI systems often fall short of meeting the needs of teachers, hindering the educational process or even causing conflicts. To bridge this gap, our study aims to explore the needs of teachers regarding AI's complementary role within K-12 classrooms. In Study 1, we conducted a focus group interview ($n=15$) to identify the roles that teachers envision AI augmenting for personalized learning. We identified eight key roles: *personalized curriculum design*, *development of instructional materials*, *foundational learning support*, *self-reflection support*, *student evaluation*, *career guidance*, *student management*, and *administrative task support*. In Study 2, we examined the preferences of 128 teachers from various school levels (elementary, middle, and high school) with regard to how they envision the use of AI in their classrooms. Our analysis revealed that teachers have differing preferences for AI roles based on the school level. Elementary school teachers placed emphasis on student assessment and management, while middle and high school teachers prioritized self-reflection support and career guidance. Interestingly, teachers underscored the significance of maintaining a complementary relationship with AI, pursuing shared objectives, and fostering sustained interaction, with the aim of evolving into "augmented teachers." The implications of these findings as design considerations are thoroughly discussed.

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Augmented teachers; artificial intelligence; complementarity; personalized learning; K–12

Introduction

Artificial intelligence (AI) offers promising opportunities for enhancing personalized learning experiences for students, leading to improved educational outcomes by reshaping traditional teaching methods (Jin et al., 2023). Recent advancements in generative AI models, exemplified by ChatGPT, have ignited the development of customized test questions and educational materials, thus augmenting the efficiency and effectiveness of teachers (Terwiesch, 2023). The rise of intelligent tutoring systems, capable of real-time analysis of students' learning processes (Jin et al., 2023), has enabled individualized learning interventions tailored to each student's unique needs (Goel & Polepeddi, 2018). AI-based analytics systems support teachers in comprehending students' progress by evaluating diverse data types, such as clickstreams, quizzes, and login/logout patterns, and even eye-tracking data (Seo, Dodson, et al., 2021). These cumulative

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advancements underscore AI's transformative potential in facilitating personalized and adaptive education, designed to meet the diverse learning requirements of students (Huang et al., 2023).

The growing prevalence of AI systems in education, while promising, also raises a number of concerns. These complex systems pose novel challenges to teachers, threatening their control over the learning process, and may cause conflicts within the classroom environment (Seo, Tang, et al., 2021). Notably, teachers worry about AI providing students with incorrect information and fear that students' overreliance on AI may impede opportunities for self-guided exploration and discovery. These challenges are further amplified by the generally limited understanding teachers have of AI operations (Xia et al., 2023). Often, teachers struggle to interpret data provided by learning analytics, lack comprehension of AI technologies' potential in education, and express uncertainty regarding the pedagogical implications of incorporating AI in teaching (Fong et al., 2019). Limited understanding of AI technologies might discourage teachers from leveraging AI as a supportive tool in their teaching (Backfisch et al., 2021). To facilitate the effective integration of AI systems into the educational landscape, further research is needed to explore how AI can support teachers' existing classroom practices (Alfoudari et al., 2021).

A question frequently posed in recent research is how AI can be designed to assist teachers (Celik et al., 2022). Holstein and Aleven (2022) introduced the concept of human-AI complementarity, endorsing the development of AI systems that work alongside human teachers rather than replacing them. Similarly, Cukurova et al. (2019) explored the potential of AI to support human teachers' decision-making processes, promoting a hybrid approach that integrates AI and human instruction. Gayed et al. (2022) also investigated how AI can assist instructors of English as a foreign language. They suggested that AI could expedite feedback on low-level writing tasks, allowing instructors to focus on higher-level writing tasks, such as organization and revision. Nonetheless, the specific complementary role that AI should play to achieve successful human-AI complementarity remains largely unanswered. In this context, Felix (2020) argued for further research to discern the strengths of human teachers and AI, facilitating the effective division of roles to ensure mutual complementarity. More recently, Guo and Wang (2023) explored the potential contributions of ChatGPT in teaching and learning writing skills, suggesting a collaboration and mutual complementarity between teachers and ChatGPT in providing student feedback. Based on these studies, our research refers to teachers whose ability to provide personalized learning is augmented through AI's complementary role as "augmented teachers."

Overall, our study aims to define the complementary relationship between human teachers and AI to materialize the concept of augmented teachers within K–12 classrooms. In Study 1, we investigated the specific roles where augmented teachers would benefit from a complementary partnership with AI to facilitate personalized learning for K–12 students (see Section 3). Due to distinct learning objectives at different school levels, teachers may possess divergent expectations for the role of augmented teachers in realizing personalized learning. In Study 2, we further examined teachers' preferences across different school levels (elementary, middle, and high school) regarding their envisioned use of AI in classrooms (see Section 4). Our study addresses the following research questions:

- **RQ1:** *What complementary role do teachers need AI to play for personalized learning in K-12 classrooms?*
- **RQ2:** *How do teachers' preferred complementarity roles for AI vary across school levels (elementary, middle, and high school)?*

The significance of our study lies in its potential to bridge the gap between theoretical concepts of human-AI complementarity and practical applications within K-12 educational settings. By addressing the research questions, our study aims to provide empirical insights into the effective integration of AI in classrooms, tailored to the unique dynamics of different school levels. The findings are expected to contribute to the ongoing discourse on the role of AI in education, offering guidelines for educators on how to effectively utilize AI as a supportive tool while maintaining their pedagogical

autonomy. Moreover, the outcomes of our study could pave the way for a more harmonious and productive coexistence of human teachers and AI in the educational landscape, enhancing the quality of teaching and learning experiences for both educators and students.

Background

The role of teachers for personalized learning

Teachers are responsible for meeting expectations of the roles. Role expectations can be defined as "the set of beliefs regarding appropriate behavior for a particular position in a social structure" (Soles, 1964, p. 227). Teachers are now perceived not merely as conveyors of knowledge, but as proactive guides and facilitators who steer students toward becoming self-directed learners (Jin et al., 2023). Based on an analysis of prior research on teachers' roles for personalized learning, our study proposed the following four key areas: *curriculum development*, *teaching and facilitating*, *guidance*, and *classroom and school management*.

