



AI-Driven Tools for Enhancing Cognitive Apprenticeship among Secondary School Students

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ABSTRACT

The advent of digital technologies, particularly artificial intelligence (AI), has opened new possibilities for enhancing cognitive apprenticeship. AI-driven tools can provide personalised learning experiences with real-time feedback and adaptive learning pathways, increasing learner engagement and facilitating deeper understanding. **Purpose-** The primary purpose of this study is to investigate how AI-driven tools can enhance cognitive apprenticeship in secondary education. **Methodology:** The research collected data from different online sources, such as Google Scholar and Research Gate, as secondary data for thematic review analysis. (Document analysis) **Results:** This study found new insights about AI-driven tools for enhancing cognitive apprenticeship in school education. By doing literature reviews, the research found new tools that assist in school education. **Conclusion:** This paper has underscored the importance of reimagining school education through the lens of AI-driven tools for Enhancing Cognitive Apprenticeship, such as learning management systems (LMS), AI tutors, and virtual simulations etc.

1. INTRODUCTION



In the evolving landscape of education, traditional teaching methodologies are continually being reassessed to meet the dynamic needs of learners. The cognitive apprenticeship model, which emphasises learning through guided experiences, has been instrumental in bridging the gap between theoretical knowledge and practical application. With the advent of Artificial Intelligence (AI), there is a burgeoning opportunity to enhance this model, making learning more personalised, engaging, and effective. The educational landscape continually evolves, with traditional teaching methods giving way to more interactive and student-centred approaches. One such approach is cognitive apprenticeship, which involves learning through guided experiences and social interactions, akin to traditional apprenticeships but focused on cognitive skills in the context of secondary education, cognitive apprenticeship has been instrumental in developing critical thinking, problem-solving, and metacognitive skills among students. (Collins, Brown, & Holum, 1991). Cognitive apprenticeship is an instructional framework that extends the traditional apprenticeship model into cognitive domains. It emphasises making thinking processes visible to learners. According to Collins, Brown, and Holum (1991), cognitive apprenticeship involves expert demonstration, guided practice, and gradual release of responsibility until the learner becomes independent. The model comprises six key phases: modelling, coaching, scaffolding, articulation, reflection, and exploration, all of which support the development of higher-order cognitive skills. The advent of Artificial Intelligence (AI) presents new opportunities to enhance and scale the cognitive apprenticeship model. AI-driven educational tools—such as intelligent tutoring systems, adaptive learning platforms, chatbots, virtual simulations, gamified environments, and automated feedback systems—analyse learner data to predict needs and personalise instruction. By offering real-time feedback, adjusting difficulty levels, and creating immersive learning experiences, AI increases engagement and supports differentiated instruction. The convergence of AI and cognitive apprenticeship has the potential to transform learning environments by making expert thinking more accessible, supporting guided practice at scale, and enabling students to develop higher-order cognitive skills with greater efficiency and autonomy.

1.1.1 Purpose of the Study

The primary purpose of this study is to investigate how AI-driven tools can enhance the cognitive apprenticeship model in secondary education. This study is significant as it bridges traditional and digital learning by demonstrating how digital tools can modernise social science instruction while maintaining inquiry-based depth. It explores how interactive technologies enhance student engagement, motivation, and understanding of complex social issues. Additionally, it supports educators by providing insights into effectively integrating digital tools to strengthen cognitive apprenticeship strategies. Lastly, it contributes



to policy and practice by offering best practices and recommendations for schools, policymakers, and curriculum developers to enhance digital integration in social science education.

1.2. OBJECTIVES

1. Identify suitable AI-driven tools to enhance cognitive apprenticeship
2. Highlighting the importance of AI-driven tools in school education
3. Identify potential challenges in implementing AI-driven tools

1.3. Methodology: -

The data for the present study were collected using a normative survey method supported by qualitative document analysis. Secondary data were sourced from peer-reviewed journals, academic reports, and credible online databases. The normative survey approach guided the systematic review, organisation, and thematic categorisation of existing literature. The analysis involved identifying patterns, examining AI-integrated educational tools, and evaluating their alignment with cognitive apprenticeship principles. Through synthesising key findings, the study provides a coherent understanding of how Artificial Intelligence supports modelling, coaching, scaffolding, and other core elements of cognitive apprenticeship in contemporary educational contexts.

