A Review of Content Guidance, Design Approaches, and Evaluation Methods in K-12 Artificial Intelligence (AI) Curriculum Design

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Abstract

A well-designed AI curriculum not only enables students to efficiently master core AI technologies but also fosters computational thinking, creativity, problem-solving abilities, and ethical awareness. This article presents a comprehensive review of the guiding frameworks and theoretical foundations underpinning K–12 AI curriculum design between 2019 and 2024. It also examines various curriculum design approaches and evaluates the effectiveness of implemented curricula. In addition, the review identifies current gaps and challenges in curriculum practices and offers practical recommendations to strengthen teacher professional development and promote collaboration among stakeholders, with the goal of supporting sustainable AI education.

Keywords: K-12 curriculum design, Artificial Intelligence Education, curriculum design framework, theoretical guidance, curriculum design approach, curriculum evaluation.

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1. INTRODUCTION

As artificial intelligence (AI) is rapidly growing and profoundly impacting our lives, AI education has been widely promoted and popularized. Research on AI education could be traced back to 1970 when Carbonnell (1970) introduced a new computer-assisted instruction system (CAI) into education, i.e., information-structure-oriented (ISO), where artificial intelligence techniques are extensively applied via a program called "Scholar" to improve students' learning experience. Considerable research has been done since then, with scopes covering kindergarten to higher education, and topics range from implementing AI technologies in education to teaching AI literacy to students.

With the emergence of machine learning, robotics, and block-based programming environments allowing students to create programs by dragging and connecting visual code blocks, making programming more accessible for beginners and young learners, AI education in K-12 has drawn increased attention of governments, educators, educational institutions, and researchers. Touretzky et al. (2019) pointed out that the young generation is growing up with AI, and they likely interacted with Siri or Alexa before starting kindergarten. He suggests equipping children with AI literacy. "We need to engage students throughout their education, starting as early as kindergarten through high school (K-12) and encourage early consideration of AI-related careers" (Touretzky, Gardner-McCune, et al., 2019, p. 88). Efforts have been made to explore teaching AI to K-12 students. The previous and ongoing research themes on this topic include curriculum design, AI literacy, AI ethical and societal issues, teaching tools, pedagogies, and the integration of AI learning into other subjects (Grover, 2024).

A well-designed AI curriculum can help students master core AI technology efficiently and cultivate their computational thinking, problem-solving skills, ethical awareness, and creativity. Therefore, this review focuses on the curriculum design of K12 AI education, aiming to synthesize the framework guidance or theoretical foundations of K12 AI curriculum design from 2019 to 2024, and to analyze the adopted design approaches and evaluation methods. Three questions are addressed:

- What are the theoretical guidelines, and how are they implemented in the curriculum design?
- What are the approaches utilized in the curriculum design?
- What methods are used to evaluate the efficiency of the curriculum design?

The goal of this review is to indicate the current research trends on designing the K-12 AI curriculum, identify the existing limits and gaps, and provide valuable insights for educators and researchers on future directions. Thus, this review will contribute to the future design of the K-12 AI curriculum and improve the teaching and learning experience in K-12 AI education.

2. METHODOLOGY

This study adopts a systematic literature review approach to explore the above-mentioned questions. A transparent and replicable process was used to ensure the credibility and comprehensiveness of the review.

The review followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework (Page et al., 2021) to ensure transparency in article identification, screening, and inclusion (see Figure 1). Databases such as IEEE Xplore, ACM Digital Library, Springer, and the academic search engine Google Scholar are used to gather relevant studies. A comprehensive search is conducted using a combination of keywords, including "K-12", "Artificial Intelligence", "AI", "curriculum design framework", "curriculum design approach", and "curriculum design evaluation", and the papers are selected from 2019 to 2024. To minimize selection bias, studies were required to be peer-reviewed journal articles or conference papers focused on K–12 AI curriculum design, including theoretical frameworks, design approaches, and evaluation methods. Only studies with clear theoretical

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foundations and research methodologies, published in English after 2019 and available in full text, were included.

All studies identified through the search process were independently screened by two trained reviewers with relevant AI curriculum design experience and IT backgrounds. Initial screening is based on titles and abstracts, followed by a full-text review to determine eligibility according to predefined inclusion criteria. Data from each eligible study is then extracted by the reviewers, capturing information such as theoretical foundations, framework, design approaches, and curriculum evaluation strategies. Any discrepancies in data extraction or eligibility assessment are resolved through discussion or, if necessary, by consultation with a third reviewer.

