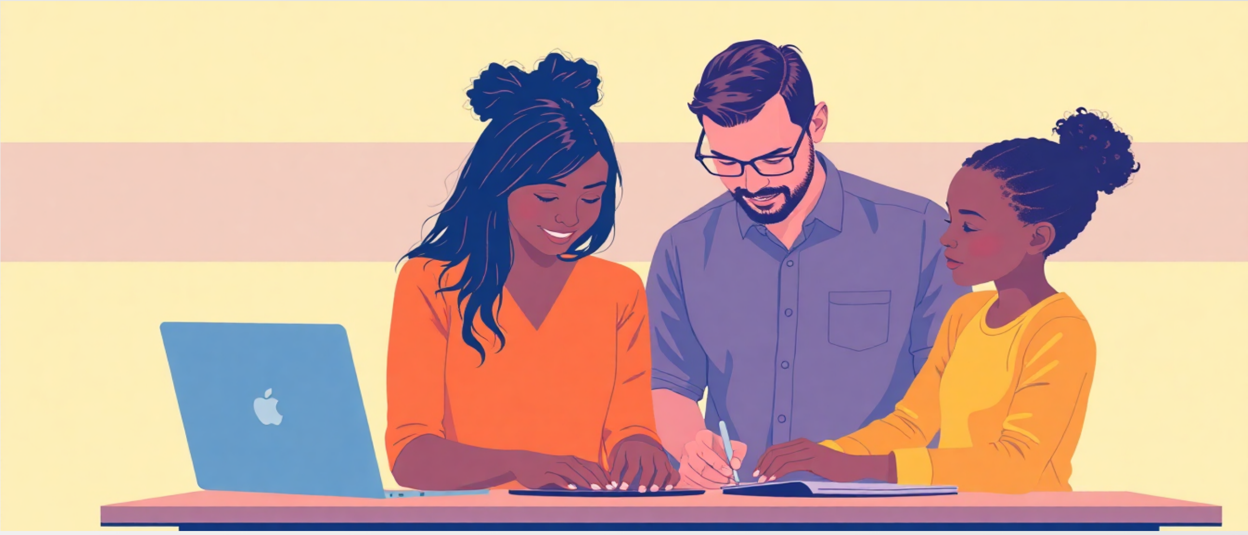
Collaborative Design for Educational AI: Empowering Educators as Co-Creators



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Abstract

This study introduces the *COALESCE* (Collaborative Adaptive Learning Ecosystem for Systems Creation and Enhancement) framework, an extension of Design-Based Implementation Research (DBIR) principles tailored to developing AI-powered educational technologies emphasizing co-creation with end users. Using lesson planning as a case study, we demonstrate how COALESCE engages educators as active collaborators, embedding their expertise to enhance transparency, adaptability, and domain specificity in AI systems. Through an iterative design process, COALESCE fostered mutual learning between educators, researchers, and technology developers, aligning AI outputs with real-world instructional needs. Our results indicate higher educator satisfaction, increased adoption intent, and improved quality of AI-generated lesson plans. While lesson planning serves as the use case here, the COALESCE framework offers a scalable approach to developing educator-centered AI tools across diverse K-12 educational applications.

1 Introduction

Scaling educational innovations to meet the diverse K-12 educational environments has been a persistent challenge in learning sciences. Educational environments vary by student demographics, cultural contexts, and geographic factors. Considering and embedding into these varying educational environments affect the degree to which new educational innovations can be scaled up and the degree to which the new innovations generate positive changes in student learning [3; 5; 22; 25]. Moreover, educators' comfort with technology, their trust in new reforms, their subject-domain expertise, and pedagogical strategies significantly influence their adoption and meaningful integration of innovations into their daily practice [4; 22; 32]. A core challenge in the design phase lies in embedding adaptability and transparency within the technology itself, ensuring it meets diverse instructional needs from the outset. Without addressing these foundational design aspects, scaling is hindered as educators may struggle with tools that lack contextual relevance.

To address these challenges, collaborative design methodologies such as Design-based Implementation Research (DBIR) have emerged, emphasizing co-creation between researchers and practitioners to generate solutions that are both adaptable and context-embedding [10; 17; 28]. These partnerships create space for identifying problems of practice, describing varying contextual constraints or resources for change, co-designing new artifacts (e.g. curriculum and technologies) to remediate teaching and learning, and even joint formulation of research questions and plans to study reform enactment that may provide insights into mutual (i.e., researcher and practitioner) interests [10; 28].

Traditionally applied to curriculum development, DBIR offers a framework to ensure educational tools are adaptable, transparent, and responsive to real-world contexts [10]. However, the application of DBIR to the development of AI-powered educational technologies remains fairly underexplored. In this work, we extend DBIR principles to address unique challenges in the design of AI-based educational technologies that assist educators in performing various instructional tasks. Existing AI tools often lack transparency and contextual specificity, making them difficult for educators to trust, adopt, and integrate. We aim to extend DBIR to ensure AI systems are pedagogically relevant and responsive to varied classroom needs.

Building on DBIR, we developed the Collaborative Adaptive Learning Ecosystem for Systems Creation and Enhancement (COALESCE) framework. COALESCE engages educators as active co-creators throughout the research and development process of AI applications, emphasizing reciprocal learning among researchers, engineers, and educators. By situating educators at the core of the process and embedding their expertise at every stage, we align AI development with the practical demands of teaching and build the trust necessary for effective adoption in school environments. In this study, we demonstrate the efficacy of COALESCE by improving an AI-powered lesson-planning application, a tool aimed at streamlining the cognitively demanding and time-consuming task of lesson planning [26].

