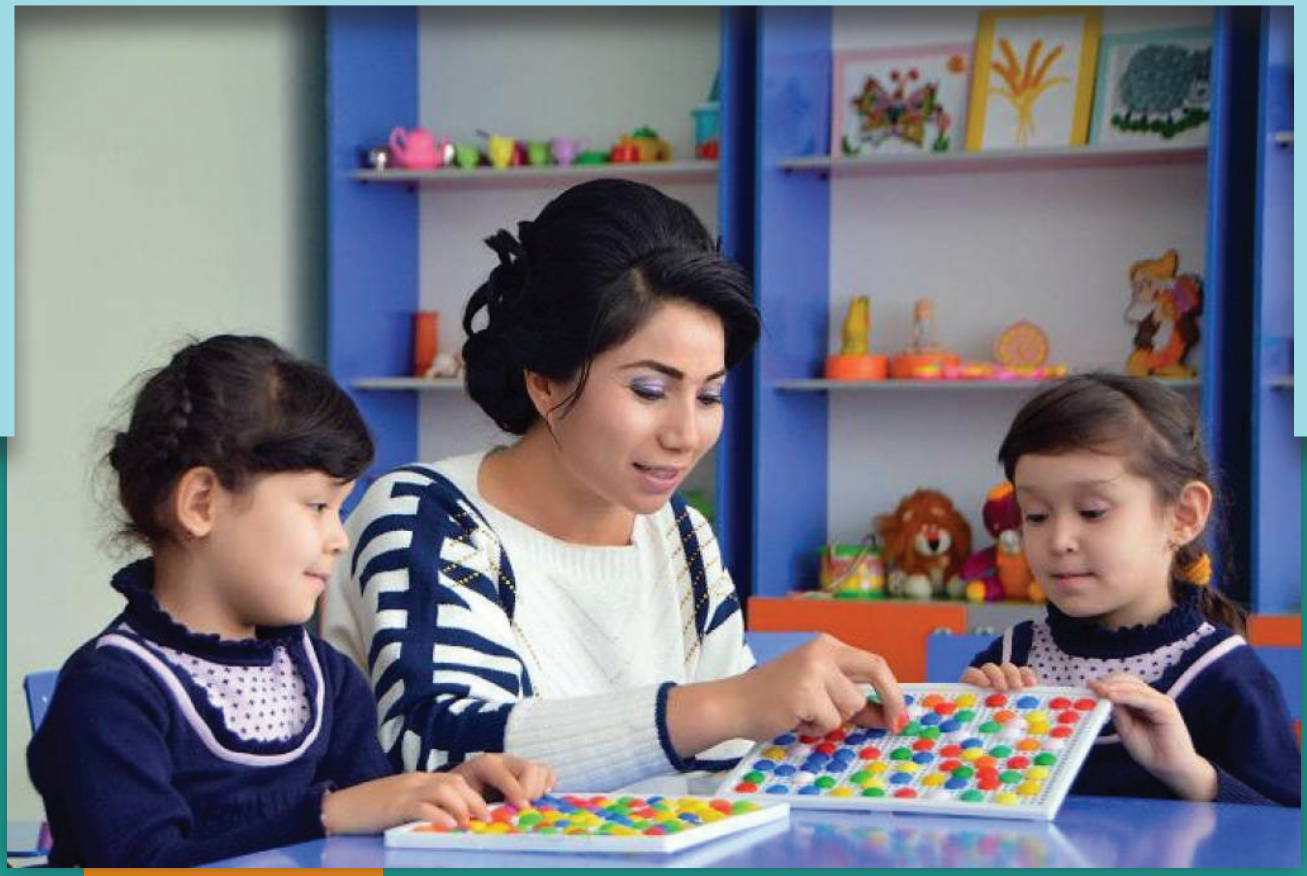
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13.00.00 Pedagogika fanlari
13.00.01 Pedagogika nazariyasi. Pedagogik ta'limotlar tarixi
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13.00.03 Maxsus pedagogika
13.00.04 Jismoniy tarbiya va sport maşğulotlari nazariyasi va metodikasi
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MAKTABGAÇA VA MAKTAB TA'LİMİ