Firstly, teachers are responsible for actively participating in the curriculum design of the subjects they teach (Eggleston, 2018). Classroom-level curriculum development typically entails "curriculum-making processes that teachers make in the official curriculum at the classroom level" (Shawer, 2017, p. 297), which is a crucial role that teachers must fulfill. This is because interpretations of the same curriculum can differ depending on the characteristics of the students and the schools where teachers are instructing, potentially influencing students' educational and learning outcomes (Jackson, 1992). Specifically, teachers need to develop guidelines on what to teach, to design learning content, teaching methods, and evaluation methods that effectively align with the lesson objectives.

Secondly, teachers are responsible for teaching students to achieve their learning objectives. Hannafin and Savenye note that the traditional role of teachers is as "a lecturer, knowledge provider, and controller of activities" (Hannafin & Savenye, 1993). Valli and Buese (2007) argue that the instructional role of teachers has expanded to assess students' learning and monitor their progress. Consequently, teachers today are expected to serve as "facilitators helping learners to make judgments about the quality and validity of new sources and knowledge, […] mediators between learners and what they need to know, and providers to scaffold their understanding" (Amin, 2016, p. 40).

Thirdly, teachers guide for students to become competent members of society. Teachers take on additional roles such as managing students' social and emotional behavior and mentoring them in their overall development as well-rounded individuals (Amin, 2016). As role models, teachers demonstrate exemplary behavior, attitude, and thinking patterns to their students. It is important to note that mentoring does not involve educational supervision; rather, it focuses on assisting students in their learning process through a supportive relationship (Lingam & Gupta, 1998). This guidance from teachers aims to unlock students' potential and equip them with the necessary knowledge and skills for adult life and the workforce.

Fourthly, teachers take responsibility for classroom and school management. Teachers' actions in the classroom have a greater impact on student achievement than school policies related to curriculum, assessment, and community involvement (Marzano, 2003). As a result, it is important for teachers to productively manage their classrooms, including "to establish order, engage students, or elicit [students'] cooperation" (Emmer & Stough, 2001, p. 103). This includes effectively understanding the individual needs and progress of students, and managing the students in the classroom. Teachers are also responsible for various administrative duties necessary for smooth school operations, including compliance with regulations and report writing (Valli & Buese, 2007).

Teachers, especially those responsible for a large number of students, face challenges in fulfilling the various roles expected of them while providing personalized education. Recent studies have confirmed that these challenges can be mitigated or supported through AI-assisted services (Goel & Polepeddi, 2018; Hwang et al., 2020). However, the extent to which AI can augment teachers' four key roles, namely curriculum development, teaching and facilitating, guidance,

and classroom and school management, remains an open question. In this regard, recent studies (Celik et al., 2022; Holstein & Aleven, 2022) underscores the imperative for additional research aimed at developing AI systems capable of augment teachers' roles.

Human-AI complementarity for augmented teachers

Past research within education has illustrated effective examples of human-AI complementarity, demonstrating cases where teachers have been able to offer personalized guidance to students needing extra assistance as they interact with AI-based software (Holstein et al., 2017; Kessler et al., 2019). In the educational environment, human teachers and AI systems exhibit distinct but complementary strengths. AI's capabilities extend to automating routine tasks, which can free up valuable time for teachers to focus on more meaningful pedagogical activities (Holstein & Aleven, 2022). AI can also support teachers in making data-informed decisions (Holstein et al., 2018). The synergistic interplay between human teachers and AI carries the potential to foster effective personalized learning by harmonizing the contributions of both entities toward a common task or learning goal.

AI systems also carry the potential risk of unintentionally exacerbating harmful inequities or replacing valuable human-to-human interactions (Alkhatib & Bernstein, 2019; Green & Chen, 2019). More research is still needed to determine what complementary role AI systems should play to truly augment teachers in K-12 classrooms (Holstein et al., 2017; Holstein & Aleven, 2022; Kessler et al., 2019). It is important to explore ways to help human teachers become augmented teachers by designing AI systems in a way that leverages the strengths of human capabilities while simultaneously addressing AI risks and limitations.

Schleiger et al. (2023) pinpointed three crucial factors integral to designing collaborative human-AI systems that leverage the different attributes and strengths of humans and AI to achieve further improvements in educational outcomes. The collaborative human-AI system framework underscores the significance of (1) complementarity, in which the collaborative efforts of humans and AI surpass what each could achieve independently, (2) a shared objective and outcome, ensuring that both humans and AI strive toward the same goal, and (3) sustained, task-related interaction between humans and AI (see Table 1). The focus shifts from mere substitution of human tasks with automated processes to harnessing the collaborative potential of humans and AI to augment human abilities (Sindhwani et al., 2022).

The design of AI-based teacher support systems is often driven more by the availability of extant technical solutions than a comprehensive analysis of teachers' needs or expectations (An et al., 2020). Consequently, these tools frequently present information that teachers find challenging to integrate into their existing practices (Holstein et al., 2017). This suggests that a greater consideration of teachers' practices is an important consideration in the design of AI-based tools, including the identification of unexpected consequences of implementing these tools in the classroom. For instance, AI tutoring software has been designed to tailor educational content and instruction pacing based on automated inferences about individual students' needs (Ritter et al., 2016), which can complicate teachers' task of tracking each student's progress. Additionally, as AI tutoring software typically operates independently from teachers in terms of curriculum

Table 1. Three Factors for Designing Collaborative Human-AI System, adapted from Schleiger et al. (2023).

