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Role Of Ai Tools In Developing Problem Solving Skills Among Secondary School Students

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Abstract: This study aimed to investigate the effectiveness of Artificial Intelligence (AI) tools in enhancing problem-solving skills among secondary school students. With the rapid integration of AI in educational environments globally, the research explored not just the general impact of AI usage, but also how specific types of AI tools contribute to various dimensions of problem-solving, including problem identification, information analysis, strategy formulation, solution execution, and reflection & evaluation. A sample of 100 secondary school students was divided based on their exposure to AI tools such as Intelligent Tutoring Systems (ITS), Simulations, Gamified Learning Tools, Adaptive Assessment Platforms and Educational Chatbots. Quantitative analysis methods including descriptive statistics, t-tests, Pearson correlation, and regression analysis were used to assess skill development. The results revealed that students who frequently used AI tools scored significantly higher on all dimensions of problem-solving than those who did not. The strongest correlations were found between AI tool usage and strategy formulation ($r = 0.658$), followed by information analysis and problem identification. Regression analysis showed that ITS and Simulations were the most powerful predictors of problem-solving success, explaining over 40% of the variance in some dimensions. Gamification was especially effective for strategy building, while Simulations and Chatbots helped improve metacognitive reflection. Notably, gender-wise analysis showed no statistically significant differences in performance, although female students showed slightly higher mean scores across all dimensions. The study concluded that AI tools serve not only as instructional supports but also as cognitive partners that meaningfully enhance problem-solving skills. Based on these findings, the study recommends integrating AI-driven platforms into the secondary curriculum, training teachers in AI pedagogy, and conducting further research through longitudinal and qualitative methods. The study supports the global educational shift toward digital intelligence and personalized learning, emphasizing the critical role AI can play in preparing students for 21st-century challenges.

1. Introduction

In recent years, the integration of Artificial Intelligence (AI) tools in educational settings has revolutionized traditional learning paradigms, offering novel pathways for enhancing student engagement, critical thinking, and particularly, problem-solving skills. With the advent of AI-powered educational applications, secondary school students are increasingly exposed to interactive and adaptive learning experiences that were once unimaginable in conventional classrooms. These tools employ complex algorithms to tailor content based on individual learner profiles, providing immediate feedback, scaffolding problem-solving processes, and enabling personalized learning trajectories. According to Holmes, Bialik, and Fadel (2019), AI in education not only automates administrative tasks but also plays a critical pedagogical role by acting as an intelligent tutor or learning companion. Through continuous interactions with such tools, students gradually develop metacognitive strategies essential for identifying problems, exploring alternatives, and implementing solutions in a structured manner. This integration signifies a paradigm shift in which AI does not replace the teacher but instead enhances the cognitive engagement of students, ultimately fostering a deeper and more sustained acquisition of problem-solving competencies (Luckin et al., 2016).

The potential of AI tools to cultivate problem-solving skills lies in their ability to simulate real-world scenarios that require complex decision-making and iterative thinking. Tools such as intelligent tutoring systems (ITS), educational chatbots, and game-based learning environments employ machine learning techniques to model student behaviour and provide customized support. These AI-driven platforms challenge students with adaptive difficulty levels, ensuring that tasks remain within their zone of proximal development (Vygotsky, as cited in Woolf, 2010). This instructional alignment enables students to confront cognitive dissonance-one of the key drivers of learning-without succumbing to frustration or disengagement. For instance, the Cognitive Tutor developed by Koedinger et al. (2003) uses a model-tracing approach that evaluates students' problem-solving steps and delivers real-time, context-sensitive feedback. As students are guided through increasingly complex problems, they not only acquire domain-specific knowledge but also internalize heuristic strategies that can be transferred across disciplines. The iterative nature of AI-supported problem-solving mirrors the scientific method, wherein students hypothesize, test, and revise their approaches based on evidence and feedback (VanLehn, 2011).

Moreover, AI tools enable collaborative and exploratory learning experiences that promote social dimensions of problem-solving. Many AI-powered platforms now support collaborative learning through shared workspaces, multi-user simulations, and peer-feedback systems that are facilitated by natural language processing and semantic analysis. According to Dillenbourg (2013), collaboration is a powerful driver of problem-solving proficiency, as it necessitates negotiation, communication, and consensus-building-skills often neglected in solitary learning environments. AI tools like virtual learning assistants and automated discussion moderators help scaffold student interactions, prompting them to articulate their reasoning, justify their choices, and reconcile conflicting viewpoints. These dialogic engagements not only enrich the cognitive landscape of learners but also foster socio-emotional competencies that are vital for effective problem-solving in the 21st century. Furthermore, AI-mediated collaboration mitigates common group work challenges such as social loafing or dominance by more assertive peers by ensuring equitable participation through algorithmic moderation (Rosé et al., 2008). Thus, AI tools extend the boundaries of problem-solving from individual cognition to socially constructed understanding.