Pedagogika, psixologiya fanlariga ixtisoslaşgan ilmiy jurnal

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TEACHER-GUIDED ARTIFICIAL INTELLIGENCE FOR DIAGNOSING AND CORRECTING STUDENTS' MATHEMATICAL ERRORS IN GRADES 5–9

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Abstract: Errors in mathematics provide valuable evidence of how students understand concepts, apply procedures, and interpret symbolic representations. However, identifying the source of an error and providing timely, appropriate feedback can be challenging in mixed-ability classrooms. This article examines how teacher-guided artificial intelligence (AI) can support the diagnosis and correction of mathematical errors among students in Grades 5–9. Drawing on research on error analysis, formative assessment, intelligent tutoring systems, and generative AI, the study adopts a qualitative, theoretical-methodological approach. It introduces the Teacher-Guided Error Diagnosis and Feedback Cycle (TED-FC), a five-stage instructional framework comprising the collection of student work, formulation of diagnostic hypotheses, targeted questioning, corrective support, and independent reassessment. Illustrative examples involving fractions, algebraic expressions, linear equations, graphs, and square roots demonstrate how AI-generated suggestions may help teachers investigate misconceptions without immediately revealing solutions. The analysis emphasises that AI output should be treated as a provisional interpretation, checked for mathematical accuracy, and adapted to students' needs. Teacher oversight, the protection of student information, and opportunities for unaided problem-solving are presented as essential conditions for responsible implementation. The article's contribution is a practical framework that connects AI-supported feedback with established principles of mathematics pedagogy. As the framework has not been tested in classrooms, no claims are made about measured gains in achievement. The model also identifies observable indicators to support teachers' decisions and assess students' independent responses. Further empirical research is needed to evaluate its effectiveness, feasibility, and implications for independent mathematical reasoning.

Key words: mathematics education; artificial intelligence; error diagnosis; formative feedback; teacher guidance; Grades 5–9.

Annotatsiya: Matematikadagi xatolar öquvchilarning tushunçalarni qanday anglaşlari, amaliy usullarni qöllaşlari va ramziy ifodalarni talqin qilişlari haqida muhim ma'lumot beradi. Biroq bilim darajasi turliça bölgan öquvchilar tahsil oladigan sinflarda xatolarning kelib çiqiş sabablarini aniqlash va öz vaqtida tegishli fikr-mulohaza bildiriş murakkab jarayon hisoblanadi. Mazkur maqolada öqituvchi rahbarligida qöllaniladigan sun'iy intellekt (SI) 5–9-sinf öquvçilarining matematik xatolarini aniqlash va tuzatishda qanday yordam berişi mumkinligi tadqiq etiladi. Xatolar tahlili, şakllantiruvçi baholaş, intellektual repetitorlik tizimlari va generativ sun'iy intellektga oid ilmiy tadqiqotlarga asoslangan holda, tadqiqotda sifat va nazariy-metodologik yondaşuv qöllanildi. Maqolada öquvçilar işlarini yiğiş, diagnostik taxminlarni şakllantiriş, maqsadli savollar beriş, tuzatuvçi yordam körsatish hamda mustaqil qayta baholaşni öz içiga olgan besh bosqiçli "Öqituvchi rahbarligida xatolarni aniqlash va fikr-mulohaza bildiriş sikli" (TED-FC) nomli pedagogik model taklif etiladi. Kasrlar, algebraik ifodalar, çiziqli tenglamalar, grafiklar va kvadrat ildizlarga oid namunaviy misollar sun'iy intellekt tomonidan yaratilgan tavsiyalar öqituvçilarga yeçimlarni darhol oşkor qilmasdan, öquvçilarнинг notöğri tunçalarini aniqlashda yordam berishi mumkinligini körsatadi. Tahlilda sun'iy intellekt natijalari dastlabki talqin sifatida qabul qilinishi, ularning matematik jihatdan töğriligi tekşirilishi va öquvçilarнинг ehtiyojlariga moslashtirilishi lozimligi ta'kidlanadi. Öqituvchi nazorati, öquvçilarнинг şaxsiy ma'lumotlarini himoya qilish hamda mustaqil ravishda masala yeçish imkoniyatlarini ta'minlash mas'uliyatli joriy etişning muhim şartlari sifatida qaraladi. Maqolaning asosiy ilmiy-amaliy hissasi sun'iy intellekt yordamida şakllantiriladigan fikr-mulohazalarni matematika ta'limining amaldagi pedagogik tamoyillari bilan boğlovçi amaliy modelni ishlab çiqişdan iborat. Mazkur model hali sinf şaroitida sinovdan ötkazilmaganligi sababli, öquvçilarнинг özlashtiriş körsatkiçlarida ölçangan ösish kuzatilgani haqida xulosa çiqarilmaydi. Şuningdek, model öqituvçilarning qaror qabul qilish jarayoni va öquvçilarнинг mustaqil javoblarini baholaşda kuzatilişi mumkin bölgan indikatorlarni ham belgilaydi. Modelning samaradorligi, amaliy qöllash imkoniyatlari va mustaqil matematik fikrlaşga ta'sirini baholaş uçun keyingi empirik tadqiqotlar talab etiladi.