2. THE IMPORTANCE OF COGNITIVE APPRENTICESHIP IN SCHOOL EDUCATION

Cognitive apprenticeship is grounded in the idea that learning is most effective when it occurs in context and through social interaction. This model emphasizes the processes involved in carrying out tasks and solving problems, making thinking visible to learners (**Collins et al., 1991**). In secondary education, cognitive apprenticeship is crucial for several reasons:

1. **Development of Higher-Order Thinking Skills:** By engaging in authentic tasks under the guidance of experts, students develop critical thinking and problem-solving skills.
2. **Transfer of Knowledge:** Learning in context allows students to apply knowledge and skills across different situations, enhancing the transferability of learning.
3. **Metacognitive Awareness:** Through reflection and discussion, students become aware of their own thinking processes, enabling them to regulate their learning strategies effectively.
4. **Social Interaction:** Collaborative learning environments foster communication skills and the ability to work effectively with others.

3. FACTORS ENHANCING COGNITIVE APPRENTICESHIP



Cognitive apprenticeship becomes most effective when certain instructional and environmental factors work together to support learner growth. One of the key factors is the use of authentic tasks, which immerse students in real-world situations that mirror professional practice. These tasks motivate learners by showing the relevance of what they study. Another essential factor is expert modelling, where teachers or skilled peers demonstrate the cognitive processes behind problem-solving, making invisible thinking visible. Scaffolding also plays a vital role, as it provides structured support that gradually fades as students develop competence. Through timely guidance, prompts, and cues, learners become capable of completing tasks independently. Equally important is reflection, which allows students to examine their performance, compare their strategies with those of experts, and refine their thinking. Articulation further supports learning by encouraging students to express their reasoning, justify their ideas, and engage in meaningful dialogue. Finally, exploration empowers learners to apply skills in new contexts, fostering independence, creativity, and adaptability. Together, these factors create a holistic learning environment that nurtures higher-order thinking, problem-solving, and self-regulated learning skills essential for academic success and future workplace readiness. Several factors can enhance the effectiveness of cognitive apprenticeship in secondary education, which are discussed below:

1. **Authentic Tasks:** Engaging students in real-world problems that are relevant to their lives increases motivation and the applicability of skills learned.
2. **Expert Modeling:** Demonstrations by teachers or advanced peers provide students with clear examples of how to approach tasks and solve problems.
3. **Scaffolding:** Providing support structures helps students perform tasks they cannot complete independently, with gradual removal of support as competence increases.
4. **Reflection:** Encouraging students to think about their learning processes and outcomes promotes deeper understanding and self-regulation.
5. **Exploration:** Allowing students to apply their knowledge in new situations fosters innovation and adaptability.

4. LEARNER ENGAGEMENT IN THE DIGITAL ERA

The digital era has transformed how students engage with learning materials and processes. Today's learners are accustomed to interactive and multimedia-rich environments, which traditional teaching methods may not fully address. Key aspects of learner engagement in the digital age include:

1. **Interactivity:** Digital tools that allow manipulation of content and active participation can increase engagement (Deterding et al., 2011; Gee, 2003).



2. **Multimodal Learning:** Incorporating text, audio, video, and interactive simulations caters to diverse learning preferences and can enhance understanding (Mayer, 2009; Moreno & Mayer, 2010).
3. **Immediate Feedback:** Digital platforms can provide instant feedback, helping students correct errors and understand concepts in real-time (Shute, 2008).
4. **Gamification:** Applying game design elements in learning environments can motivate students through rewards, challenges, and a sense of achievement (Anderson & Reder, 2020; Anderson et al., 2019).
5. **Social Connectivity:** Online forums and collaborative tools enable students to connect, discuss, and learn from peers, fostering a sense of community (Greenhow & Lewin, 2016; Siemens, 2005).