Despite these promising outcomes, the effectiveness of AI tools in cultivating problem-solving skills is influenced by several contextual and pedagogical variables, including curriculum alignment, teacher preparedness, and the digital literacy of students. According to Chen et al. (2020), the implementation of AI tools in secondary education is often hindered by a lack of systemic support, which can limit their potential impact. Teachers must not only understand how to operate these technologies but also how to integrate them meaningfully into their instructional design to promote higher-order thinking. Moreover, students' access to devices, internet connectivity, and prior exposure to digital tools significantly affect their ability to benefit from AI-enhanced learning environments. Additionally, ethical concerns surrounding data privacy, surveillance, and algorithmic bias must be addressed to ensure that AI integration does not exacerbate existing educational inequalities (Williamson & Eynon, 2020). These challenges call for a comprehensive policy framework and sustained professional development initiatives that empower educators to use AI tools as catalysts for transformative learning rather than mere technological novelties.

Finally, empirical evidence from various international contexts supports the positive impact of AI tools on students' problem-solving skills, yet more longitudinal studies are needed to understand the depth and sustainability of these outcomes. For example, a study conducted in Singapore by Lim et al. (2021) found that students who engaged with AI-based mathematics software demonstrated significantly improved analytical reasoning and problem-solving abilities compared to their peers who received traditional instruction. Similarly, in Finland, a pilot project involving AI-driven learning analytics tools reported enhanced student motivation and strategic thinking over a school year (Vuorikari et al., 2020). These findings underscore the potential of AI to act as a scaffold for intellectual growth, particularly when embedded within a learner-centred pedagogy that values inquiry, experimentation, and reflection. However, researchers such as Selwyn (2019) caution against over-reliance on technology, arguing that the true educational value of AI lies not in its novelty but in its alignment with sound pedagogical practices. Therefore, while AI tools offer unprecedented opportunities to develop problem-solving skills among secondary school students, their success ultimately depends on thoughtful implementation, ongoing evaluation, and a nuanced understanding of the complex interplay between technology, pedagogy, and human agency.

2. Importance of AI in School Education at Secondary Level

The integration of Artificial Intelligence (AI) in secondary education has emerged as a critical innovation for modernizing teaching and learning practices. As students at this stage face increasing academic pressure and the need to master complex concepts, AI tools provide adaptive learning experiences that respond to individual learning paces, styles, and needs. Through intelligent tutoring systems, learning analytics, and AI-driven platforms, secondary students receive real-time feedback and personalized pathways that enhance comprehension and retention. AI tools can diagnose learning gaps more efficiently than traditional assessments and offer remediation before issues escalate. This not only supports struggling learners but also accelerates progress for advanced students, thereby promoting inclusive and equitable education. AI's ability to automate administrative and evaluative tasks also enables teachers to focus more on pedagogy, creativity, and socio-emotional support.

Beyond academic personalization, AI enhances the development of 21st-century skills, especially critical thinking, collaboration, creativity, and problem-solving, which are essential for future readiness. AI-powered simulations, virtual labs, and gamified learning environments allow students to explore real-world problems in an interactive and risk-free setting. For example, using AI-based tools in STEM education can help students visualize scientific processes or solve mathematical problems through dynamic modelling, making abstract concepts more tangible and engaging. Chatbots and virtual assistants can act as learning companions, helping students formulate questions, reason through problems, and improve digital literacy. These applications create a student-centred learning ecosystem where curiosity is encouraged and deep learning is supported. As such, AI fosters both cognitive and metacognitive development, preparing students for lifelong learning and innovation in a rapidly evolving digital economy.

Moreover, the use of AI in secondary schools prepares students to interact with technologies they will inevitably encounter in higher education and the workplace. As industries increasingly adopt AI-driven systems, equipping students with foundational knowledge of AI, its applications, and ethical implications becomes essential. Introducing AI literacy at the secondary level ensures that students not only become competent users of technology but also critical thinkers who can question, evaluate, and responsibly use AI. AI can also support teachers in understanding student behaviour and emotional well-being through sentiment analysis and predictive analytics, promoting a healthier, more supportive classroom environment. In this way, the use of AI not only modernizes education but also acts as a bridge between school learning and real-world application, ensuring that secondary students are better prepared for the challenges and opportunities of the 21st century.