A lesson plan is an educator's intended curriculum – a personalized script that outlines learning objectives, instructional strategies, and assessments for a specific lesson [8; 27]. Lesson plans serve as the foundation for instructional design, bridging state learning standards with classroom teaching and integrating educators' unique pedagogical styles to meet diverse student needs [16]. However, lesson planning is often a cognitively demanding and time-consuming task in K-12 education. In recent years, generative AI tools have emerged as promising aids to lesson planning, offering efficiency but often falling short in providing subject-specific knowledge and pedagogical understanding, and contextual adaptability required for high-quality and effective lesson planning [7]. Most existing specialized education AI platforms focus on quick, technical solutions that prioritize automation, and often fail to integrate educator insights from the outset, resulting in platforms that may not promote high-quality instructional practices and create effective learning opportunities for students. This disconnect calls for a shift in how we approach AI technology development for education. By applying COALESCE, we show how sustained educator involvement enhances the contextual adaptability and pedagogical soundness of AI tools. Specifically, we investigate how deep educator involvement impacts user satisfaction and specialized AI model performance in lesson planning, focusing on user-centered and context-responsive design. Specifically, we investigate two primary research questions:

RQ1: Qualitative Evidence of Buy-In and Adoption: How does deep educator involvement in the AI development process affect educators' satisfaction with the prototype AI tool and willingness to integrate it into their teaching practices?

RQ2: Quantitative Evidence of Model Performance: How do educators perceive and evaluate AI-generated lesson plan quality after researchers and engineers incorporated educators' insights and labeled data into specialized model development? By addressing these research questions, our COALESCE approach not only contributes to the broader discourse on DBIR but also offers new insights into how educators can be empowered to shape AI technologies that align with their pedagogical needs.

2 Background and related works

In this section, we highlight some existing literature pertinent to our study, focusing on two key areas. By doing so, we situate our research within the broader context of educational research and technology development, identifying gaps and opportunities that our work seeks to address by extending the DBIR framework for AI design.

2.1 AI-powered technologies in education

Integration of AI into K-12 education has gained momentum with the development of large language models (LLMs) like ChatGPT [23], which can offer personalized learning experiences and enhanced task efficiency [21]. AI applications now support a range of educational tasks, from intelligent tutoring to lesson plan generation, aimed at assisting educators and improving student outcomes [15; 31]. Holmes et al. [11] and Holmes and Tuomi [13] provide comprehensive reviews of AI in education, highlighting both its transformative potential and associated risks for learning enhancement and teacher productivity. Despite these benefits, AI systems are often criticized for their opaque nature, making it difficult for educators to interpret AI-driven decisions and limiting trust and adoption [13]. Moreover, AI tools frequently lack domain (teaching) specificity, leading to generic solutions that may not align with the nuanced demands of varied educational contexts [2; 6]. These limitations highlight the importance of transparent, adaptable AI tools that meet diverse classroom needs.

Recent studies have explored AI's potential in assisting educators with lesson planning, focusing on reducing cognitive load and time investment while emphasizing the importance of teacher involvement in tool design [22]. AI literacy among educators is crucial to foster effective teacher-student connections while ensuring ethical implementation [12; 20]. By involving educators from the outset, we can develop AI systems that are pedagogically relevant and contextually responsive, fostering greater adoption and trust and developing educators' AI literacy.

2.2 Participatory design and educational technology development

Participatory design (PD) involves stakeholders in design processes to ensure resulting tools meet their needs and contexts [9]. In education, PD has been employed to create tools that are user-centered and pedagogically sound. For example, Holstein et al. [14] engaged teachers in designing real-time classroom orchestration tools, while Moundridou et al. [22] investigated the potential of AI tools as educators' assistants. Engaging educators in the design process fosters a sense of ownership, leading to more effective technology adoption that prioritizes user values and ethical standards [29]. Koehler et al. [18] argue that to integrate AI meaningfully, educators must develop a nuanced understanding of how technology intersects with pedagogy and content. Studies show that, for AI tools, participatory and co-design processes help address complexities such as algorithm transparency and usability, ensuring alignment with classroom realities [14; 24].

Design-Based Implementation Research (DBIR) is a PD approach that unites researchers and practitioners to address persistent problems in educational practice through iterative design and systematic inquiry [10]. The methodology emphasizes the co-creation of interventions that are both theoretically grounded and practically applicable, ensuring scalability and sustainability within educational systems. DBIR is guided by four core principles: (i) focusing on persistent problems of practice, (ii) iterative and collaborative design, (iii) developing theory and knowledge, and (iv) building capacity for sustaining change [10]. Penuel et al. [24] emphasize the adaptability of DBIR principles across educational contexts, highlighting its potential to bridge the gap between theory and practice, particularly in curriculum development and educational program design, by fostering sustained, context-specific collaboration. Expanding DBIR into classroom AI design can ensure that AI tools not only align with educational goals but also address the unique complexities of AI that are critical for fostering trust and usability in educational settings.