Kalit sözlar: matematika ta'limi; sun'iy intellekt; xatolar diagnostikasi; şakllantiruvçi fikr-mulohaza; öqituvchi rahbarligi; 5–9-sinflar.

Аннотация: Ошибки в математике предоставляют ценную информацию о том, как учащиеся понимают математические понятия, применяют процедуры и интерпретируют символические представления. Однако выявление причин возникновения ошибок и предоставление своевременной и соответствующей обратной связи могут представлять сложность в классах с учащимися разного уровня подготовки. В данной статье рассматривается, каким образом искусственный интеллект (ИИ), применяемый под руководством учителя, может способствовать диагностике и исправлению математических ошибок учащихся 5–9-х классов. Основываясь на исследованиях в области анализа ошибок, формирующего оценивания, интеллектуальных обучающих систем и генеративного ИИ, исследование использует качественный теоретико-методологический подход. В статье предлагается пятиэтапная педагогическая модель "Цикл диагностики ошибок и обратной связи под руководством учителя" (TED-FC), включающая сбор работ учащихся, формулирование диагностических гипотез, постановку целенаправленных вопросов, предоставление корректирующей поддержки и самостоятельную повторную оценку. Иллюстративные примеры, охватывающие дроби, алгебраические выражения, линейные уравнения, графики и квадратные корни, демонстрируют, как рекомендации, сгенерированные ИИ, могут помогать учителям выявлять ошибочные представления учащихся, не раскрывая при этом готовые решения. В исследовании подчёркивается, что результаты работы ИИ следует рассматривать как предварительную интерпретацию, подлежащую проверке на математическую корректность и адаптации к потребностям учащихся. Контроль со стороны учителя, защита персональных данных учащихся и предоставление возможностей для самостоятельного решения задач без помощи ИИ рассматриваются как необходимые условия ответственного внедрения данной технологии. Научно-практический вклад статьи заключается в разработке прикладной модели, объединяющей обратную связь с использованием ИИ с общепринятыми принципами преподавания математики. Поскольку предложенная модель ещё не прошла апробацию в школьных классах, в статье не делается выводов об измеримом повышении учебных достижений. Модель также определяет наблюдаемые показатели, которые могут использоваться учителями при принятии решений и оценке самостоятельных ответов учащихся. Для оценки эффективности модели, возможностей её практического применения и влияния на самостоятельное математическое мышление необходимы дальнейшие эмпирические исследования.

Ключевые слова: математическое образование; искусственный интеллект; диагностика ошибок; формирующая обратная связь; руководство учителя; 5–9-е классы.