The data from the selected studies were synthesized using a qualitative thematic analysis approach to identify recurring patterns and key concepts across different research outputs. An iterative coding process was applied to categorize findings into broader themes related to theoretical foundations, curriculum design approaches, and evaluation strategies. All coding was conducted by each reviewer to ensure consistency, with differences resolved through discussion.

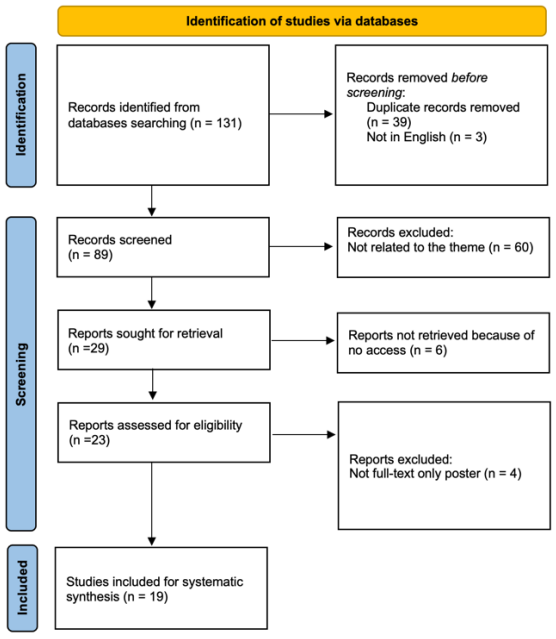

Figure 1: PRISMA Diagram

3. RESULT

This section presents the key findings of the study, focusing on three main aspects of K-12 AI curriculum design: content design guidance, content design approaches, and content evaluation methods.

Content Design Guidance

Curriculum design needs to be guided by scientific theories and frameworks to ensure its systematicity, effectiveness, and adaptability (Tyler, 2013). The curriculum design framework provides structured guidance for learning objectives, instructional methods, and assessment strategies, ensuring that the curriculum meets the needs of diverse learners and adapts to the rapidly changing social and technological environment (Wiggins & McTighe, 2005). This highlights the global recognition of the importance of structured AI curriculum design in K-12 education, leading to efforts at the national level to establish standardized frameworks and curricula. Therefore, many national and international representative institutions have dedicated themselves to providing guiding frameworks.

According to Touretzky et al. (2019), there is little guidance for teaching at the K-12 level about AI teaching compared with the general subject of computing before 2018, so in May 2018, the Association for the Advancement of Artificial Intelligence (AAAI) and the Computer Science Teachers Association (CSTA) launched a collaborative initiative to establish national guidelines for K-12 AI education. Additionally, organizations such as AI4All and the International Society for Technology in Education (ISTE) have acknowledged these needs and have started taking steps to address them (Touretzky, Gardner-McCune, et al., 2019). These initiatives are laying the groundwork for AI education in K-12.

In 2019, AI4K12 released the "Five Big Ideas in AI" poster and graphic, which includes Perception (Computers perceive the world using sensors), Representation and Reasoning (Agents maintain representations of the world and use them for reasoning), Learning (Computers can learn from data), Natural Interaction (Making agents interact comfortably with humans is a substantial challenge for AI developers), and Societal Impact (AI applications can impact society in both positive and negative ways). Together, these ideas define the scope of the field and make it more accessible to teachers. The framework is further divided into four grade bands—K–2, 3–5, 6–8, and 9–12—allowing curriculum designers to

align AI courses with students' cognitive development and ensure progressive learning across levels (Touretzky, Gardner-McCune, et al., 2019). This framework provides definitions and examples for each principle and detailed guidance on what K-12 students are expected to accomplish in each area.

The United Nations Educational, Scientific, and Cultural Organization (UNESCO) has also made important efforts in promoting the standardization of AI. The UNESCO (2022) report, "K-12 AI Curricula — A Mapping of Government-Endorsed AI Curricula", aims to support the development of tools and frameworks to create a comprehensive guiding framework for AI competencies. For example, there are three frameworks, the AI Literacy Competency Framework, AI4K12: Five Big Ideas, and Machine Learning Education Framework, developed to inform the development of AI curricula. By analyzing these AI curriculum guidelines from various countries, UNESCO has proposed recommendations on curriculum content, learning objectives, and implementation strategies to guide the K-12 AI curriculum development.