Factor	Description
Complementarity	The goal of interaction between the human and AI agents must be designed to leverage each agent's unique strengths to achieve improved outcomes that cannot be achieved individually (e.g., Gao et al., 2021)
Shared objective	The human and AI agents should align their focus on a shared objective, with their activities integrated and indivisible in generating the final output (Dellermann et al., 2021)
Sustained interaction	The human and AI agents should have reciprocal communication, enabling each agent to effectively grasp and respond to changes in the state of the objective or the other agent (Madni & Madni, 2018)

sequencing and pacing, conflicts can surface between AI decision-making and teachers' intended plans and objectives for the class (Holstein et al., 2017; Holstein & Aleven, 2022; Ritter et al., 2016). In response to these challenges, our study aims to explore the needs of K–12 teachers concerning the relationships they envision with AI to effectively bolster personalized learning, deploying the framework for a collaborative human-AI system, as described in Table 1.

Study 1: Identifying teachers' needs for AI roles in personalized learning

Methods

Participants

We conducted a focus group interview (FGI) with 15 teachers regarding their needs on the complementary roles of AI in implementing effective personalized learning. We recruited K–12 teachers from public schools in, a large metropolitan city S. As shown in Table 2, of the 15 teachers interviewed, 9 are female and 6 are male. All 15 teachers had more than 5 years of teaching experiences, and all of them had used AI-based education services in their class. For diversity, five teachers were recruited from each elementary, middle, and high school. To explore teachers' thoughts about AI-augmented classrooms, three rounds of FGIs were conducted. Each round lasted for 90 min and involved five teachers from each school level, totaling 15 teachers.

Procedure

To identify the teachers' needs to become augmented teachers, we designed an interview questionnaire. This questionnaire primarily focused on gathering their perspectives regarding the role of augmented teachers and the factors that should be considered in its design and development. The questions were shared with the participants one week before the FGI session. During the FGI, we began by explaining the research objectives and then conducted semi-structured face-to-face interviews with 15 participants. The aim was to elicit their needs regarding the roles of augmented teachers and to extract insights that could inform the design and development of such a role. Our approach involved initiating the discussion by asking participants about the specific role they wished AI could assist them with. We then proceeded to inquire about the type of augmented teacher they aspired to become through collaborative efforts with AI. The interviews, divided by school level (elementary, middle, and high school), each lasted approximately 90 min. The following questions were posed to participants:

- "Which of your roles would you like AI to help you with?"
- "How would you specifically like AI to help you?"

Table 2. Summary of the Teachers' Information.

ID	Teaching experience	School level	Teaching subject	Gender
P01	5–10 years	Elementary school	Homeroom teacher	F
P02	5–10 years	Elementary school	Homeroom teacher	F
P03	15–20 years	Elementary school	Homeroom teacher	M
P04	10–15 years	Elementary school	Homeroom teacher	F
P05	15–20 years	Elementary school	Homeroom teacher	F
P06	10–15 years	Middle school	Classroom teacher (Science)	F
P07	Over 20 years	Middle school	Classroom teacher (Reading)	F
P08	Over 20 years	Middle school	Career Guidance Counselor	F
P09	Less than 5 years	Middle school	Classroom teacher (Foundational Learning)	M
P10	10–15 years	Middle school	Classroom teacher (Math)	M
P11	5–10 years	High school	Classroom teacher (Math)	M
P12	15–20 years	High school	Classroom teacher (Information studies)	M
P13	Over 20 years	High school	Classroom teacher (English)	F
P14	Over 20 years	High school	Special education teacher	M
P15	Over 20 years	High school	Classroom teacher (Math)	F

- "What key aspects do you perceive as imperative to be proactively addressed during the design and development of AI-based augmented teachers for the successful application in the school setting?"

Data analysis

The responses from the FGI were recorded in audio format and transcribed for further qualitative data analysis. We carried out a thematic analysis (Braun & Clarke, 2006) to analyze the interview data. Initially, one author read through the transcribed interview data, generated initial codes, and outlined preliminary themes about what tasks the participants want to form a complementary relationship with AI to deliver personalized learning in classroom environments. Subsequently, two other authors iteratively read the interview data, reviewed the codes and generated themes. We continued to inductively read the interview data and create and revise codes and themes. We participated in three rounds of deliberations and discussions until reaching a consensus. Ultimately, the research team collaboratively identified content related to the research questions.

Results

In study 1, we explored what roles augmented teachers want to do to form a complementary relationship with AI in K-12 school settings. As a result of the study, Table 3 illustrates the themes derived from the results of the analysis, along with the corresponding list of codes. The eight themes are as following: (1) personalized curriculum design, (2) development of instructional materials, (3) foundational learning support, (4) self-reflection support, (5) student evaluation, (6) career guidance, (7) student management, and (8) administrative task support.

Personalized curriculum design

All high school teachers expressed their desire for AI to actively contribute to the creation of customized curricula, particularly in response to the critical nature of students' elective subject choices for their future careers. Despite teachers' involvement in researching materials and providing guidance during this process, the complexity of the high school credit system and the challenge of comprehending individual student characteristics hinder their ability to tailor curricula effectively (P15, P12, and P14). Consequently, teachers seek AI assistance in analyzing student data to develop personalized curricula, thereby improving overall work efficiency. While

Table 3. Thematic framework for analysis.

Theme	Code
Personalized curriculum design	Customized (personalized) curriculum
	Subject recommendations
	School credit systems
Development of instructional materials	Developing (Creating) instructional materials
	Customized Learning contents
Foundational learning support	Lack of foundational learning skills
	Not understanding contents
Self-reflection support	Reflection
	Learning progress
Student evaluation	Grading
	Evaluation
Career guidance	Career decision
	Career guide
	Career path
Student management	Attendances
	Student data
Administrative task support	Administrative tasks
	Administrative responsibility

acknowledging the potential of AI-recommended curricula, teachers (P11 and P13) emphasized the importance of reviewing the connection between these recommendations and students' future prospects. They stressed the necessity of integrating data-driven AI evaluation with teachers' subjective judgment and educational objectives (P11).