INTRODUCTION

Mathematical errors are among the most informative occurrences in a mathematics lesson. For example, a student who adds fractions by adding both the numerators and denominators is not merely providing an incorrect answer; rather, the student is revealing a particular interpretation of fraction notation. Similarly, an error when distributing a coefficient across parentheses may indicate an incomplete understanding of algebraic structure. Teachers regularly use such responses to determine whether to revisit a concept, provide a counterexample, or modify a task. The challenge is that these decisions often need to be made while supporting multiple learners with different levels of mathematical understanding. Digital platforms make it easier to collect students' responses, but collecting answers is not equivalent to understanding them. Generative artificial intelligence (AI) introduces an additional possibility: it can analyses learners' intermediate steps, suggest potential misconceptions, and generate follow-up questions in natural language. However, speed should not be confused with reliability. AI-generated mathematical explanations may contain inaccuracies, while ready-made solutions can reduce students' opportunities to engage in independent reasoning. A field experiment in secondary mathematics found that unrestricted access to a general-purpose AI tutor improved performance during assisted practice but could negatively affect subsequent unaided performance; teacher-designed safeguards within the tutoring system mitigated much of this risk [1].

The present article therefore positions the teacher, rather than the AI system, at the center of the diagnostic process. Its object is mathematics teaching and learning in Grades 5–9, while its subject is the instructional application of AI-supported error analysis and corrective feedback. The aim is to develop an operational model through which teachers can identify students' mathematical difficulties, select appropriate instructional responses, and determine whether learners can subsequently solve related tasks independently.

Three research questions guide the study:

1. Which types of student errors can reasonably be investigated through AI-supported dialogue?
2. How can AI-generated feedback be structured without undermining students' mathematical thinking?
3. What forms of teacher verification and independent reassessment are necessary to ensure that the process is educationally responsible?

These questions are addressed through a focused review of published literature and an illustrative design analysis rather than through claims based on an unreported classroom experiment.

LITERATURE REVIEW

Error analysis has long played an important role in mathematics education. Radatz [8] examined mathematical errors in relation to information processing, identifying difficulties associated with language, prerequisite knowledge, spatial information, and the inappropriate application of rules. This perspective remains relevant because an observable mistake may have several underlying causes. The same incorrect answer may result from a conceptual misunderstanding, a computational slip, or a misinterpretation of the task. Therefore, an instructional diagnosis should remain provisional until the teacher has gathered additional evidence. The work of Black and Wiliam [2] established formative assessment as a process through which evidence of learning informs subsequent instructional decisions.

Hattie and Timperley [3] further distinguished effective feedback from comments that merely evaluate performance, emphasizing the importance of learning goals, current progress, and subsequent steps. Similarly, Shute [9] highlighted the value of formative feedback that is specific, supportive, and conducive to learning. Collectively, these studies suggest that feedback is valuable not simply because it is immediate, but because it enables students to respond constructively to an identifiable learning difficulty.

Research on intelligent tutoring systems provides a related, although not identical, theoretical foundation. In their meta-analysis, Kulik and Fletcher [5] reported generally positive learning outcomes associated with structured intelligent tutoring systems, while also demonstrating that results depend on system design and evaluation conditions. Such systems should not be equated with open-ended generative AI applications. Although the latter can produce flexible explanations, their responses may vary across similar prompts and are not necessarily mathematically accurate.

Kasneci and colleagues [4] discuss opportunities for personalized learning and educational content development alongside the need for fact-checking, critical judgement, and human oversight. The large-scale mathematics experiment reported by Bastani and colleagues [1] is particularly relevant to the present study. Its findings demonstrated that an AI tutor incorporating teacher-informed hints and safeguards produced meaningfully different outcomes from a general-purpose interface that primarily provided solutions. This reinforces the case for an instructional design in which AI supports students in continuing their mathematical reasoning rather than completing the reasoning process on their behalf. Ethical guidance is equally important. UNESCO's guidance on generative AI [7] advocates human-centred and age-appropriate educational applications, with particular attention to personal data protection and institutional readiness. Its AI Competency Framework for Teachers [6] identifies pedagogical, ethical, and technical competencies as interrelated requirements. The distinctive contribution of the present study is to integrate these insights into a practical error-diagnosis sequence for regular mathematics lessons in Grades 5–9, incorporating explicit checkpoints for teacher approval and students' independent performance.