Through research, we have found that different scholars adopted different strategies when selecting guiding frameworks or theories during the curriculum content design, and the ways are mainly divided into the following aspects (see Table 1).

Integrating Established Frameworks and Theories in Curriculum Design

Different scholars have modified these established frameworks based on their contexts and have integrated other educational theories during the curriculum design.

Sabuncuoglu (2020) developed a 36-week open-source AI curriculum for middle school education by using "Five Big Ideas on AI Education" as its foundational framework. The author presented the curriculum design process and design details about the lecture structures in the article. There are three modules in the curriculum, and each module covers the Five Big principles. Besides, the author also utilized Akker's spider web curriculum development framework (Jan van den Akker, 2010) when designing a new curriculum. There are ten points, which are rationale, objectives, content, learning activities, teacher role, materials and resources, grouping, location, time, and assessment in the design journey to keep the balance of course, and these ten elements are interconnected within the framework, and the web metaphor highlights both the delicate and interdependent nature of designing a new curriculum.

Kim et al. (2021) designed a curriculum mainly focusing on parts of the Five Big Ideas. They also constructed the curriculum's content by surveying Computer Science Curricula 2013 (CS2013) (ACM Computing Curricula Task Force, 2013) with an adjusted difficulty, which is suitable for elementary school students by adopting a backward curriculum design approach, which means that they identified the desired learning outcomes first and then designed those related learning activities with instructional strategies to ensure that the course content aligns with the CS2013 computer science education framework. The authors identified three core competencies essential for achieving AI literacy: AI Knowledge, AI Skill, and AI Attitude.

Su & Yang (2024) primarily refined AI4K12's Five Big Ideas (AI4K12, 2025) by employing a conceptual analysis approach to make them more suitable for early learners. Combining with robotics, this study proposes an AI curriculum framework suitable for young children, providing valuable guidance for future early childhood AI education.

It can be observed that while some scholars adopted the "Five Big Ideas" framework, they modified it by integrating additional frameworks and theories or selectively omitting certain components to better align with their specific curriculum design needs. Many scholars have also designed curricula by integrating their own teaching experiences with other educational frameworks or theories. To design an AI curriculum for kindergarten children, Su and Zhong (2022) applied the framework developed by Scott, which includes four key dimensions: (1) aims, goals, objectives, or declarations of outcome, (2) subject matter, domains, or content, (3) methods or procedure, (4) evaluation and assessment. They also adopted points from Kim et al., who summarized three competencies to achieve AI literacy: AI Knowledge, AI Skill, and AI Attitude (S. Kim et al., 2021). With the guidance of these frameworks and theories, the authors modified the curriculum content suited for kindergarten children.

Building on the curriculum recommendations of Kim et al. (2021) and Su and Zhong (2022), Zhao et al. (2024) developed an AI course that includes 10 units, covering a wide range of content from basic AI knowledge to specific applications for grades three and four, and the authors examined

the changes in students after using a mixed-methods assessment approach.

While using frameworks or theories to guide course design, some scholars have specifically developed curricula tailored for specific students, like female high school students. Alvarez et al. (2022) integrated social media bots, the sentiment of natural language in different media, and the role of AI in criminal justice to spark their interest and career identity in computer science. In the curriculum design, the authors referred to the AI4K12 Big Idea 3 progression chart because it included high school-level objectives specifically related to machine learning algorithms, neural networks, and datasets.

AI is a complex topic that integrates extensive information from various disciplines, ranging from mathematical algorithms to ethical considerations, making comprehensive knowledge transfer challenging (Sabuncuoglu, 2020). Therefore, some scholars have also incorporated interdisciplinary concepts during the design to help students better understand AI. Sabuncuoglu (2020) designed the course to help students better understand how science and innovation work in conjunction by combining artificial intelligence courses with Biology, Physics, and Sociology. In the curriculum, under the guidance of "Five Big Ideas", each module begins with a relevant physical explanation to help students understand how computers perceive the world — including how they see, hear, and even how they might simulate the sense of taste. To understand how to build a human-like computational device, students need to know how human organisms work first, and this is exactly where the interdisciplinary course design of AI connects. Monteith et al. (2022) combined AI concepts with different artistic disciplines like art, music, and poetry to design a course covered in 20 hours in high school.