3 COALESCE framework

To advance AI integration in education, our study [19] revealed that effective educational tools must be developed through a deep, sustained collaboration among educators, researchers and developers. This insight led us to create the COALESCE framework. The COALESCE framework extends traditional DBIR to AI technology development by transforming educators' roles from passive end-users to active co-creators as well as learners in the process. The framework fosters a sustained, reciprocal learning environment where educators, researchers, and developers engage in mutual, iterative processes to ensure that AI technologies are pedagogically robust, contextually relevant, and transparent.

3.1 The foundations and extension of DBIR in COALESCE

COALESCE builds on the four DBIR principles discussed in the literature review by embedding educator expertise at every stage of design. This creates a framework that is adaptable, iterative, and responsive to educators' needs, directly addressing the challenges of designing and scaling educational innovations discussed earlier. This extended framework introduces a focus on continuous educator collaboration and real-time feedback loops, embedding their domain knowledge directly into AI model development and refinement. The framework iteratively refines AI technology through educators' direct input, using data-driven decision-making processes grounded in real-time educational contexts. Within COALESCE, educators collaborated closely with engineers, and researchers to form a dynamic community of practice. Their contributions shaped both the AI model's core functionality and the interface design, establishing a foundation for mutual learning. Moreover, the sustained collaboration fostered a reciprocal learning environment where researchers, technology developers, and educators all benefited: educators gained insights into AI systems, developing a sophisticated literacy that informed their instructional strategies and the ongoing evolution of the tool; developers refined the technology based on practical and real experiences of educators; and researchers deepened their theoretical frameworks and generated new insights on the integration of AI in educational settings. Figure 1 demonstrates the COALESCE workflow, depicting the iterative collaboration between educators, researchers, and developers at different stages of AI development within the COALESCE framework. Note that, COALESCE can guide both design and implementation stages; however, this paper only demonstrates its application in the design phase.

3.2 Stages and processes within COALESCE

The COALESCE framework, as shown in Figure 1, is designed as a generalizable approach for participatory design in AI-powered educational technologies, encompassing a continuous cycle of design and mutual learning rather than distinct, isolated stages. It integrates all four DBIR principles dynamically, reflecting the iterative and collaborative nature of the framework. While the framework is adaptable to various educational AI tasks, this study demonstrates its specific application to lesson planning, where educators play a central role as co-creators. The process begins with the collective learning design stage, followed by iterative testing and collaborative refinement, allowing real-time educator feedback to shape AI models. These stages inform theory and knowledge development, building both pedagogical theory and practical AI artifacts, and culminate in capacity for sustained change and trust building, ensuring long-term adaptability and educator ownership. While this study applies COALESCE to lesson planning as a specific use case, its principles and processes are

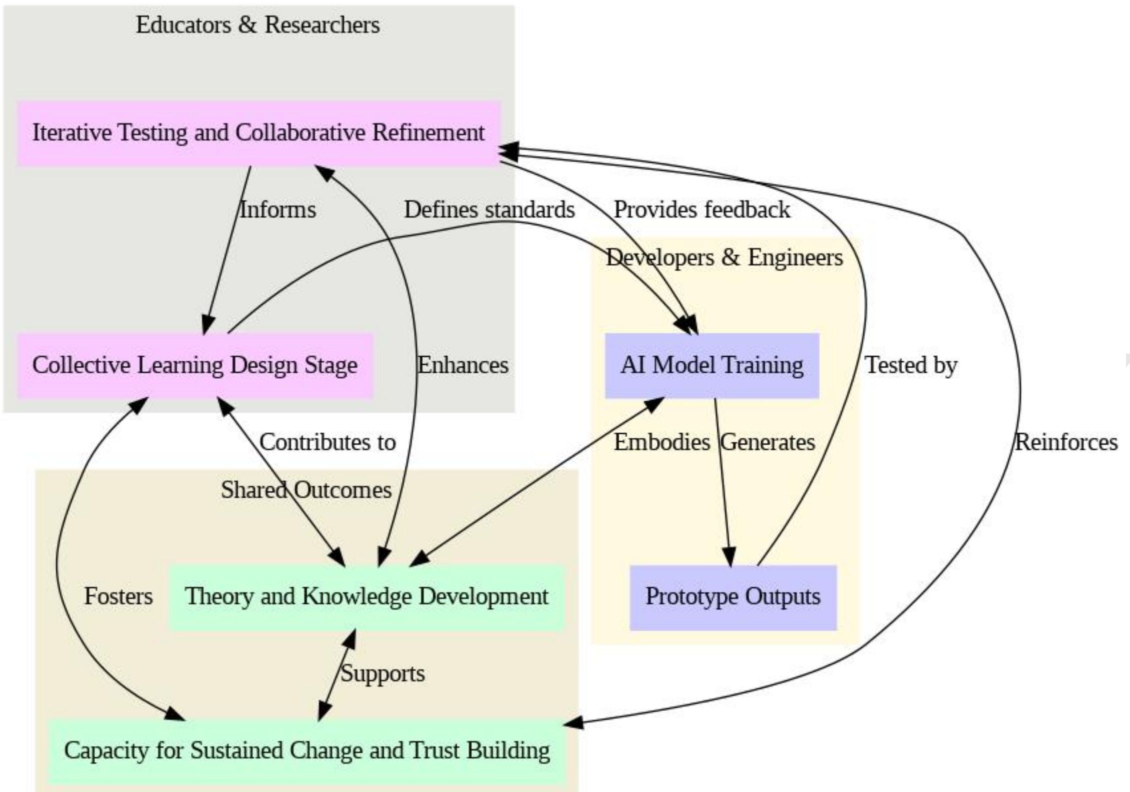

Fig. 1. Workflow of COALESCE in lesson planning tool design

broadly adaptable to other educational technology development processes. Below, we outline the stages of the COALESCE framework in its general form and illustrate how it extends DBIR principles and procedures using AI-powered lesson planning tool development as a use case:

Collective Learning Design Stage: Initial ideation and design involve educators in defining lesson quality standards and data labeling criteria that guide AI model training (more details in Methods: Stage 1). This foundational stage ensures that AI-generated content aligns with classroom realities and educators' pedagogical objectives. Educators and researchers collaborate by establishing a collective understanding of effective lesson planning metrics.

Iterative Testing and Collaborative Refinement: In this phase, educators test prototype outputs and provide feedback on model predictions and usability. COALESCE's iterative refinement occurs within the design stage, allowing educators to directly influence the AI model's adjustments. This iterative phase ensures continuous educator-driven recalibration and improvement, making AI tools adaptable to diverse instructional needs.

Theory and Knowledge Development Through Technology Creation: Educators at this stage contribute to AI tool development while creating new knowledge in an area that they themselves know little about, such as what AI is and how AI can do for teaching and learning. Their input not only shapes the AI model but also enhances pedagogical theory about effective lesson planning in AI-supported environments. This stage embodies a co-learning process, where educators and researchers generate new domain knowledge, such as quality measures for lesson plans, while also creating technology that integrates these measures.

Capacity for Sustained Change and Trust Building: Trust and ownership are central to the COALESCE framework, fostering a transparent, ongoing partnership that aligns AI development with educators' instructional values. By deeply involving educators in the AI development process, COALESCE fosters a strong sense of ownership over technology. Educators' active participation in defining, refining, and iterating the AI tools builds trust, as they understand the system's inner workings and see their input reflected in its functionality. This collaborative engagement not only demystifies the AI's opaque nature but also ensures that educators feel confident and invested in using the technology. This dynamic not only increases the likelihood of sustained use and adoption but also ensures that the AI evolves alongside educational needs, reinforcing its relevance and reliability over time. Table 1 briefly shows how COALESCE stages reimagined DBIR's principles.

Table 1. A brief overview of DBIR principles adaptation by COALESCE

DBIR Principles	**COALESCE Implementation and Adaptation**
Persistent problems of practice	Educators identify and address limitations in AI's transparency and contextual adaptation, directly influencing lesson planning features and aligning AI models with instructional practices.
Iterative, collaborative design	Educators, researchers, and developers foster a reciprocal, mutual learning space where they learn alongside one another.
Theory, knowledge, and technology development	The dual-direction knowledge exchange generates new knowledge around lesson quality standards and develops technology solutions (e.g., domain-specific AI models).
Capacity for sustaining change	Educator involvement in defining and refining AI systems promotes trust, ownership, and ensures relevance and adaptation.

Through this application, COALESCE sets a precedent for a DBIR-informed model in AI development, providing a pathway for creating AI tools that empower educators and enhance educational outcomes in K-12 classrooms. In the next section, we will describe the process of these principles being implemented.

4 Empirical studies: Evaluating the COALESCE framework in lesson planning

To assess the effectiveness of COALESCE, we addressed the two research questions through a two-stage process: Stage 1 established foundational elements with deep educator involvement, while Stage 2 examined the impact of iterative testing and comparative evaluation on the quality of AI-generated lesson plans.

4.1 Stage 1: Initial implementation and design probe

In the initial stage, we applied the COALESCE framework to create a design probe to improve an AI-powered lesson-planning application prototype. This stage aligns with the framework's core steps:

4.1.1 Step 1. establish collaborative partnership (weeks 0-1). We recruited 20 experienced K-12 mathematics educators, including district mathematics education specialists, classroom teachers and teaching aides/tutors, across all grade levels, from diverse educational contexts (e.g., family income, race/ethnicity, urbanicity, AI familiarity). These educators participated in foundational activities, including initial co-design workshops, fostering dialogue and shared decision-making. The diverse educational contexts of the participating educators guard the broad applicability of COALESCE and the tools developed under this framework.

4.1.2 Step 2. co-define goals and standards (weeks 2-4). Educators collaborated with researchers to review, discuss, and define lesson plan quality measures through workshops and focus groups. These quality measures pertained to critical instructional components such as warm-up relevance, the rigor and engaging nature of main instructional tasks, and cool-down assessments, providing foundational standards for data annotation and AI model training.

4.1.3 Step 3: co-create and share knowledge (weeks 5-10). After establishing a shared understanding of what an effective mathematics lesson should look like, educators reviewed and verified AI-generated quality ratings of human-designed lesson plans according to the defined criteria. The AI used in this stage was a custom prompt-based LLM such as GPT-4 [1], which provided initial ratings. Educators modified the ratings if they disagreed with the AI and made adjustments to lesson content to improve quality and relevance. These hands-on activities allowed educators to apply their expertise to improve the quality of the lesson plans. Weekly discussions (on e.g., what AI/ML was capable of capturing, how to interpret AI ratings and use them in teachers' daily life, and how we define and redefine the details of math classroom instruction across contexts), Slack messaging, and meetings helped align rating practices and ensure inter-rater reliability. This stage captured educators' evolving understanding of AI's capabilities and how AI-generated lesson content could be integrated into their instructional practices.