RESEARCH METHODOLOGY

The study adopts a qualitative, theoretical-methodological research design. It is based on a purposive analysis of relevant academic publications and policy documents addressing mathematical error analysis, formative assessment, intelligent tutoring systems, and generative AI. Sources were selected according to their conceptual relevance to the research questions rather than through a preregistered systematic review protocol. Accordingly, this article does not claim to provide exhaustive coverage of the literature or a pooled estimate of effectiveness. The analysis was conducted in three stages.

First, recurring principles were identified from the literature:

- errors should be interpreted in context;
- feedback should encourage a subsequent learning action;
- teacher expertise should be used to validate suggested explanations;
- and learning outcomes should be assessed independently, without assistance.

Second, these principles were translated into a five-stage instructional cycle designed for implementation in short classroom activities. Third, the proposed cycle was applied to representative curricular examples involving algebra, fractions, and elementary functions. All student responses presented in these examples are constructed illustrations rather than observations obtained from identifiable pupils. The proposed framework is termed the Teacher-Guided Error Diagnosis and Feedback Cycle (TED-FC). It represents a design proposal rather than a validated assessment instrument. Its potential value is examined in terms of internal pedagogical coherence and alignment with findings from published research. Its practical effectiveness, feasibility, and potential unintended consequences require empirical investigation in future studies.

ANALYSIS AND RESULTS

1. From a Wrong Answer to an Instructional Hypothesis

An incorrect answer alone rarely reveals the precise misconception underlying a student's reasoning. Consider the equation $3(x - 2) = 2x + 5$. If a learner writes $3x - 2 = 2x + 5$, an AI system may identify the issue as an error in applying the distributive property. Although this is a plausible hypothesis, it does not yet constitute a confirmed diagnosis. The learner may have forgotten to multiply the constant term, may be focusing only on the first term inside the parentheses, or may have copied the expression incorrectly. An appropriate follow-up question would be: "When the 3 is placed outside the parentheses, which terms must it multiply?" The teacher can then examine the learner's explanation to determine the underlying difficulty. Treating AI-generated output as a hypothesis rather than a definitive judgement constitutes the first design principle. Errors can be provisionally classified into four categories: conceptual, procedural, representational, and verification-related. These categories may overlap, and the same response may require further questioning before an appropriate instructional decision can be made. Table 1 illustrates how a teacher can move from an observed written response towards a more focused instructional question.

Table 1: **Illustrative error patterns and diagnostic follow-up questions (author-developed examples)**

Topic and level	Illustrative student response	Possible interpretation / diagnostic question
Grade 5–6: fractions	2/3 + 1/4 = 3/7	Numerators and denominators may be treated as independent whole numbers. "What would these fractions look like on the same number line?"
Grade 7: algebra	$3(x - 2) = 3x - 2$	The coefficient may not be applied to both terms. "What is $3 \times (-2)$?"
Grade 8: linear graphs	The point (2, 5) lies on $y = 2x + 3$	The point may not have been checked by substitution. "What is $2(2) + 3$?"
Grade 9: square roots	$\sqrt{(x^2)} = x$ for all real x	The non-negative principal root may be misunderstood. "What happens when $x = -3$?"

2. The five-stage TED-FC model

The cycle begins with work students have already attempted; it does not ask an AI system to generate a diagnosis from grades alone. Each stage contains a teacher decision so that responsibility for correctness and appropriateness remains explicit. Table 2 summarises the proposed sequence and the artefact produced at each stage.