Developing Self-Designed Frameworks for Curriculum Design

Recent research indicates that many scholars are developing their own self-designed frameworks for curriculum design in addition to relying on established theoretical models.

Chiu et al. (2022) introduced the AKIEE framework, a modular, level-based curriculum co-created with multiple stakeholders. The term AKIEE stands for the five modules—Awareness, Knowledge, Interaction, Empowerment, and Ethics—organized across varying difficulty levels to support differentiated instruction. Chiu (2021) also developed a framework based on four dimensions—content, product, process, and praxis—using teacher interviews to align instructional strategies with curricular goals.

Framework Construction Strategies	Brief Description	Sample Studies
Integrating Established Frameworks	Full use or part use of "Five Big Ideas on AI Education"	Sabuncuoglu (2020); Kim et al. (2021); Su & Yang (2024); Alvarez et al. (2022)
	Computer Science Curricula 2013 as the guidelines.	Kim et al. (2021)
	Akker's spider web curriculum development framework.	Sabuncuoglu (2020)
	Scott framework	Su and Zhong (2022)
	Curriculum recommendations from Kim et al. and Su and Zhong	Zhao et al. (2024)
Developing Self-Designed Frameworks	AKIEE curriculum framework	Chiu et al. (2022)
	A curriculum framework combining four aspects: content, produce, process, and praxis.	Chiu (2021)
	SAC Model (Student-AI Collaboration Model)	J. Kim et al. (2022)
	A comprehensive four-dimensional AI Literacy Framework (AILF)	Kong et al. (2024)

	The "Why-What-How" early childhood AI curriculum design framework	Yang (2022)

Table 1: Framework Construction Strategies: Descriptions and Representative References

Other frameworks draw on established theories. J. Kim et al. (2022) proposed the Student-AI Collaboration (SAC) Model which emphasizes the distributed roles of students, AI tools, and the learning environment in fostering AI literacy and collaborative skills, grounded in Distributed Cognition theory, emphasizing the interplay between students, AI tools, and the learning environment. Kong et al. (2024) presented the AI Literacy Framework (AILF), which includes cognitive, metacognitive, affective, and social dimensions, providing a comprehensive structure for developing AI literacy.

For younger learners, Yang's team (2022) proposed the "Why-What-How" early childhood AI curriculum design framework and designed a course, "AI for Kids," with course objectives, core knowledge areas, and specific teaching methods under the guidance of constructivist learning theory, sociocultural learning theory, and AI education framework. Additionally, the authors also emphasized interdisciplinary integration and cultural relevance.

Content Design Approaches

Designing curricula for K-12 education is more complex than for higher education, as it requires careful consideration of how new initiatives are put into practice, with significant variation in implementation anticipated across different schools (Chiu & Chai, 2020), it also involves rapidly evolving technological advancements, different cognitive backgrounds, and the diverse needs of learners. Therefore, more relevant stakeholders should be involved in the initial stages of curriculum design to minimize inconsistencies in implementation and ensure that the curriculum aligns with diverse needs. Through the analysis of these papers, we divided the methods of curriculum design into independent design and co-design from the perspective of collaboration level in curriculum design (see Table 2).

Independent Design and Co-design

In the literature on K-12 AI education, curriculum design approaches vary, with some authors developing curricula independently and others adopting collaborative co-design methods. Several studies report curricula created solely by individual instructors or researchers. In contrast, many others highlight the importance of co-design, involving multiple stakeholders in the curriculum development process. These collaborative efforts include partnerships among researchers, K-12 teachers (with and without subject-matter expertise), university faculty, industry professionals, and government agencies. For example, Chiu et al. (2022) illustrated this trend through a cross-sector initiative that brought together five key groups—university educators with expertise in education, AI specialists, K–12 teachers, industry representatives, and government partners. Their AI4Future co-creation framework not only exemplifies the collaborative process but also provides a useful model for how diverse stakeholders can be effectively engaged in AI curriculum development. This suggests that co-design may offer greater potential for sustainability and relevance compared to independently developed curricula.