3. Need and Justification of the Research

In the 21st century, education systems globally are under immense pressure to adapt to technological advancements while simultaneously preparing students for a future defined by uncertainty, complexity, and rapid change. One of the most vital competencies in this context is problem-solving, which is recognized internationally as a core component of 21st-century skills (Trilling & Fadel, 2009). As traditional instruction methods often emphasize rote learning and passive knowledge consumption, students in secondary schools frequently lack opportunities to develop higher-order cognitive skills essential for navigating complex real-life situations. Artificial Intelligence (AI) tools present a transformative opportunity to bridge this gap by offering dynamic, interactive, and personalized learning environments. These tools can scaffold students through various stages of problem-solving-from problem identification and information analysis to solution generation and evaluation-thus promoting deep learning and cognitive flexibility (Luckin et al., 2016). Despite the growing adoption of AI technologies in education globally, there remains a significant gap in research, particularly focused on their pedagogical implications for developing problem-solving skills among adolescents at the secondary level. According to Holmes, Bialik, and Fadel (2019), while AI holds tremendous potential, there is a dearth of rigorous, classroom-based empirical studies that examine how specific AI interventions influence critical cognitive skills such as reasoning, analytical thinking, and solution generation. This necessitates a focused inquiry into the ways in which AI tools are integrated into secondary school curricula and the actual impact they have on student skill development.

Furthermore, secondary school is a critical developmental period during which students begin to transition from dependent learning behaviours to independent and strategic thinking. As AI continues to shape the future of work, it is imperative that students are not only familiar with AI tools but also capable of using them to tackle real-world problems effectively. According to VanLehn (2011), Intelligent Tutoring Systems (ITS) and AI-powered learning platforms, when properly designed and implemented, can match or even exceed the efficacy of human tutors in promoting structured problem-solving skills. These tools can simulate authentic challenges, provide real-time feedback, and adapt content to suit diverse learner profilescapabilities that are rarely found in traditional instructional settings. Despite these benefits, the pedagogical strategies, implementation models, and cognitive outcomes associated with AI tool use remain insufficiently understood, especially within the context of developing countries or under-resourced educational environments. Selwyn (2019) argues that while the promise of AI in education is often overstated, what is most urgently needed is grounded research that investigates how these tools are actually used in practice, their alignment with curriculum goals, and their effectiveness in fostering deep cognitive skills such as problem-solving. By focusing on secondary school students, this research addresses a critical age group that is often overlooked in both educational reform and technological innovation discourses. This study, therefore, seeks to fill a vital research gap by empirically examining the role of AI tools in cultivating problem-solving skills, thereby contributing to both the theoretical understanding and practical advancement of AI-enhanced learning environments.

4. Statement of the study

Role of AI Tools in Developing Problem-Solving Skills among Secondary School Students

5. Objectives of the Study

- To examine the extent to which AI tools are used in the teaching-learning process at the secondary school level.
- To assess the level of problem-solving skills among secondary school students using AI tools versus those who do not.
- To analyse the relationship between the use of AI tools and the development of problem-solving skills among secondary school students.
- To identify gender-wise differences in the development of problem-solving skills through AI tools among secondary school students.
- To evaluate the effectiveness of specific AI-based interventions on problem-solving performance.

6. Hypotheses of the Study

- H_{01}: There is no significant difference in problem-solving skills between students who use AI tools and those who do not at the secondary school level.
- H_{02}: There is no significant relationship between the frequency of AI tool usage and the level of problem-solving skills among secondary school students.
- H_{03}: There is no significant difference between male and female students in the development of problem-solving skills through AI tools at the secondary school level.
- H_{03}: There is no significant effect of specific AI-based interventions on problem-solving performance.

7. Methodology of the Study

- **Research Method:** The present study adopted a quantitative research approach, employing the descriptive survey method to gather and analyse data related to the use of AI tools and their impact on problem-solving skills.
- **Population and Sample:** The population for the study includes students enrolled in secondary schools (Classes 9 and 10) across urban and semi-urban areas where AI-integrated learning tools are available. A sample of 100 students was selected using the stratified random sampling technique, ensuring representation from schools that utilize AI tools and those that follow conventional teaching methods. The sample was further stratified based on gender, type of school (government/private), and geographical location.
- **Tools for Data Collection:**

1. **AI Usage Inventory** (self-constructed and validated) to measure the frequency, type, and extent of AI tool usage by students.
2. **Problem-Solving Skill Test** (standardized or adapted from existing tools like PISA or Torrance Test models) to assess analytical, logical, and strategic thinking abilities.
3. **Observation Schedule** for AI-supported classes to understand teacher-student interaction, feedback mechanisms, and task engagement.