Table 2: **Teacher-Guided Error Diagnosis and Feedback Cycle (TED-FC)**

Stage	Teacher and AI-supported action	Expected evidence
1. Capture	Collect the original response and relevant intermediate steps; remove identifying information before using any approved external tool.	A traceable student attempt, not merely a final score.
2. Hypothesise	Ask AI to identify up to two plausible sources of error; teacher verifies calculations and selects a hypothesis.	A provisional description of the difficulty.
3. Probe	Pose a short question, counterexample or visual prompt without displaying the final answer.	Student explanation that can confirm or challenge the hypothesis.
4. Repair	Offer a targeted explanation and an analogous problem; teacher checks the proposed material.	An improved explanation or independently completed correction.
5. Reassess	Remove AI assistance and administer a transfer item; record whether the misconception persists.	Evidence of unaided understanding and the next teaching decision.

The critical distinction lies between feedback that replaces independent thinking and feedback that stimulates it. At Stage 3, AI-supported prompts should generally take an interrogative rather than a declarative form. At Stage 4, a fully worked solution may be appropriate once the learner has attempted to correct the error, but it should not be provided as the default initial response. Stage 5 then completes the cycle: a correct answer obtained with AI assistance should not be considered sufficient evidence that the underlying concept has been fully understood.

3. An Example of Classroom Implementation

In a Grade 7 lesson on linear equations, the teacher asks students to solve $3(x - 2) = 2x + 5$ and show each step of their working.

One constructed student response is as follows: $3x - 2 = 2x + 5$; $x = 7$.

Before providing any AI-generated explanation, the teacher examines the likely source of the error and verifies the correct solution: $3x - 6 = 2x + 5$, hence $x = 11$.

The teacher then uses an AI system, within an institutionally approved workflow, to generate a short sequence of questions targeting the application of the distributive property. A suitable teacher-controlled instruction would be:

"A Grade 7 learner transformed $3(x - 2)$ into $3x - 2$. Do not solve the equation for the learner. Propose two brief questions that help the learner reconsider this step. Use plain language and do not include any personal information."

One useful follow-up activity is to ask the learner to compare $3(x - 2)$ with $(x - 2) + (x - 2) + (x - 2)$. If the student can explain why the constant term is subtracted three times, the teacher may assign $4(x - 3) = 2x + 6$ as a comparable independent task. The correct result is $x = 9$. The teacher evaluates the student's problem-solving process rather than focusing exclusively on the final answer.

The same model can be adapted for Grade 6 fractions through the use of common visual partitions or for Grade 9 functions by asking students to verify whether a proposed point satisfies the equation represented by a graph. Technology is not the methodological centre of these lessons; rather, the central focus is the progression from a student-generated error to explanation, revision, and independent performance. A paper-based worksheet and teacher-led discussion can fulfil the same pedagogical functions when an appropriate digital tool is unavailable.

4. Practical and Ethical Conditions

AI-assisted diagnosis may introduce several potential risks. An inaccurate AI-generated explanation may reinforce an existing misconception; students may copy suggested procedures without understanding them; and sharing identifiable student work may raise concerns regarding personal data protection. To mitigate these risks, the proposed model requires teachers to verify mathematical accuracy, avoid uploading students' names or other personally identifiable information, comply with school policies and applicable child-protection requirements, and ensure age-appropriate, supervised access to AI tools [6, 7]. Where the use of an external AI tool has not been approved, its proposed function can be replaced with a teacher-developed bank of instructional hints.

The model also raises questions concerning teacher workload. Requiring teachers to review every AI-generated suggestion may undermine the efficiency that the technology is intended to provide. A practical approach is to begin with a limited number of frequently occurring misconceptions within a particular topic and develop a verified bank of prompts, worked examples, and transfer tasks. The teacher retains responsibility for the final instructional decision without having to formulate every question from scratch. This resource bank should be regularly reviewed and updated whenever examples prove ambiguous or students demonstrate alternative but mathematically valid solution methods.