Design Approaches	Brief Description	Sample Studies
Independent design	The authors designed the curriculum independently, without collaboration with external stakeholders.	Alvarez et al.(2022); Kim et al. (2021); Kong et al. (2024); Monteith et al. (2022); Su and Yang (2024); Yang (2022); Zhao et al. (2024)
Co-design	Authors co-designed the curriculum with university specialists, industry professionals, government agencies, and K-12 teachers, with collaboration formats varying across studies.	Chiu et al. (2022); Sabuncuoglu (2020); Chiu (2021); Lin & Van Brummelen (2021)

Table 2: Curriculum Design Approaches

Other studies have emphasized the role of teacher input in curriculum development. Sabuncuoglu (2020) used semi-structured interviews with 17 ICT teachers to gather feedback that ultimately led to revising the course structure from interconnected modules to more independent ones. Chiu (Chiu, 2021) also incorporated semi-structured interviews, working with three experienced research assistants and educators to identify key curriculum components through a hybrid approach of inductive and deductive thematic analysis. This collaborative process informed both the content and implementation strategy of the curriculum.

Co-design not only supports curriculum relevance but also fosters mutual learning. Gardner-McCune et al. (2022) collaborated with middle school teachers and university researchers to ensure that the resulting curriculum was both pedagogically sound and engaging for students. Recognizing that teachers without computer science backgrounds may face challenges teaching AI, Lin and Van Brummelen (2021) emphasized the need to tailor curriculum development to teachers' expertise. They proposed a teacher-led workshop involving 15 K-12 teachers and researchers, where participants collaboratively developed AI modules that integrated with core school subjects. In this model, teachers contextualized AI within familiar content areas while researchers provided technical guidance. Similarly, Xie et al. (2024) described a co-design process involving participants from diverse disciplines to create a cross-curricular AI program.

Content Evaluation Methods

A well-designed curriculum ensures that course objectives align with learners' needs and plays a critical role in maintaining high-quality teaching and learning outcomes. As such, evaluating curriculum content is essential. However, research indicates that not all curriculum designers conduct a formal evaluation of their content. Among those who do, various evaluation methods are employed, including qualitative, quantitative, and mixed methods approaches (see Table 3).

Qualitative Research

Qualitative evaluation methods are commonly used, such as self-assessment (Su & Zhong, 2022), thematic analysis (Chiu & Chai, 2020), semi-structured interviews (Chiu, 2021), classroom observation, feedback (Sabuncuoglu, 2020) and teacher reflections (Gardner-McCune et al., 2022). For instance, Sabuncuoglu (2020) gathered feedback from 60 students regarding their learning experiences, enjoyable moments, areas of confusion, and their interest in further AI learning. Similarly, Chiu (2021) conducted semi-structured interviews with 24 middle school teachers to explore their perspectives on AI curriculum design.

Quantitative Research

Some scholars adopted quantitative methods to assess the curriculum's impact. Kim et al. (2021),

Research Methods	Tools	Sample Studies
Qualitative	Self-assessment Semi-structured interviews Feedback Classroom observation Teacher reflections	Sabuncuoglu (2020); Chiu (2021); Su & Zhong (2022); Chiu & Chai (2020); Gardner-McCune et al. (2022)
Quantitative	T-test A 5-point Likert scale	Kim et al. (2021); Kit Ng et al. (2023)
Mixed Methods	A statistical analysis using the Wilcoxon signed-rank test Self-reflection reports Group interviews	Kong et al. (2024)
	Different types of T-tests Self-Assessment Questionnaire PATT Attitude Questionnaire Expert consensus assessment Semi-structured interviews	Zhao et al. (2024)
	Pre-and post-tests, paired t-tests, and ANCOVA Semi-structured interviews	Chiu et al. (2022)

	A pre-test and post-test Observing Interviews Self-assessment questionnaire	Su and Zhong (2022)

Table 3. Content Evaluation Methods

for example, employed statistical analyses (t-tests) on data from 60 elementary students to measure improvements in AI literacy across three competencies, using a five-point Likert scale. Their results indicated significant gains after the curriculum intervention. Likewise, Kit Ng et al. (2023) developed and validated an AI literacy questionnaire for secondary students, administering it to 363 participants school students from two different schools in Hong Kong. The validity and reliability of the tool were confirmed through Confirmatory Factor Analysis (CFA).