Development of instructional materials

Many teachers (12 out of 15) expect AI to play a complementary role in developing grade-appropriate instructional materials that are tailored to students' levels of proficiency. P10 and P11 said that they always worry about how to find appropriate instructional materials for their students. They expressed the need for an AI system that can analyze a variety of related materials and generate content that matches the teacher's learning objectives. Teachers have limited time for creating instructional materials (P03 and P06). Therefore, teachers (6 out of 15) expected that their work efficiency would increase if the AI system could analyze available learning materials and generate new, customized learning content. P02—a mathematics instructor—suggested, "If teachers and AI can collaborate to create and provide instructional materials tailored to students' proficiency levels in near real-time during class, truly personalized learning will be possible."

Foundational learning support

P06, P08, and P09 reported that it is difficult to address the needs of students who lack foundational learning skills. Class progress slows or stops when caring for these students. P06 emphasized that students who lack foundational learning have difficulty actively engaging in the classroom because they do not understand the content and have difficulty asking teachers for help and communicating their needs. Many teachers (11 out of 15) suggested that it would be helpful if AI could identify students who are lacking foundational learning and provide personalized content and feedback. P08 said, "Students who lack foundational learning may experience greater difficulties as they move into higher grades, so it is very important to detect and resolve these problems early." P10 hoped that AI would complement teachers by taking on the responsibility for helping students who lack foundational learning, helping them reach an average level. P06, P08 and P09 expected that such an AI would play a complementary role in the classroom by allowing teachers to focus on the progress of the entire class.

Self-reflection support

Many teachers (11 out of 15) suggested that it would be beneficial to provide students with opportunities for self-reflection on their learning activities; however, this takes considerable time and effort on the part of the instructor to create reflection questions. P09 emphasized that it would be more effective for students' self-reflecting if AI instead complemented teachers to analyze and visualize students' learning progress and provide it to students. P13 envisioned that "AI could provide students with opportunities for basic self-reflection by providing feedback or badges on their achievements." Overall, teachers agreed that AI provides analysis of objective data to help students self-reflect, and were willing to provide help to students if additional counseling was needed thereafter.

Student evaluation

Many teachers (11 out of 15) indicated that they would like to receive complimentary assistance from AI with inputting comprehensive student evaluations into educational portals such as the National Education Information System (NEIS) which is an educational administration information system as a centralized platform managing diverse educational activities. P01 and P02 responded that they would like AI to analyze the available data, such as students' grades, reading

records, and volunteer work, to generate sample feedback phrases for student evaluations. P11 and P15 noted the considerable amount of time and effort required to analyze various digital data of individual students. They expected that this work could be aided by AI. Similarly, P13 expressed her expectations for a collaborative student evaluation methodology in which analysis of objective data through AI and insight into the larger framework of human teachers complement each other.

Career guidance

Ten out of fifteen teachers emphasized the need for AI support in delivering personalized career guidance to students, considering their individual career preferences and aptitudes. Particularly, students in the second and third years of high school face critical career decisions, often showing skepticism toward school-provided information and favoring visually appealing materials from private academies for counseling purposes (P13). Although schools conduct various career assessments, including personality and aptitude evaluations, teachers primarily base their career recommendations on academic scores alone. According to P12, comprehensive AI assistance in understanding students' characteristics could enable a more holistic approach to career guidance beyond exam-centric suggestions. Effective communication between teachers and students holds vital significance in high schools where students explore diverse career paths. However, as pointed out by P13, teachers find it challenging to provide truly personalized counseling due to the difficulty in deeply understanding each student and being aware of all suitable career paths. P12 and P13 envisioned AI providing career path recommendations for teachers to utilize.

Student management

Many teachers (10 out of 15) responded that it is important to detect "at-risk" students early, so interventions can be made. P01, P02, and P04 said that although a variety of student data is collected—such as attendance and assignment evaluations—it is not easy to continuously monitor these data for each student. Teachers expected AI could analyze the available student data, and provide teachers with an overview of the entire class noting which, if any, students are falling behind. Furthermore, if AI provides information by linking past student records, it is expected that the problem of lack of continuity in student management whenever the homeroom teacher changes every year can be overcome (P04). P01 and P02 hoped that AI would go further by supporting teachers to take action directly with students, rather than simply providing a learning analytics dashboard to help teachers understand student data.

Administrative task support

About half of the teachers (8 out of 15) expressed their expectations for AI to assist with administrative tasks. They referred to a messenger group chat utilized by lead teachers to collectively address administrative issues and share information (P02). This collaborative platform inspired the notion of implementing a chatbot or similar tool to assist in tackling complex patterns within their administrative responsibilities. Furthermore, due to the yearly repetitive nature of school tasks, teachers expressed their desire for AI to take on the role of providing guidance for administrative tasks. Several teachers (P03, P06 and P10) expressed a desire to receive support from AI in performing administrative tasks according to the academic schedule. If AI can assist in administrative tasks by analyzing the tasks performed annually and providing guidance, such as which tasks should be completed in the current month and which tasks should be addressed in the following month, it would enable teachers to anticipate and prepare in advance. This would alleviate the ambiguity and concerns of human teachers and prove to be highly beneficial (P10). Teachers expected that with the help of AI, they would be able to perform administrative tasks more efficiently and without mistakes.

Discussion

In Study 1, we explored what roles augmented teachers want to form a complementary relationship with AI in K–12 classroom environments. The findings showed that teachers are interested in collaborating with AI on eight different tasks: (1) personalized curriculum design, (2) development of instructional materials, (3) foundational learning support, (4) self-reflection support, (5) student evaluation, (6) career guidance, (7) student management, and (8) administrative task support. As shown in Table 4, these augmented roles can be interpreted as an expansion of the four traditional roles of teachers previously identified in the literature (Section 2.1): (1) curriculum development, (2) teaching and facilitating, (3) guidance, and (4) classroom and school management.

Teachers emphasized their desire to improve their role in curriculum development through AI support. They acknowledged the intricate nature of curriculum development, necessitating attention to individual student capabilities and the incorporation of new educational insights. Schimpf et al. (2019) propose that AI-based agents can augment teachers' roles in curriculum design by offering automated assistance rooted in extensive data analysis. Our findings underscore that teachers aspire to forge a collaborative synergy with AI to streamline *personalized curriculum design* and *development of instructional materials*, thereby evolving into augmented teachers.