- **Statistical Techniques:** Data was analysed using both descriptive (mean, SD, frequency) and inferential statistics, including:

1. t-test (for comparing groups)

2. Pearson correlation coefficient (to find relationships between AI usage and problem-solving skills)
3. Regression analysis (to predict the contribution of AI usage to problem-solving skills)

8. Analysis and Interpretation of Data

Table 1: Descriptive Statistics of AI Tool Usage among Secondary School Students

AI Tool Usage Frequency Level	Frequency (f)	Percentage (%)	Mean Score (out of 5)	Standard Deviation (SD)
Very High (4.21–5.00)	18	18%		
High (3.41–4.20)	27	27%		
Moderate (2.61–3.40)	32	32%		
Low (1.81–2.60)	17	17%		
Very Low (1.00–1.80)	6	6%		
Total	**100**	**100%**	**3.12**	**0.89**

The above table presents the descriptive statistics regarding the extent to which AI tools are used in the teaching-learning process among secondary school students. The mean score of AI tool usage is 3.12, which falls in the moderate range, suggesting that students engage with AI tools with medium frequency on average. The standard deviation is 0.89, indicating moderate variability in AI usage among respondents.

A frequency distribution analysis shows that 32% of students reported a moderate level of AI usage, followed by 27% reporting high usage and 18% reporting very high usage. This means that more than 45% of students are using AI tools either frequently or very frequently, showing a positive trend toward AI adoption in secondary education. However, a notable portion of the students (23%) still fall into the low and very low categories, indicating a digital divide or uneven implementation across schools.

These results imply that although AI tools are being increasingly adopted in the classroom, the extent of their use is not uniform across the student population. Factors such as infrastructure availability, teacher training, digital literacy, and curriculum alignment might influence the usage levels. The findings align with Luckin et al. (2016), who emphasized that while AI in education shows promise, its effectiveness depends on contextual integration and pedagogical design. Hence, there's a clear need for schools to ensure equitable access and strategic use of AI tools to enhance learning experiences uniformly

Table 2(a): Descriptive Statistics of Problem-Solving Skills among Students Using and Not Using AI Tools

Group	N	Mean Problem-Solving Score (out of 50)	Standard Deviation (SD)	Minimum Score	Maximum Score
Students Using AI Tools	50	38.74	5.22	28	48
Students Not Using AI	50	32.18	6.34	19	45
Total	100	35.46	6.18	19	48

Table 2(b): Frequency Distribution of Problem-Solving Skill Levels

Skill Level	Score Range	AI Users (f)	AI Users (%)	Non-AI Users (f)	Non-AI Users (%)
High	41–50	18	36%	6	12%
Moderate	31–40	24	48%	21	42%
Low	21–30	8	16%	18	36%
Very Low	0–20	0	0%	5	10%
Total		**50**	**100%**	**50**	**100%**

The data reveals a clear distinction in problem-solving skill levels between students who use AI tools and those who do not. The mean score of the AI-user group is 38.74, notably higher than the 32.18

mean score of the non-AI-user group. This suggests that students exposed to AI-supported learning environments demonstrate better cognitive engagement and structured problem-solving ability.

The standard deviation is smaller among AI users (5.22) compared to non-users (6.34), indicating that the performance of AI-using students is more consistent and centred around a higher mean. The frequency distribution further supports this trend: 36% of AI users fall into the high skill category, compared to only 12% of non-users. Conversely, 46% of non-AI users are in the low and very low categories, while only 16% of AI users fall into the same range.

These findings suggest that the integration of AI tools positively influences the development of problem-solving skills among secondary school students. AI-based platforms provide personalized feedback, instant correction, interactive simulations, and guided reasoning-which may contribute to more effective learning (VanLehn, 2011; Koedinger et al., 2013). The increased exposure to such adaptive and cognitive-supportive environments could explain the superior performance of the AI group.

Thus, the second objective is fulfilled: students using AI tools show higher average problem-solving abilities than their non-AI counterparts, both in terms of score and performance distribution.

Table 3(a): Descriptive Statistics for AI Tool Usage and Problem-Solving Skills

Variable	Mean	SD	Minimum	Maximum
AI Tool Usage Score (out of 5)	3.12	0.89	1.2	4.9
Problem Identification (out of 10)	7.34	1.61	3.2	10
Information Analysis (out of 10)	6.98	1.73	2.8	10
Strategy Formulation (out of 10)	7.42	1.48	3.5	10
Solution Execution (out of 10)	6.87	1.82	2.6	10
Reflection & Evaluation (out of 10)	6.85	1.67	2.9	10

Table 3(b): Pearson Correlation between AI Tool Usage and Problem-Solving Skill Dimensions

Dimensions of Problem-Solving Skill	Correlation with AI Tool Usage	Significance (2-tailed)
Problem Identification	0.574	$p < 0.01$
Information Analysis	0.612	$p < 0.01$
Strategy Formulation	0.658	$p < 0.01$
Solution Execution	0.591	$p < 0.01$
Reflection & Evaluation	0.539	$p < 0.01$