In Stage 1, we collected both qualitative data (weekly discussions, interviews, and chat messages) and quantitative data (ratings and modifications of lesson plans) to provide insights into RQ1. Particularly, the qualitative data provided insights into RQ1 by capturing educators' satisfaction and their readiness to adopt the tool into their instructional practices, with a total of approximately 800 lesson plans. This stage highlighted mutual learning within COALESCE, as educators interacted with AI responses while deepening their understanding of AI-driven lesson planning. The modified lesson content and ratings were then used to fine-tune the LLaMA-2 model [30] for lesson planning tasks, and educator feedback helped customize prompts which was further evaluated in Stage 2.

4.2 Stage 2: Iterative testing and comparative evaluation

The second stage evaluated the impact of educator-driven improvements on refining the AI's lesson planning capabilities. Sixteen experienced K-12 mathematics educators participated in blind, pairwise evaluations of lesson plans generated by human curriculum designers, a customized GPT-4, and a fine-tuned LLaMA-2-13b model (fine-tuned with the educators' modified lesson plans in Stage 1).

Educators evaluated 529 lesson plan pairs across four dimensions (quality and relevance of overall and each lesson plan sections: warm-up, main tasks, cool-down), based on criteria defined in Stage 1. This stage focused on examining whether the iterative adjustments made through COALESCE in Stage 1 enhanced the AI's alignment with pedagogical standards and instructional relevance. This approach provided nuanced insights into which aspects of lesson planning were effectively supported by AI and where further refinement was needed. The feedback loops enabled the AI tool to evolve, better aligning it with classroom needs and demonstrating the benefits of the COALESCE in creating contextually adaptive AI.

5 Findings

Our findings highlight how the reciprocal learning guided by the COALESCE framework positively influences the usability of AI-based lesson planning tools and improves the quality of generated lesson plan content. Our results address each research question and demonstrate the transformative potential of COALESCE in creating educational technology aligned with classroom realities.

5.1 Qualitative evidence of COALESCE effects (RQ1): Educator satisfaction and willingness to adopt the new technology

5.1.1 Key finding 1: Educators gain knowledge in AI literacy and adaptive applications for K-12 education. Through COALESCE, educators developed valuable AI literacy, understanding how domain-specific AI models can adapt to diverse K-12 needs. During Stage 1, educators actively engaged in evaluating human-created lesson plans, reviewing AI-generated ratings, and modifying these ratings and lesson plan content when necessary. This process allowed educators to better grasp the capabilities of the AI model and envision specific applications that could benefit various stakeholders within educational settings. During individual interviews, educators articulated higher context specificity and adaptability of the AI to meet educational goals. Educators appreciated COALESCE's integration of educator-driven standards, making the lesson planning tool more responsive to specific instructional needs than generic LLM-based applications. One educator commented, *I think it is so much more education-focused [...] I feel like I would get more generic responses from ChatGPT.* Another educator highlighted the tool's strengths in simplifying complex concepts for teachers, explaining, *With this tool, the generated lesson doesn't need a whole rewrite - it's only modification of small pieces. It also simplifies math concepts in language that teachers can easily understand.* These insights illustrate educators' growing knowledge in AI-powered tools as they distinguished the tool's alignment with K-12 educational standards in a way that generalized AI tools could not, highlighting COALESCE-guarded AI's unique strengths.

Moreover, educators demonstrated foresight in envisioning potential applications for the prototype lesson planning tool across different instructional contexts. They identified various roles and scenarios that could benefit, including support for PLC leaders, special education coordinators, and intervention specialists. This strategic perspective indicates the success of COALESCE in fostering AI literacy and empowering educators to effectively leverage AI tools in K-12 education.

5.1.2 Key finding 2: Increased efficiency and efficacy in instructional planning. The qualitative data from Stage 1, gathered through focus groups, interviews, and weekly discussions, played a critical role in understanding how educators perceived the efficiency and applicability of the lesson planning prototype. These insights informed further development and customization, ensuring that the tool aligned with the practical demands of instructional planning while achieving the collaborative design principles of DBIR.

Educators observed substantial improvements in both the efficiency and perceived efficacy of their instructional planning assisted by the interactive tool through the reciprocal learning design and iterative refinement stages of COALESCE. One teacher highlighted that, *I can actually interact with the generated content if I don't* *understand something, whereas with a traditional guide, I cannot.* This interactive capability allowed for real-time clarification and customization, enhancing the overall planning experience. One participant explained, *The activities generated are relevant to real-world problems, activating students' background knowledge and making math meaningful and concrete.* This focus on real-world relevance contributes to more engaging and effective lesson plans by bringing students connections between concepts and their own experiences. The time-saving aspect of the tool was a significant benefit noted by many educators. This reduction in planning time, without compromising on quality, allowed educators to allocate more time to direct student engagement and instructional improvement. A teacher shared, *With this tool, my math expertise now matters ... AI generates an engaging math activity, giving me a starting point. It literally takes seconds to generate, rather than the 30 or 40 minutes it would have taken me to design the activity myself.* This rapid generation of high-quality content allowed educators to focus more on customization and refinement rather than starting from scratch.