Secondly, teachers seek AI to augment their roles teaching and facilitation roles, enhancing the educational process and enabling personalized learning. Traditionally, teachers have been regarded as the guiding forces in students' acquisition of knowledge and skills (Harden & Crosby, 2000), tasked with facilitating learning and providing scaffolding for students (Amin, 2016). Consequently, teachers are often stretched thin in fulfilling their responsibilities of scaffolding, teaching, and facilitating in the classroom. Teachers anticipate that AI can enhance these roles by, for instance, deploying AI tutoring systems in classrooms with students of varying cognitive abilities, allowing for individualized learning paces (Schimpf et al., 2019). More specifically, teachers envision AI providing diverse forms of support, including conceptual, metacognitive, and procedural scaffolding throughout lessons (Schimpf et al., 2019). AI's ability to offer such scaffolding at any time and place can notably enhance *foundational learning support*, *self-reflection support*, and *student evaluation*, facilitating the evolution of teachers into augmented teachers.

Third, traditional teachers have played a pivotal role not only in enhancing students' academic performance but also in guiding their career development, including formulating future career paths (Zhang et al., 2018). Previous research (Di Fabio & Kenny, 2015) highlights the significance of teachers' guidance in helping students unlock their full potential and prepare for their professional lives or adulthood. Although crucial, comprehending every facet of career-related information and providing personalized guidance for each student poses a formidable challenge for teachers. In this regard, teachers anticipate that AI can analyze all career-related data and student characteristics, offering comprehensive support for personalized career guidance. Additionally, teachers envision this form of human-AI partnership allowing them to allocate more attention to the human aspect of their role, such as engaging in meaningful conversations with students, while relinquishing the more data-intensive aspects like researching career-related information to AI.

Lastly, teachers desire AI to enhance their roles in classroom and school management, including student management and administrative tasks. Traditionally, teachers have shouldered various responsibilities and encountered challenges independently, consuming significant time and energy. They seek AI's assistance in student management and administrative tasks, aiming to dedicate more time and energy to direct interactions with students. As AI assistants become more prevalent in K–12 school settings (e.g. Murphy, 2019), AI has the potential to augment teachers' classroom and school management roles, alleviating their workload and providing valuable insights for intervention and support.

Table 4. Eight roles of augmented teachers for a complementary relationship with AI in K–12 classroom environments.

Roles of traditional teachers		Roles of augmented teachers complemented by AI
Curriculum development	Personalized curriculum design	AI leverages student data to formulate individualized curricula customized for each student. Subsequently, the teacher evaluates the personalized curriculum proposed by AI and, informed by these recommendations, provides curriculum suggestions to the students.
	Development of instructional materials	AI conducts an analysis of diverse content to assist teachers in crafting instructional materials. Subsequently, AI generates content aligned with the teacher's educational objectives, enabling the teacher to finalize instructional materials based on the content provided by AI.
Teaching and facilitation	Foundational learning support	AI identifies students with foundational academic skill deficiencies through the analysis of student databases. It then delivers tailored content to these students, addressing their specific academic needs. Consequently, students enhance their foundational academic skills by engaging with personalized AI-generated content.
	Self-reflection support	AI scrutinizes students' learning progress and offers feedback to facilitate self-reflection. Students engage in self-reflection by reviewing the feedback and badges provided by AI. In cases where students have additional concerns, the teacher offers counseling and support.
	Student evaluation	AI conducts a comprehensive analysis of various data points, including students' grades, reading records, and volunteer activities. Subsequently, AI generates sample phrases for student evaluations based on this analysis. The teacher then formulates student evaluations, utilizing the AI-generated phrases as reference points.
Guidance	Career guidance	AI conducts an in-depth analysis of students' career prospects, taking into account various career-related factors and aptitude characteristics. AI furnishes the teacher with comprehensive analysis results pertaining to students' career paths. The teacher then offers personalized career guidance, incorporating insights from AI's analysis.
Classroom and school management	Student management	AI scrutinizes data encompassing attendance, assignments, and individual student evaluations. AI then offers an overview of the entire class based on this individual student analysis. The teacher identifies and manages students at risk of falling behind based on the insights provided by AI's analysis.
	Administrative task support	AI performs an analysis of academic schedule data and administrative tasks organized by time periods. An AI chatbot designed to assist with academic scheduling provides teachers with guidance on their activities for each time slot. The teacher efficiently manages administrative tasks with the support and guidance offered by the AI chatbot.

Study 2: Examining teachers' preferred complementarity roles for AI across school levels

Methods

Participants and procedure

A total of 128 teachers from public schools in City S, participated in an online questionnaire regarding their preferences for roles they wish to be augmented by AI in K–12 education: 43 elementary school teachers from grades 1–6, 41 middle school teachers from grades 7–9, and 44 high school teachers from grades 10–12. The participant's gender and teaching experiences are shown in Table 5. An official letter encouraging survey participation was sent to 121 schools selected by the Education Research and Information Institute in City S. Participants voluntarily responded to the call for participation.

Materials

The questionnaire asked 11 questions, which focused on teachers' needs regarding roles for personalized education. The first question asked participants about their school level, gender, and teaching experience. Participants were presented with two questions (Cronbach's $\alpha = 0.845$), employing a 5-point Likert scale to assess their perception of the necessity and effectiveness of

Table 5. Gender and teaching experiences of research participants.