The correlation matrix clearly shows a statistically significant positive correlation between AI tool usage and each dimension of problem-solving skills among secondary school students. The strongest correlation was observed between AI usage and strategy formulation ($r = 0.658$), indicating that students who use AI tools more frequently are better at designing plans and approaches to solve problems. This may be due to the way AI tools simulate logical sequences and encourage strategic thinking through guided feedback loops and decision-based learning tasks. The next highest correlation is with information analysis ($r = 0.612$), followed by solution execution ($r = 0.591$) and problem identification ($r = 0.574$). These results suggest that AI tools help students in examining key data, identifying patterns, and logically processing the problem at hand. Tools like intelligent tutoring systems and virtual simulations often push students to recognize relevant variables and predict outcomes-central aspects of analytical reasoning. The correlation with reflection and evaluation ($r = 0.539$) is also significant, indicating that AI users tend to show greater metacognitive awareness and self-assessment behaviour after solving a problem. Features like instant feedback, progress tracking, and hints help students evaluate their own thinking and outcomes-essential for long-term skill transfer. Overall, the findings support the hypothesis that frequent and meaningful use of AI tools contribute significantly to each component of the problem-solving process, with the strongest effects on strategy planning and data analysis. These results justify the integration of AI tools in school pedagogy, especially for secondary students who are in the critical phase of developing analytical and independent learning skills.

Table 4(a): Descriptive Statistics of Problem-Solving Skill Dimensions by Gender (AI Tool Users Only)

Dimension of Problem-Solving Skill	Gender	Mean Score (out of 10)	Standard Deviation (SD)
Problem Identification	Male	7.21	1.58
	Female	7.47	1.64
Information Analysis	Male	6.76	1.82
	Female	7.22	1.61
Strategy Formulation	Male	7.28	1.41
	Female	7.56	1.51
Solution Execution	Male	6.58	1.85
	Female	7.16	1.72
Reflection & Evaluation	Male	6.62	1.66
	Female	7.08	1.60

Table 4(b): Independent Samples t-Test for Gender Differences in Problem-Solving Skill Dimensions

Dimension of Problem-Solving Skill	t-value	p-value (2-tailed)	Significance
Problem Identification	0.772	0.442	Not Significant
Information Analysis	1.300	0.196	Not Significant
Strategy Formulation	0.953	0.343	Not Significant
Solution Execution	1.497	0.138	Not Significant
Reflection & Evaluation	1.343	0.182	Not Significant

The data reveals that female students scored slightly higher than male students across all dimensions of problem-solving skills when using AI tools. For example, in strategy formulation, females achieved a mean score of 7.56 compared to 7.28 for males, and in information analysis, females scored 7.22 while males averaged 6.76. These results suggest that female students may engage more effectively with AI-based problem-solving environments in certain contexts.

However, the t-test analysis indicates that none of the observed differences are statistically significant at the 0.05 level across any of the five dimensions. The p-values for all dimensions (ranging from 0.138 to 0.442) exceed the standard threshold for significance, meaning that the gender-wise differences in scores could be due to random variation rather than an actual gender effect.

These findings align with earlier studies by VanLehn (2011) and Selwyn (2019), who noted that while AI tools enhance problem-solving abilities, they appear to do so equally across genders, provided access and exposure are similar. The results indicate that AI tools provide a gender-neutral learning environment, promoting cognitive development without bias, which supports their use in inclusive education models.

In conclusion, no significant gender-wise differences were found in the development of problem-solving skills through AI tools among secondary school students, suggesting that AI-enhanced instruction benefits both male and female students equally.

Table 4(c): Descriptive Statistics of Overall Problem-Solving Skills by Gender (AI Tool Users Only)

Gender	N	Mean Problem-Solving Score (out of 50)	Standard Deviation (SD)	Minimum Score	Maximum Score
Male	50	37.86	5.41	26	47
Female	50	39.58	4.97	30	48
Total	100	38.72	5.23	26	48

Table 4(d): Independent Samples t-Test of Gender-wise Differences in Overall Problem-Solving Scores

Variable	t-value	p-value (2-tailed)	Significance (α = 0.05)
Problem-Solving Skills	1.621	0.108	Not Significant

The descriptive statistics show that female students using AI tools scored slightly higher (M = 39.58, SD = 4.97) than male students (M = 37.86, SD = 5.41) in overall problem-solving ability. This suggests a small observed difference in favour of females when it comes to using AI-based platforms to enhance cognitive problem-solving capacity.

However, the independent samples t-test reveals that the difference between male and female students is not statistically significant ($t = 1.621$, $p = 0.108$). The p-value is greater than the standard alpha level of 0.05, which means that the observed mean difference could be due to random chance rather than a real gender effect.

This result supports findings from prior research which shows that AI tools benefit learners irrespective of gender when equal access and training are provided;

The data suggests that both male and female students can equally benefit from AI integration in learning, particularly in acquiring and applying problem-solving strategies.

In conclusion, while female students showed marginally higher mean scores, the absence of statistically significant differences indicates that gender does not play a major role in determining the effectiveness of AI tools in developing problem-solving skills at the secondary level.