Moreover, the prototype tool's ability to simplify complex concepts into actionable steps was particularly appreciated. One educator noted, *This technology makes the professional learning I've done actionable, allowing what I've learned to reach my classroom.* This feature helped bridge the gap between professional development and classroom implementation, making it easier for teachers to apply new strategies and concepts in their teaching.

5.1.3 Key finding 3: Transparency, trust, and sense of ownership. Evidence from individual interviews highlights educators' strong commitment to and sustained interest in using the improved prototype lesson planning tool, along with their confidence in recommending it to peers. This reflects the success of the COALESCE framework in promoting transparency, building trust, and fostering a sense of ownership among users.

Participants expressed a desire to incorporate the tool into their lesson planning, showing its perceived value and relevance. One educator stated, *I would definitely recommend it to other colleagues*, and noted that *this would benefit a variety of teaching contexts.* This willingness to recommend the tool indicates a high level of trust, which in this context refers to confidence in its reliability, utility, and alignment with educators' instructional goals across different educational settings. Educators valued their roles as co-creators in the development process, noting that it gave them a meaningful sense of ownership and relevance, with one educator mentioning that it felt "applicable to real classrooms." This perception aligns with COALESCE's goal of promoting sustained engagement by aligning AI functionality with practical instructional needs.

The sense of ownership extended beyond daily use, as educators remained committed to refining and enhancing the tool for broader educational purposes. They recognized that their feedback was central to shaping the tool's adaptability, increasing their willingness to advocate for its adoption. This ongoing involvement further strengthened their trust in the system and sense of ownership over its development. By fostering a strong sense of agency and continuous involvement, COALESCE encouraged educators to see the AI tool as a lasting, relevant component of their instructional toolkit, contributing to long-term adoption and advocacy. The transparency of the development process, combined with the trust built through collaborative design, has led to a community of educator-advocates committed to the tool's success and ongoing improvement.

5.2 Evidence in model performance (RQ2): The quality of lesson plans generated by specialized AI models

Our findings from Stage 2 focus on how the reciprocal design process within COALESCE influenced the quality and effectiveness of AI-generated lesson plans. By participating in the iterative co-design process, educators gained both practical and strategic insights, preparing them for the subsequent evaluation phase in Stage 2, where they would further refine and assess the tool's effectiveness in meeting classroom needs. This iterative process helped achieve the four core principles of DBIR: addressing persistent problems of practice, collaborative and iterative design, developing theory and knowledge, and building capacity for sustainable change.

5.2.1 Key finding 1: Preference for human-created content with growing acceptance of AI-generated. The comparative analysis (Figure 2) revealed a preference for lesson plans created by human curriculum designers, receiving 42.1% of total preferences. Customized prompt-based GPT-4 followed with 30.6%, while LLaMA-2-13b FT received 27.3%. These results suggest that human-designed plans remain favored, likely due to their alignment with nuanced pedagogical practices. However, the significant portion of preferences for customized GPT-4 highlights an emerging acceptance of AI-generated content, particularly when models are fine-tuned with educator-driven data, as in COALESCE. This indicates that iterative co-design can enhance AI relevance, making AI-generated plans a viable instructional resource.