	Gender		Years of Teaching Experiences					
School Level	Male	Female	Less than 5	5–10	11–15	16–20	Greater than 20	Total
Elementary	14	29	12	15	12	3	1	43
Middle	11	30	11	16	8	4	2	41
High	25	19	8	12	12	8	4	44
Total	50 (39%)	78 (61%)	31 (24.2%)	43 (33.6%)	32 (25.0%)	15 (11.7%)	7 (5.5%)	128 (100%)

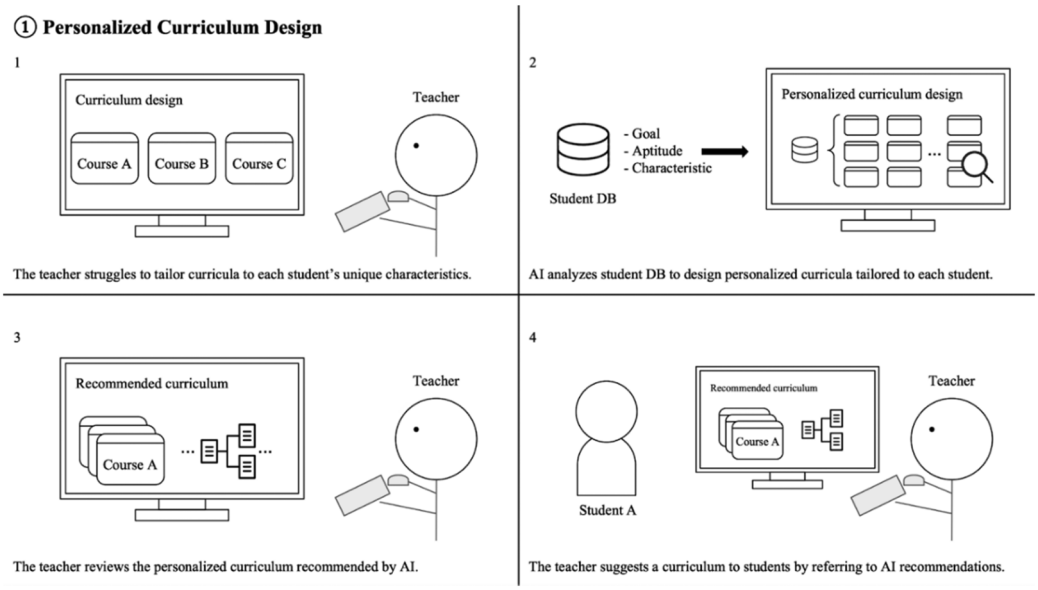

Figure 1. An example of a storyboard showing an augmented teacher's *personalized curriculum design*.

using AI in teaching activities to implement personalized education. The two questions were: "Do you believe that AI assistance is (1) necessary and (2) effective in fulfilling the role of a teacher to achieve personalized education?"

To investigate teachers' preferences for the eight augmented teacher roles identified in Study 1, scenarios were created as examples for each role (see Figure 1). Storyboards are well-suited for collecting opinions from participants who may lack knowledge or experience with AI (Zimmerman & Forlizzi, 2017). To design and create eight scenarios for augmented teachers' roles (See Table 4), we conducted three rounds of brainstorming sessions. Three subject experts were recruited. Two of the experts are from the field of educational technology, and the other is from artificial intelligence. On average, the experts have 12 years of research experience in AI for education. In addition to these experts, we further tested the feasibility and usability of the storyboards with two teachers with experiences in K–12 settings. Each storyboard consisted of four cut scenes: (1) depicting the challenges faced by a traditional teacher in their role, (2) illustrating AI's engagement as a complement to address these challenges, (3) showcasing the collaborative synergy between a human teacher and AI as they jointly fulfill a role, and (4) presenting the performance of an AI-augmented teacher. As illustrated in Figure 1, each scene was presented using images and keywords, accompanied by a descriptive sentence to enhance participants' comprehension of the storyboard. Based on the experts' feedback, we modified the expressions and explanations in the storyboards (See Appendix A, Supplementary material).

Research participants were asked to rate the helpfulness of the AI assistant presented in the eight storyboards using a 5-point Likert scale (with 1 being "strongly disagree" and 5 being

"strongly agree"). To minimize the ordering effects, the presentation of the eight storyboards was randomized. The item reliability for the 8 items was Cronhach's $\alpha = 0.883$. Furthermore, research participants were asked to select their top three preferences among the eight scenarios for supporting teaching activities.

Data analysis

A multivariate analysis of variance (MANOVA) was conducted to investigate the differences in teachers' awareness and needs regarding the performance of augmented teachers' roles for individualized education depending on school levels. We assessed the assumptions of the test: multivariate normality, homogeneity of the variance-covariance matrix, and multicollinearity. Pearson's correlation results indicated that all the overall correlations among the ten dependent variables were statistically significant at the .01 level. Additionally, the results of Box's M and Levene's test demonstrated that the assumption of equal variance was met at the .05 level. The order of preferences for the augmented teachers' roles by school level was analyzed using the multiple-ranked response analysis method. The score was converted by assigning a weight of 3 to the first rank, 2 to the second rank, and 1 to the third rank. This allowed us to determine which role had the highest priority for each school level.

Results

This study examined teachers' perceptions of performing augmented teacher roles for personalized education. The results indicate that teachers believe AI assistance is necessary and effective at a higher-than-average level (see Table 6). However, the MANOVA analysis conducted to examine the differences in teachers' recognition of the necessity and effectiveness of AI assistance based on school levels yielded no statistically significant variations. This suggests that regardless of the school level, teachers generally perceive AI assistance to be equally necessary and effective for their teaching practices.

The findings suggest the prioritized order of teachers' preferences for the eight augmented teacher roles are: Foundational Learning Support, Student Management, Student Evaluation, and Career Guidance (see Table 7). To ascertain potential discrepancies in these preferences across school levels, a MANOVA analysis was conducted. The results established that elementary school teachers exhibit greater preferences in the areas of Student Evaluation and Student Management when compared to middle school and high school teachers. Conversely, no statistically significant distinctions were observed in the preferences for the remaining six augmented teacher roles based on school levels.

To investigate the priority of augmented teacher's roles recognized by teachers at each school level, a ranked multiple-response analysis was conducted (see Table 8). The results confirmed that teachers at all school levels prioritize providing *Foundational Learning Support* for students through AI assistance. Additionally, the *Development of Instructional Materials* was a high priority for teachers across all levels. Elementary school teachers expressed a higher need for roles related to *Student Evaluation* and *Student Management* than those in teaching at middle and high schools. In contrast, middle and high school teachers expressed a greater need for *Self-reflection Support* and *Career Guidance*.