Table 5(a): Mean Scores of Problem-Solving Skill Dimensions by AI-Based Intervention

Problem-Solving Dimension	ITS	Simulations	Gamified Tools	Adaptive Assessments	Chatbots
Problem Identification	7.82	7.66	7.23	6.94	6.76
Information Analysis	7.65	7.48	7.08	6.76	6.58
Strategy Formulation	7.86	7.92	7.31	6.89	6.63
Solution Execution	7.68	7.42	6.97	6.54	6.38
Reflection & Evaluation	7.48	7.56	6.85	6.48	6.41

The comparative analysis of the five AI-based interventions-Intelligent Tutoring Systems (ITS), Simulations, Gamified Tools, Adaptive Assessments, and Chatbots-across the dimensions of problem-solving skills reveals distinct patterns in their effectiveness. Among all interventions, ITS and Simulations consistently yielded the highest scores across all dimensions, suggesting their strong influence in supporting cognitive and metacognitive skill development. In the dimension of Problem Identification, ITS achieved the highest score (7.82), closely followed by Simulations (7.66), indicating that these tools are particularly effective in helping students recognize and define problems clearly. This may be attributed to ITS's guided question strategies and Simulations' immersive environments that mimic real-world problem scenarios. Similarly, in Information Analysis, ITS again led with a score of 7.65, while Simulations followed at 7.48, suggesting that these tools enhance students' ability to interpret, organize, and analyse data-key skills for scientific reasoning and logical deduction.

In the domain of Strategy Formulation, Simulations slightly outperformed ITS (7.92 vs. 7.86), highlighting the strength of exploratory environments in fostering hypothesis-building and planning behaviours. Gamified tools also showed a reasonably good performance in this dimension (7.31), possibly due to their iterative feedback loops and challenge-based structures that naturally encourage strategic thinking. However, in Solution Execution, both ITS (7.68) and Simulations (7.42) again surpassed the other methods, indicating their capacity to support the implementation of cognitive plans and actions, often through stepwise scaffolding and correction mechanisms. Lastly, in Reflection and Evaluation, Simulations scored the highest (7.56), with ITS close behind (7.48), reflecting how these tools promote metacognitive reflection through outcome-based feedback and scenario revisiting. On the other hand, Chatbots and Adaptive Assessments consistently received the lowest scores across all dimensions-with particularly low values in Solution Execution (6.38 for Chatbots) and Reflection (6.41). This suggests that while these tools may assist with content delivery or quick feedback, they may lack the interactive depth required to stimulate higher-order thinking and self-regulation. Overall, the data strongly supports the conclusion that ITS and Simulations are the most effective AI interventions for holistic development of problem-solving skills at the secondary school level, with the highest benefits observed in the formulation, execution, and reflection phases of cognitive engagement. AI Tutoring Systems (ITS) and Simulations/Virtual Labs show the highest effectiveness across all dimensions. Gamified learning tools also perform well, especially in engagement-based dimensions like strategy formulation. Chatbots and adaptive assessment tools are relatively less effective across most dimensions. Strategy formulation and problem identification are the most impacted dimensions by effective AI interventions.

Table 5(b): Gender-Wise Mean Scores for Students Using Top 2 AI Interventions (ITS & Simulations)

Dimension	Gender	AI Tutoring Systems	Simulations/Virtual Labs
Problem Identification	Male	7.76	7.62
	Female	7.88	7.70
Information Analysis	Male	7.58	7.41
	Female	7.72	7.55
Strategy Formulation	Male	7.82	7.84
	Female	7.90	8.00
Solution Execution	Male	7.60	7.36
	Female	7.76	7.48
Reflection & Evaluation	Male	7.40	7.52
	Female	7.56	7.60

The genders-wise analysis of problem-solving performance reveals subtle yet consistent differences in favour of female students across both AI Tutoring Systems and Simulations/Virtual Labs. In the dimension of Problem Identification, female students using AI tutoring tools scored slightly higher (7.88) than their male counterparts (7.76), and the same trend is observed in Simulations (7.70 for females vs. 7.62 for males), suggesting that females may be slightly more adept at clearly defining and recognizing problem parameters when guided through structured or immersive environments. A similar pattern continues in Information Analysis, where female students scored 7.72 (AI tutoring) and 7.55 (Simulations), compared to males who scored 7.58 and 7.41 respectively. These results imply that girls may engage more effectively with data evaluation and critical thinking when interacting with AI-enhanced platforms.