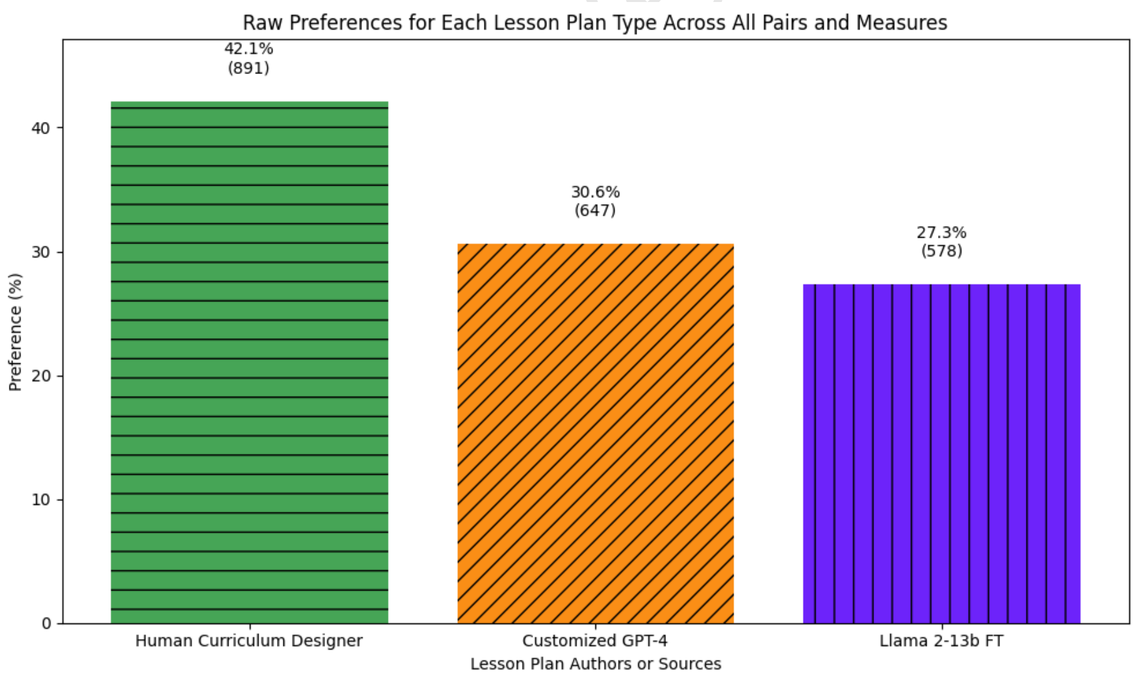

Fig. 2. Educators' preferences for lesson plan authors

5.2.2 Key finding 2: Task-specific AI strengths in specific lesson plan aspects. The analysis of preferences by specific lesson sections shows that customized GPT-4 outperformed human designers in the cool-down section, receiving 37.4% of preferences compared to 30.8% for human-created plans and 31.8% for LLaMA-2-13b FT (Figure 3). Educators indicated that the AI-generated cool-downs effectively facilitated lesson closure and reflection, likely due to COALESCE's focus on embedding instructional strategies directly into the AI models. However, it is important to note that these findings are based on expert evaluations of lesson plans rather than actual classroom implementation. While this demonstrates the COALESCE framework's potential to produce task-specific improvements in AI design enabling it to support particular phases of instruction with comparable or superior quality to human-generated plans, further research is needed to assess the effectiveness of these plans in live instructional settings.

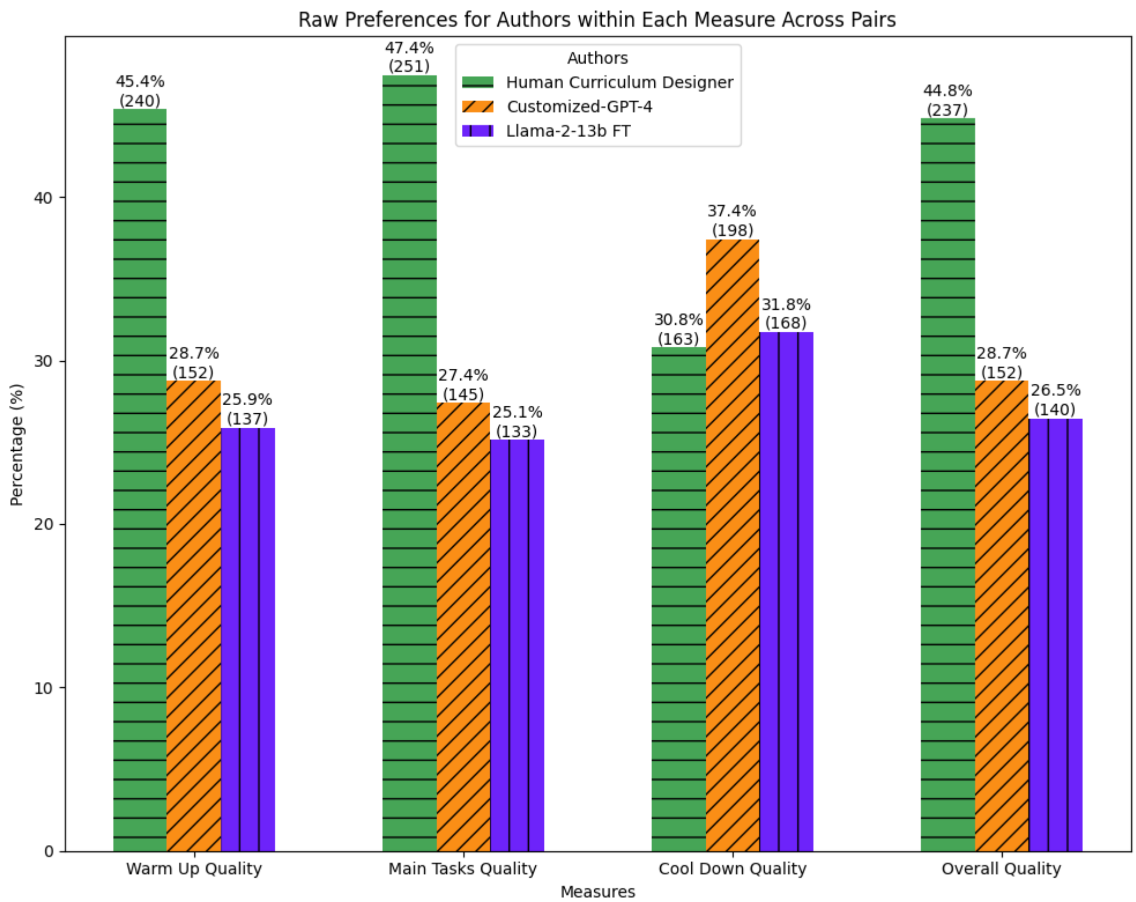

Fig. 3. Educators' preferences by lesson plan aspect

5.2.3 Key finding 3: AI-generated lesson plans show higher applicability and preference at higher grade levels. A breakdown of preferences across grade levels (Figure 4) indicated significant variations in acceptance of AI-generated plans. In elementary grades, human designers received the highest preference (45.9%), with a notable preference for their age-appropriate and pedagogically nuanced content. In contrast, at the high school level, LLaMA-2-13b FT closely matched human curriculum designers (37.9% vs. 36.2%, respectively), suggesting that AI models trained on domain-specific data are more favorably received in higher-grade instruction. The COALESCE framework's Stage 1 data was instrumental in fine-tuning LLaMA-2-13b, enhancing the model's contextual understanding and relevance to real classroom settings. This refinement through educator-generated data underscores COALESCE's effectiveness in creating task-specific improvements, helping LLaMA-2-13b meet the complex instructional needs of advanced learners.