Table 6. Teacher perceptions of AI assistance across school levels ($n = 128$).

	School levels			
Items	Elementary ($n = 43$) *M* (*SD*)	Middle ($n = 41$) *M* (*SD*)	High ($n = 44$) *M* (*SD*)	*F* (2, 125)
Necessity awareness	4.44 (0.73)	4.27 (0.89)	4.23 (0.77)	.870
Perceived effectiveness	4.30 (0.83)	4.22 (0.88)	3.98 (1.00)	1.506

Table 7. Differences in perceived effectiveness of the augmented teachers' role by school levels.

Eight roles of augmented teachers complemented by AI	Total ($N = 128$)	School levels: Elementary ($n = 43$) M (SD)	Middle ($n = 41$) M (SD)	High ($n = 44$) M (SD)	F (2, 125)	η^2
Personalized curriculum design	3.71 (1.10)	3.84 (1.05)	3.61 (1.07)	3.68 (1.20)	0.466	
Development of instructional materials	3.98 (0.99)	4.09 (0.92)	3.95 (1.02)	3.91 (1.03)	0.407	
Foundational learning support	4.19 (0.83)	4.33 (0.83)	4.22 (0.73)	4.02 (0.90)	1.504	
Self-reflection support	3.92 (0.94)	4.00 (0.98)	3.93 (1.05)	3.84 (0.81)	1.803	
Student evaluation	4.08 (0.96)	4.44 (0.80)	3.93 (1.08)	3.86 (0.91)	4.981** (E > M, H)	0.074
Career guidance	4.02 (0.97)	4.09 (0.87)	4.00 (1.03)	3.95 (1.03)	0.226	
Student management	4.14 (0.93)	4.47 (0.74)	3.95 (1.02)	4.00 (.94)	4.184* (E > M, H)	0.063
Administrative task support	3.96 (1.01)	4.21 (0.86)	3.83 (1.11)	3.84 (1.03)	1.970	

*$p < 0.05$, ** $p < 0.01$.

Table 8. Differences in the prioritization of the augmented teachers' role across school levels.

Eight roles of augmented teachers complemented by AI	School levels: Elementary ($n = 43$) 1st	2nd	3rd	Score	Middle ($n = 41$) 1st	2nd	3rd	Score	High ($n = 44$) 1st	2nd	3rd	Score
Personalized curriculum design	1	3	5	14[a]	1	2	4	11	2	2	0	10
Development of instructional materials	8	4	5	37	7	6	6	39	5	9	1	34
Foundational learning support	17	9	5	74	19	5	3	70	19	2	10	71
Self-reflection support	2	4	8	22	4	7	8	34	5	6	8	35
Student evaluation	11	8	4	53	3	3	6	21	4	6	7	31
Career guidance	0	3	3	9	3	8	6	31	4	8	7	35
Student management	1	10	10	33	3	5	4	23	4	7	6	32
Administrative task support	3	2	3	16	1	5	4	17	1	4	5	16

[a]1*3 + 3*2 + 5*1 = 14.

Discussion

This research project aimed to better understand teachers' perceptions of performing augmented roles for personalized education, and identify possible differences in their preferences across school levels. The results suggest that teachers, overall, believe that AI assistance is necessary and could be effective. This is aligned with previous research that has highlighted the positive impact of AI in supporting personalized learning (e.g. Mousavinasab et al., 2021). We focused on eight specific roles that teachers perform and found that teachers at all school levels consider *foundational learning support* and the *development of instructional materials* as the primary roles that could be aided by AI. Prior studies have revealed that AI applications have the potential to support foundational learning, such as "identifying students who may be struggling to learn and make progress" and "providing them differentiated instruction and feedback in mixed-ability classrooms" (Murphy, 2019, p.2). For instance, intelligent tutoring systems possess a crucial feature whereby instructional activities and strategies can be personalized according to the learner's characteristics and needs (Keleş et al., 2009). These systems can detect students' knowledge gaps, and then provide students with personalized content to address their needs (Mousavinasab et al., 2021).

Teachers across all school levels recognize the value of AI technology for creating instructional materials that align with students' learning needs. Previous research has highlighted the role of authentic materials in achieving personalized education by drawing on learning content that meets learners' needs. Furthermore, as teachers tend to dedicate a substantial amount of their

time to preparing learning materials (Bryant et al., 2020), this demand can be effectively met by developing and modifying learning content generated by AI (Fitria, 2021).

While they shared many opinions, teachers across the school do have different preferences. Elementary school teachers emphasize student evaluation and management, while middle and high school teachers seek self-reflection support and career guidance. These variations can be attributed to a number of contextual factors. Firstly, the developmental stage and learning abilities of students at different school levels play a significant role in what support teachers are seeking. Elementary education aims to provide basic education and holistic development for learners at a lower level of cognitive development (Ryu, 2006). Consequently, elementary school students may require more frequent and detailed evaluations to ensure students' learning is progressing. Managing student behavior and classroom dynamics may also be more crucial at the elementary level due to the students' early stages of social and emotional development. On the other hand, there are higher expectations of independent academic performance for secondary school students, who, generally, require less intervention from teachers (Hanewald, 2013). For example, some of the educational goals in high school involve exploring careers that align with students' aptitudes and talents (Curriculum Policy Division, 2015). As they explore their interests, passions, and potential career pathways, middle and high school students may benefit more from support in self-reflection and career guidance. Differences in students' characteristics and developmental needs likely influence teachers' priorities and preferences regarding augmented teacher roles.

Another reason contributing to the variation in teachers' preferences is the subject matter and curriculum complexity at different school levels. Elementary school teachers may have a broader range of subjects to teach, and require more support in managing and evaluating student performance across multiple disciplines. In contrast, middle and high school teachers often specialize in specific subjects, which may lead to a greater need for instructional planning and personalized feedback tailored to subject-specific content and assessments.