5. Analytical Findings and Boundaries of Inference

The reviewed literature supports four principal design propositions:

- diagnosis should be grounded in students' actual reasoning [8];
- feedback should identify an actionable next step [2, 3, 9];
- tutoring design and appropriate safeguards are important for supporting independent learning [1, 4, 5];
- and teacher competence and data protection measures are essential prerequisites for responsible implementation [6, 7].

The TED-FC model translates these propositions into an operational classroom sequence. These findings represent conceptual conclusions derived from literature synthesis and design analysis rather than empirically measured improvements in student achievement.

Table 3: **Analytical propositions and evidence needed for future validation**

Design proposition	Observable indicator in a future school study
A targeted question is preferable to an immediate answer.	Rate of self-correction before any worked solution is shown.
Teacher verification reduces inappropriate feedback.	Proportion of AI suggestions rejected or revised by teachers.
Independent reassessment is necessary.	Score on parallel transfer items completed without AI.
Implementation should remain workable and equitable.	Teacher preparation time, student access and feedback quality across groups.

A future empirical study could compare conventional formative assessment with a teacher-guided TED-FC intervention across comparable Grades 5–9 classes. Baseline knowledge, topic difficulty, and teacher experience should be documented to account for relevant contextual differences. Potential outcome measures could include the frequency of conceptual errors, unaided transfer performance, teacher workload, and student perceptions. Such a study should incorporate explicit consent procedures and appropriate data-governance measures, a prespecified assessment rubric, and transparent reporting of both positive and negative findings. Until such evidence is available, it would be inappropriate to claim that the proposed model has improved student achievement.

CONCLUSION

Artificial intelligence can expand the range of questions and explanations available to mathematics teachers; however, it cannot independently establish why a learner has made an error or whether the underlying misconception has been successfully addressed. The analysis presented in this article suggests that the educational value of AI depends less on its ability to generate rapid answers than on how it structures the instructional process following an incorrect response. Within the proposed TED-FC cycle, the student's own work initiates the diagnostic process, AI contributes potential questions, the teacher validates the proposed instructional response, and unaided reassessment informs subsequent instructional decisions. For practical implementation, mathematics teachers should begin by identifying a limited set of frequently occurring errors, preserve students' original reasoning, prioritise prompts that encourage explanation, and verify every mathematical claim generated by AI.

Schools should establish clear guidelines concerning approved tools, age-appropriate access, and the collection, processing, and protection of student data. Professional development for teachers should address both the design of diagnostic questions and fundamental AI literacy. Subsequent research should investigate whether the proposed model improves conceptual understanding, reduces the recurrence of mathematical errors, and remains feasible under actual classroom conditions. The article's contribution therefore lies in presenting a structured methodological proposal and a set of empirically testable indicators. It does not report the results of a school-based intervention or statistically significant improvements in learning outcomes. This limitation also identifies an important direction for future research: only carefully designed and conducted classroom studies can establish the effectiveness of the proposed model across different mathematical topics, learner groups, and educational settings.

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13.00.00 Pedagogika fanlari
13.00.01 Pedagogika nazariyasi. Pedagogik ta’limotlar tarixi
13.00.02 Ta’lim va tarbiya nazariyasi va metodikasi (sohalar böyiça)
13.00.03 Maxsus pedagogika
13.00.04 Jismoniy tarbiya va sport maşğulotlari nazariyasi va metodikasi
13.00.05 Kasb-hunar ta’limi nazariyasi va metodikasi
13.00.06 Elektron ta’lim nazariyasi va metodikasi (ta’lim sohalari va bosqiçlari böyiça)
13.00.07 Ta’limda menejment
13.00.08 Maktabgaça ta’lim va tarbiya nazariyasi va metodikasi
13.00.09 Ijtimoiy pedagogika
07.00.00 Tarix fanlari
19.00.00 Psixologiya fanlari
01.00.00 Fizika-matematika fanlari
02.00.00 Kimyo fanlari
03.00.00 Biologiya fanlari
09.00.00 Falsafa fanlari
10.00.00 Filologiya fanlari
11.00.00 Geografiya fanlari

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