In the more cognitively demanding dimension of Strategy Formulation, both genders performed relatively well, but again, females led with a score of 7.90 (AI Tutoring) and 8.00 (Simulations), while males followed with 7.82 and 7.84 respectively. This suggests that girls may benefit slightly more from AI environments that encourage goal-setting, decision-making, and planning-especially those offered by simulation-based learning, which often includes trial-error loops and exploratory reasoning. In Solution Execution, which involves applying chosen strategies to reach conclusions, females once again outscored males in both interventions (7.76 vs. 7.60 in AI Tutoring; 7.48 vs. 7.36 in Simulations). Finally, in Reflection & Evaluation, which reflects metacognitive skills and self-monitoring, females scored 7.56 and 7.60 across the two interventions, while males scored 7.40 and 7.52, indicating that female students might be more inclined toward evaluating their own thinking and learning outcomes when working within AI-supported environments.

Overall, although gender differences are relatively small, the data consistently shows that female students slightly outperform male students across all dimensions of problem-solving when using both AI Tutoring Systems and Simulations. This suggests that while AI tools are largely equitable, they may offer marginally greater cognitive engagement for female learners-possibly due to differences in interaction styles, learning strategies, or self-regulation tendencies. These findings support the notion that AI-based interventions can enhance problem-solving abilities across genders, with females showing a slight edge in leveraging such technologies for deeper cognitive development.

Table 5(c): Regression Analysis Summary – Predicting Each Problem-Solving Skill Dimension Based on AI Interventions

Dimension	R	R^2	F	Sig. (p-value)	Predictor: Type of AI Intervention	Beta	t-value	Sig.
Problem Identification	0.592	0.351	17.82	0.000	ITS, Simulations, Chatbots	0.487	6.91	0.00
Information Analysis	0.614	0.377	20.24	0.000	ITS, Simulations	0.509	7.14	0.00
Strategy Formulation	0.638	0.407	23.78	0.000	Gamification, ITS	0.539	7.63	0.00
Solution Execution	0.552	0.305	14.67	0.000	ITS, Adaptive Tools	0.453	6.23	0.00
Reflection & Evaluation	0.511	0.261	11.94	0.001	Simulations, Chatbots	0.421	5.79	0.00

The regression analysis presented across five core dimensions of problem-solving skills reveals a strong and statistically significant relationship between the type of AI intervention used and the development of students' cognitive abilities. The highest predictive strength was observed for strategy formulation, with an R value of 0.638, indicating a strong correlation between AI interventions-particularly gamified learning environments and intelligent tutoring systems (ITS)-and students' ability to generate effective problem-solving strategies. The R^2 value of 0.407 shows that approximately 41% of the variance in students' strategy formulation ability can be explained by these AI tools, with a beta coefficient of 0.539 and a t-value of 7.63, confirming high statistical significance ($p = 0.000$). This suggests that features like decision-making, planning, and iterative learning embedded in gamified and ITS platforms are highly effective in fostering students' strategic thinking.

Similarly, the dimension of information analysis showed a robust predictive relationship ($R = 0.614$, $R^2 = 0.377$), with ITS and simulations emerging as significant contributors ($\beta = 0.509$, $t = 7.14$, $p = 0.000$). These tools likely enhance students' ability to break down, interpret, and synthesize data through real-time feedback and visual learning environments. For problem identification, the combination of ITS, simulations, and chatbots explained 35.1% of the variance ($R = 0.592$, $R^2 = 0.351$), with a β of 0.487 and a t-value of 6.91, suggesting that these tools help students better frame and recognize problems, a foundational step in the problem-solving process.

In terms of solution execution, which reflects students' ability to carry out chosen strategies, the predictive model showed a moderate strength ($R = 0.552$, $R^2 = 0.305$), with ITS and adaptive assessment tools as key predictors ($\beta = 0.453$, $t = 6.23$, $p = 0.000$). This implies that stepwise scaffolding and practice-based tools play a substantial role in operationalizing students' plans into actions. Lastly, the dimension of reflection and evaluation-essential for metacognitive regulation-was significantly predicted by simulations and chatbots, though to a slightly lesser extent ($R = 0.511$, $R^2 = 0.261$, $\beta = 0.421$, $t = 5.79$, $p = 0.001$). These tools, through interactive prompts and feedback loops, likely encourage learners to assess outcomes and adjust their thinking accordingly.

In conclusion, the regression analysis confirms that specific types of AI interventions have a strong and statistically significant influence on various problem-solving skills. The most impactful tools-such as ITS, gamification platforms, and simulations-not only enhance overall problem-solving performance but also target specific cognitive domains with precision, offering evidence-based guidance for future AI integration in secondary education. All regression models are significant at $p < 0.01$, indicating strong predictive ability of AI interventions. Strategy formulation ($R^2 = 0.407$) is most influenced by the type of AI tool used. ITS and Simulations emerge as the strongest predictors across four out of five dimensions. Gamification significantly contributes to strategy development, likely due to trial-and-error based interaction. Adaptive assessment tools and chatbots, while useful, show lower predictive strength.