Overall discussion and conclusion

In this study, our first research question focused on the roles where teachers expect a complementary relationship with AI to provide personalized learning experiences within K–12 classrooms. Despite the increasing integration of AI techniques into educational research (e.g., Jin et al., 2023), little has been done to understand what teachers really want from AI while implementing personalized learning for students. Through our analysis of the focus group interviews with elementary, middle, and high school teachers, we identified the needs of K–12 teachers regarding the roles of complementary AI in the classroom (see Table 4). According to our findings, teachers expect that AI can augment their roles by complementing them in eight key roles: curriculum design, development of instructional materials, foundational learning support, self-reflection support, student evaluation, career guidance, student management, and administrative task support.

Our second research question aimed to discern the variations in teachers' preferences across different school levels (i.e. elementary, middle, and high school). Findings revealed both similarities and differences. Foundational learning support and instructional material development were valued by teachers across all levels. Teachers desire AI augmentation in foundational learning assistance for struggling students and the creation of high-quality instructional materials. Differences in teachers' expectations emerged among school levels for other roles. Elementary school teachers underscored student assessment and management, whereas middle and high school teachers emphasized self-reflection support and career guidance. This underscores the fact that while elementary teachers primarily focus on student assessment and management, middle and high school educators find value in providing opportunities for self-reflection to facilitate effective student self-learning and offering career guidance to aid students in establishing long-term

objectives. Overall, the findings emphasize that the design of human-AI complementarity needs to adapt to the school level.

Based on a theoretical framework for collaborative human-AI systems (see Table 1), our findings suggest three design implications for the development of future AI systems in education. Firstly, the interaction between human teachers and AI should harness their respective strengths to achieve enhanced educational outcomes. Our research revealed that teachers excel in building meaningful connections with students, providing motivation, and offering coaching, while AI's strength lies in real-time analysis of extensive student and academic data, enabling tailored interventions. Consequently, teachers expressed a desire for AI systems to provide insights drawn from vast data sets that they could use to humanely guide students, without encroaching upon their authority or classroom control.

Secondly, human teachers and AI must converge their focus on common educational goals. Teachers voiced concerns that AI might prioritize short-term objectives, while they, as educators, were more attuned to nurturing students toward long-term goals. For instance, in the realm of foundational learning support, AI aims to fill knowledge gaps, whereas teachers aspire to spark students' enduring interest in the subject. Current AI systems tend to concentrate on specific goals, such as identifying at-risk students or delivering personalized exercises, often overlooking the broader, long-term educational objectives. To forge a genuine shared objective in the future, it is imperative to design AI functions that can encompass these longer-term educational goals.

Lastly, human teachers and AI should engage in ongoing, reciprocal communication to enable each agent to effectively discern and respond to changes in the educational context or the other agent's actions. Teachers expressed concerns that AI interventions, initiated without prior notice, sometimes hindered their understanding of the curriculum coverage and students' learning trajectories and interests. Additionally, AI, in its current form, provides primarily simplistic analytics, often lacking the capacity to convey the holistic narrative of how students are progressing in their studies. To position AI as a true partner that complements rather than merely supplants teachers, it is imperative to employ explainable artificial intelligence, placing teachers in the decision-making loop and providing actionable insights through sustained, transparent interaction.

The evolution of classrooms is increasingly marked by the seamless incorporation of AI systems. Yet, the success of this integration, particularly for personalized student learning, hinges on aligning with teachers' envisioned AI utilization. Our findings underscore teachers' apprehensions about potential AI-driven obsolescence and their loss of classroom control. They wish to harness AI to enhance their roles, transitioning into augmented teachers. Regrettably, prevailing AI systems often neglect these desires, prompting teachers to adapt to the system rather than the other way around. The next wave of classroom AI should be crafted with three factors for a collaborative human-AI system (i.e. complementarity, shared objective, and sustained interaction) at its heart. Our insights pinpoint the essential blueprints for molding the future's augmented teachers, a symbiotic blend of human teachers and AI.

This study has several limitations. Firstly, the envisioned augmented teacher scenarios, conceptualized by 15 teachers, were translated into storyboards and remained untested and unevaluated through actual systems. Subsequent research endeavors should focus on the development of AI systems tailored for augmented teachers, subjecting them to validation within real classroom environments. This validation process would facilitate a quantitative exploration of teachers' perceptions regarding usability and user experience in relation to these AI systems. Secondly, the scope of this research was limited to the perspectives and requisites expressed solely by teachers, inadvertently omitting the viewpoints of other stakeholders such as students and parents. To enrich the comprehension of the intricacies and prerequisites of human-AI complementarity across diverse stakeholders, forthcoming research should encompass these varied viewpoints. Lastly, a constraint arises from the qualitative nature of Study 1, wherein interpretation is inevitably shaded by the researchers' perspectives. Therefore, replicating a comparable approach with researchers hailing from distinct cultural backgrounds would be of significant value. Considering the influences of cultural contexts and educational systems, it's conceivable

that teachers' expectations and preferences for augmented teacher models could diverge. Consequently, future studies should embrace diverse cultural settings, including non-Asian and Western contexts, to yield a more comprehensive and globally applicable understanding.

Despite these limitations, this study remains valuable for its role in solidifying a comprehensive understanding of K–12 teachers' requisites concerning the complementary contributions of AI in effective personalized learning implementation. It underscores that designing the collaboration between AI and humans as an inferior process could potentially weaken teachers rather than enhance their roles. Conversely, the exploration advocates for a more effective collaboration between humans and AI, one that empowers teachers to evolve into augmented teachers, consequently enhancing personalized education delivery. The research outcomes pinpoint eight key roles where collaborative endeavors between human teachers and AI should coalesce to create an automated teaching model. Informed by these revelations, future AI research in the educational sector has the potential to pivot toward a teacher-centric approach, shaping the advancement of AI technologies within the realm of education.

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