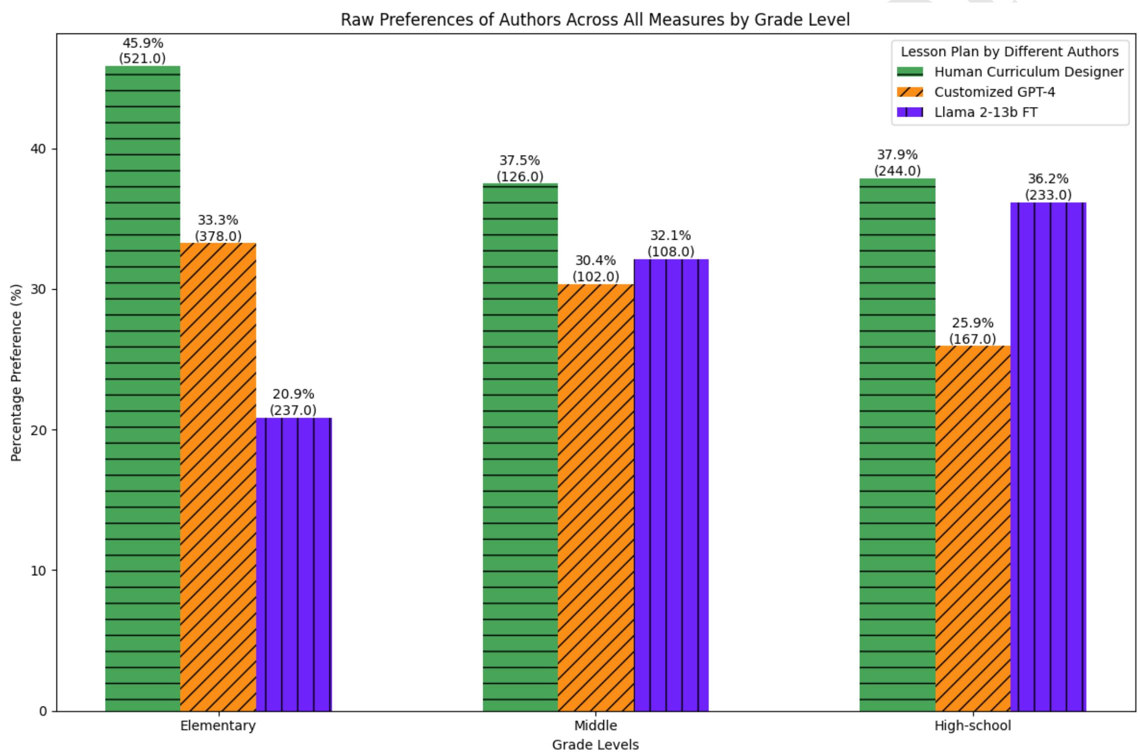

Fig. 4. Educators' grade-level preferences by lesson plan type

Together, these results demonstrate COALESCE's potential and efficacy in creating a specialized, user-centered AI tool that supports meaningful, domain-specific lesson planning for diverse educational contexts. The preference for human designers highlights the importance of pedagogical expertise, yet the growing acceptance of AI-generated lesson plans when domain-specific training data was incorporated, affirming the value of sustained educator involvement in enhancing AI content accuracy and instructional soundness. COALESCE's iterative design approach enabled educators to influence and refine AI model outputs, resulting in improvements across lesson phases and grade levels. This process addressed initial limitations of generic AI tools, increasing the adaptability, transparency, and instructional relevance of the AI lesson plans.

6 Discussion and Conclusion

This study introduces COALESCE, a DBIR-informed framework designed for AI technology development, emphasizing sustained, educator-centered design. By positioning educators as co-creators in a reciprocal learning environment, COALESCE addresses key challenges of transparency, adaptability, and domain-specificity, ensuring AI tools align with classroom realities and instructional needs.

A central contribution of COALESCE is its emphasis on transparency, which fosters trust between educators and AI systems. Through direct involvement in shaping the tool, educators gained a deeper understanding of its functionality, enabling them to trust its output and appreciate its advantages over generic AI solutions. This trust-building process is crucial for sustained integration of AI into teaching practices. Moreover, COALESCE's participatory design approach bridges the gap between AI's general capabilities and K-12 educational needs by involving educators in co-creating lesson quality standards and iterative testing. This ensures the resulting tools remain contextually relevant, adaptable, and responsive to diverse teaching styles.

COALESCE illustrates how a DBIR-informed approach can transform educators into technology co-creators, aligning AI tools with professional knowledge and values. This study contributes to academic discourse on participatory design methodologies, offering a replicable model for creating contextually relevant AI tools that enhance educational outcomes and support sustainable adoption in K-12 environments.

Future work could explore COALESCE's scalability across other subjects and educational innovation contexts beyond lesson planning, as well as its potential for training educators in using emerging AI-driven pedagogical tools. While this study applies COALESCE to the specific context of lesson planning, the framework's principles and processes offer a generalizable approach to educational technology development. By situating educators as co-creators from the outset, COALESCE aims to produce AI solutions that resonate with real-world needs, fostering meaningful and sustainable improvements in teaching and learning.

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