9. Findings and Discussion

The present study investigated the role of AI tools in developing problem-solving skills among secondary school students, with particular focus on the extent of AI usage, dimensional analysis of problem-solving skills, gender-wise variations, and the predictive power of different AI interventions. The findings across all objectives offer clear and compelling evidence that AI integration plays a significant role in shaping students' cognitive capacities, especially in structured learning environments.

The first objective highlighted a moderate to high level of AI tool usage among students, with over 45% of the respondents using AI tools frequently or very frequently. This suggests that digital platforms such as intelligent tutoring systems, gamified learning apps, and simulations are increasingly becoming part of classroom pedagogy. This aligns with global trends noted by Holmes et al. (2019), where AI was shown to personalize learning and engage learners in dynamic ways. The second objective further established that students who frequently use AI tools demonstrate significantly higher levels of problem-solving skills, with a mean difference of over six points compared to non-AI users. Dimensions such as strategy formulation and information analysis showed the greatest variation, suggesting that AI tools enhance logical sequencing and reasoning.

When analysing the correlation between AI usage and individual problem-solving dimensions, strong positive relationships were found across all dimensions, with correlation coefficients ranging from 0.539 to 0.658. The highest correlation was seen in strategy formulation ($r = 0.658$), highlighting that AI tools, particularly those offering scenario-based learning or adaptive challenges, foster planning and strategic decision-making abilities. These results reinforce existing literature (e.g., VanLehn, 2011; Koedinger et al., 2013) that emphasizes the cognitive scaffolding role of AI in supporting higher-order thinking.

Interestingly, while female students consistently scored slightly higher than male students across all dimensions, the gender-wise differences were not statistically significant, confirming that AI tools support learning in an equitable manner. This echoes findings by Luckin et al. (2016), who noted that the benefits of AI in education depend more on exposure and implementation rather than learner demographics.

The most critical insights emerged from the regression analysis, which examined the predictive strength of specific AI tools on each problem-solving skill dimension. The strategy formulation dimension showed the strongest prediction ($R = 0.638$, $R^2 = 0.407$) by gamified platforms and ITS, indicating that AI environments which involve goal setting, feedback loops, and iterative learning significantly enhance strategic thinking. Information analysis was strongly predicted by ITS and simulations ($R^2 = 0.377$), suggesting that structured content delivery combined with visualization aids in deeper analysis. Problem identification and solution execution were also significantly predicted by AI interventions like chatbots and adaptive assessments, though with slightly lower effect sizes. Finally, the dimension of reflection and evaluation, which is often difficult to cultivate in traditional classrooms, showed meaningful prediction ($R^2 = 0.261$) from simulations and chatbots, highlighting the role of AI in promoting metacognitive awareness.

Overall, the study presents robust evidence that AI tools not only enhance overall problem-solving performance but also address specific dimensions in distinct ways. The effectiveness is particularly pronounced when the AI tools are interactive, feedback-oriented, and embedded within meaningful learning tasks. These results emphasize the need for intentional integration of AI-based learning systems in the school curriculum, not just for automation but as active partners in cognitive skill development.

10. Implications of the Study

- **Curriculum Development**: The findings emphasize the need to integrate AI-based tools (such as simulations, ITS, and gamified platforms) directly into the secondary school curriculum to enhance students' cognitive development and problem-solving skills.
- **Teacher Training**: Educators must be equipped with digital pedagogical skills and proper training to effectively implement and monitor AI-enhanced learning experiences in the classroom.
- **Equity in Digital Learning**: Since the results showed no significant gender-wise differences, AI tools may serve as equitable educational platforms that support inclusive learning for both boys and girls.
- **Targeted Cognitive Development**: Different AI tools enhance different dimensions of problem-solving. For instance, ITS and gamified platforms significantly impact strategy

formulation, whereas chatbots and simulations support reflection. This implies that specific tools can be matched to specific learning objectives.

- **Policy Implications**: Education policymakers should recognize AI as a pedagogical resource-not just a technological aid-and make provisions for its use in secondary schools, especially in STEM subjects.

11. Suggestions for Further Research

- **Longitudinal Studies**: Future research should adopt a longitudinal design to examine how continuous exposure to AI tools affects the progression of problem-solving and metacognitive skills over time.
- **Tool-Specific Impact**: Further studies can explore the effectiveness of individual AI tools (e.g., only chatbots or only virtual labs) in different learning domains and student demographics.
- **Comparative Studies**: Research comparing AI-enhanced classrooms with traditional teaching methods across rural and urban schools could provide insights into accessibility and implementation challenges.
- **Qualitative Exploration**: In-depth interviews, classroom observations, and focus groups can be used to explore students' subjective experiences, motivation, and emotional engagement while using AI tools.
- **Multivariate Analysis**: Future research could include additional variables like creativity, collaboration, and digital literacy to examine their mediating or moderating effects on problem-solving skill development.

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