Mixed Methods Research
Several studies utilized a mixed-methods approach to achieve a more comprehensive evaluation. For the quantitative research, 128 high school students, in Kong's research (2024), participated in the course and completed an AI concept test and a survey. The authors then conducted a statistical analysis using the Wilcoxon signed-rank test. For the qualitative research, self-reflection reports and group interviews were adopted. Finally, the authors employed thematic analysis to examine students' feedback on their AI learning experiences. Zhao et al. (2024) used a mixed-methods approach to evaluate the AI curriculum, combining quantitative analyses (e.g., paired and one-sample t-tests on knowledge tests and a revised version of the Pupils' Attitude Toward Technology (PATT) questionnaire) with qualitative methods, including expert consensus assessment and semi-structured interviews. Results showed significant improvements in students' knowledge, skills, creativity, and technological attitudes.

Similarly, Chiu et al. (2022) quantified the impact of the course on students' AI learning ability, attitudes, and motivation through pre-and post-tests, paired t-tests, and ANCOVA, demonstrating statistically significant results. Additionally, they conducted qualitative research using semi-structured interviews. Su and Zhong (2022) combined pre/post testing, classroom observations, teacher interviews, and student self-assessment to evaluate curriculum effectiveness.

4. DISCUSSION

Research has shown that scholars have chosen different theories or frameworks to guide curriculum content design by adopting either independent or collaborative design methods, and scholars have evaluated the effectiveness of the content by using qualitative (interviews, observations, and questionnaires, etc.), quantitative (t-test, analysis of covariance, etc.), or mixed research methods. Overall, the entire design process is complete; however, in every step, we have also identified certain areas with deficiencies that require further refinement and improvement.

Content Design Guidance
Our research shows that multiple frameworks and theories have guided K-12 AI curriculum design, with the "Five Big Ideas" widely used, suggesting its growing dominance. Scholars have approached design in different ways: some adopted institutional frameworks with minor adjustments, some integrated them with other theories, and others created new instructional models. This diversity of theories, frameworks, and models highlights the complexity of establishing solid theoretical foundations in educational research.

However, we have found that some scholars offered vague explanations when it comes to selecting or applying theoretical frameworks. First, some scholars briefly mention the frameworks or theories they reference without introducing specifically. Second, some papers do not explain how the authors integrate frameworks or theories into specific curriculum design content. Third, in some cases, scholars do not justify their choice of a particular theory or framework as a reference standard for curriculum design. Lastly, it is important to highlight that some of the reviewed studies did not clearly identify an educational theory, design model, or AI framework underpinning their AI curriculum design.

In addition to these issues, poor or unbalanced curriculum design is also reflected in some papers. For instance, Kong et al. (2024) observed that traditional AI literacy programs often emphasize technical content while underemphasizing ethical reasoning during their study, which can affect students' holistic understanding of AI. The findings suggest the

importance of balanced exposure across conceptual, metacognitive, affective, and social dimensions. This is the pressing challenge faced by educators and learners in real-world AI-integrated learning environments. Besides, with the widespread adoption of artificial intelligence in education and everyday life, the emergence of AI-generated misinformation has become an increasingly pressing issue. This phenomenon not only poses risks to information integrity but also challenges the ability of young learners to critically evaluate the content they encounter online. As a result, there is a growing need to design curriculum components specifically aimed at addressing these challenges. Such curricula should equip K-12 students with the skills to identify, analyze, and question the accuracy and reliability of AI-generated content. By fostering digital literacy and critical thinking, these educational interventions can better prepare students to navigate an AI-mediated information landscape responsibly and thoughtfully. Therefore, curriculum designers should promptly revise and enrich the content in response to emerging issues associated with AI, ensuring that the curriculum remains relevant and capable of addressing evolving educational challenges.

Content Design Approaches

Independent curriculum design offers scholars significant flexibility to develop instructional content tailored to their vision. However, co-design approaches also present substantial advantages. Through the collaborative design process, teachers who lacked formal AI training were able to acquire essential AI knowledge necessary for curriculum development, thereby increasing their perceived competence and confidence in delivering AI education. Furthermore, co-design fosters teachers' professional autonomy, enabling them to design classroom activities and school-based curricula more effectively. This autonomy enhances their ability to lead, support, and inspire students, ultimately contributing to more personalized and impactful learning experiences.

However, co-design also presents challenges. Some studies note that even when teachers participate in early curriculum design, their input is often disregarded due to time constraints, standards, or policy requirements. This reflects the complexity of the process from conceptualization to implementation. A complete curriculum design cycle requires close collaboration among educational administrators, curriculum designers, teachers, and policymakers to ensure that teachers' professional insights are effectively incorporated into the curriculum. Therefore, the content aligns with actual teaching needs, which is necessary to enhance the feasibility, sustainability, and overall effectiveness of the curriculum.

When examining curriculum design, the choice between independent and co-design approaches should be understood as context-dependent, with each offering distinct advantages and limitations that may be appropriate depending on institutional resources, policy environments, and educator expertise, etc. Besides, we found that established frameworks (e.g., Five Big Ideas) often support independent curriculum design and are typically evaluated with quantitative tools. This indicates that the selection of frameworks not only shapes the level of collaboration in curriculum design but also conditions the preference for evaluation methods.

Content Evaluation Methods

Although the authors mentioned the use of relevant research methods to evaluate the curriculum in different papers, we still identified some issues in these papers.

Firstly, in some articles, the authors Su and Zhong (Su & Zhong, 2022)mentioned they used pre-test and post-test methodology to evaluate how much the effectiveness of the course is, but it does not seem to provide specific statistical results or numerical data from these tests. Besides, some scholars have only evaluated the effectiveness of certain parts of the designed curriculum because of other reasons (S. Kim et al., 2021; Chiu et al., 2022). Kim et al only conducted a trial run by implementing only the first module of the curriculum as a pilot test given experimental subjects have no prior learning experience on AI.

Moreover, due to other reasons like the tight schedule of the school program, the author had to change the three-week study to a three-hour-long "Introduction to Computer Vision" workshop, so it is hard to see the holistic results, but it did show that students are interested in the learning.

Additionally, there are other problems some studies have unrepresentative samples, as they focus only on regional participants and lack cross-cultural validation (S. Kim et al., 2021; Zhao et al., 2024); the sample size of the participants is too small; the content of the questionnaire should be demonstrated to give clear guidance.

Lastly, we noticed that factors that may cause

bias in self-report questionnaire surveys, such as teachers' instructional methods and students' preferences for their teachers, have not been fully considered or mentioned in many studies. Perhaps in the future, AI experts could design more rigorous experiments to validate the effectiveness of curriculum content to conduct more precise scientific measurements, so maybe co-designing with education scholars is a good choice.

All in all, some of the above issues are from the designers themselves, while others are caused by external objective factors. These limitations and feedback may provide some insights for educational administrators and scholars, helping to refine future AI curriculum design and improve its effectiveness, accessibility, and adaptability across different educational contexts.

5.CONCLUSION

In summary, over the past five years, research on K-12 AI curriculum design has grown steadily, and this article is a review of research literature on the theoretical guidance, design approaches, and evaluation methods in current K-12 AI curriculum content design. A review of research shows that, overall, the entire curriculum design process is complete. Scholars have selected different theories, frameworks, or models to guide curriculum content. In terms of design approaches, they have adopted either individual design or co-design. Regarding collaboration choices, some have partnered with university teachers and institutions, while others have collaborated with K-12 teachers, students, or a combination of experts, including educators specializing in education, AI professionals, government representatives, and AI industry stakeholders. This diversity highlights the various forms of collaborative design. For curriculum evaluation, scholars have employed qualitative, quantitative, or mixed research methods. However, various issues still arise in different stages of the process. A well-designed curriculum requires guidance from a comprehensive and widely recognized theoretical framework, the selection of appropriate instructional design methods, and a rigorous, evidence-based evaluation of its effectiveness to ensure its educational impact and achievement of learning objectives. In the future, scholars may consider making improvements in the aspects to better align curriculum design with societal needs and ensure a more rigorous evaluation and validation process.

Although this review included a wide range of studies, some relevant research may have been overlooked, and the limitation of this review is that the author's literature screening is not comprehensive enough, which may result in the omission of some key studies, especially those classic literatures that only focus on certain specific databases or journals, ignoring other potentially relevant resources. The resources of the article are limited to the past five years, so the comprehensiveness is somewhat lacking. In addition, the article may lack more in-depth analysis and insufficient critical analysis. Finally, we should consider the diversity and applicability of research methods. Although various frameworks and theories were discussed, this review did not thoroughly compare the advantages and disadvantages of these frameworks and theories. A more detailed comparison of these frameworks and theories will provide clearer guidance for educators.

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