5. HOW AI TOOLS SUPPORT COGNITIVE APPRENTICESHIP: -

Artificial Intelligence tools play a transformative role in strengthening the phases of cognitive apprenticeship—modelling, coaching, scaffolding, articulation, reflection, and exploration. AI-powered tutoring systems such as Khan Academy, Socratic by Google, and Querium provide adaptive coaching, real-time feedback, and personalised learning pathways, allowing students to observe expert problem-solving and practice skills at their own pace. AI-enhanced LMS platforms like Google Classroom, Moodle, and Canvas extend these benefits by using automated grading, personalised recommendations, and intelligent tutoring features that support continuous scaffolding and guided practice. AI chatbots and virtual assistants such as IBM Watson Tutor, ChatGPT, and Google Bard enhance articulation and coaching by offering instant explanations, answering complex questions, and guiding learners through difficult concepts. Meanwhile, AI-driven VR tools and simulations—including Google Expeditions and Mission US—create immersive environments that promote exploration, experiential learning, and reflective thinking. Collaborative tools powered by AI, such as Microsoft Teams Insights, Padlet suggestions, and Flipgrid speech analytics, further support peer interaction and constructive feedback. Finally, AI tools for research and writing, such as Elicit, Scite, Grammarly, and QuillBot, help students articulate ideas clearly, evaluate evidence, and improve academic writing. Collectively, these AI-driven tools enhance every stage of cognitive apprenticeship, fostering deeper understanding and independent learning.

1. **AI-Powered Tutoring Systems:** Khan Academy, Socratic by Google, Querium provide adaptive coaching, automated feedback, and personalised learning experiences for secondary students (Luckin et al., 2016).



2. **AI-Enhanced Learning Management Systems (LMS):** Google Classroom, Moodle, Canvas with AI integrations use AI for automated grading, personalised recommendations, and intelligent tutoring to support student learning (Nguyen, 2022).
3. **AI Chatbots & Virtual Assistants:** IBM Watson Tutor, ChatGPT, Google Bard assist secondary school students by answering questions, explaining concepts, and guiding research (Hwang et al., 2020).
4. **AI-Driven Virtual Reality (VR) & Simulations:** Google Expeditions, Mission US, and Classroom offer immersive experiences to enhance reflection, exploration, and deeper learning (Merchant et al., 2014).
5. **Collaborative AI-powered platforms:** Microsoft Teams (AI-powered insights), Padlet (AI suggestions), and Flipgrid (speech analysis) promote articulation, peer discussions, and intelligent feedback in classroom activities (Greenhow & Askari, 2017).
6. **AI-Powered Research & Writing Tools:** Elicit, Scite, Grammarly (AI-powered feedback), Quill Bot support secondary students in research, citation management, and academic writing (Crossley et al., 2021).

6. CHALLENGES OF IMPLEMENTING AI-DRIVEN TOOLS IN COGNITIVE APPRENTICESHIP: -

Despite the growing potential of Artificial Intelligence in enhancing cognitive apprenticeship, several challenges hinder its effective implementation in secondary education. One of the major concerns is technical limitations, as many schools—particularly in rural or underserved areas—lack reliable infrastructure such as high-speed internet, adequate bandwidth, and updated digital devices needed to run AI applications (Zawacki-Richter et al., 2019). Teacher preparedness poses another significant challenge, since educators often receive limited training on AI-based pedagogies, making it difficult for them to integrate AI tools into classroom practices confidently and effectively (Holmes et al., 2022). Additionally, concerns about data privacy and security remain prominent, as AI systems depend on large amounts of student data, raising issues related to consent, surveillance, and ethical data management (Williamson & Eynon, 2020). Equity issues further complicate implementation because access to AI technologies may be uneven, potentially widening disparities between students from different socioeconomic backgrounds (Luckin et al., 2016). Finally, ethical considerations such as algorithmic bias, fairness, and transparency must be addressed to avoid reinforcing stereotypes or inequities in the learning process (Hwang et al., 2020). Collectively, these challenges highlight the need for thoughtful



planning, policy support, and professional development to ensure responsible and equitable AI integration. Some challenges are mentioned below:-

1. **Technical Limitations:** Many schools may lack the necessary infrastructure, such as high-speed internet and modern hardware, to support AI applications (Zawacki-Richter et al., 2019).
2. **Teacher Preparedness:** Educators often do not receive sufficient training or professional development, making it difficult for them to effectively integrate AI tools into their teaching practices (Holmes et al., 2022).
3. **Data Privacy Concerns:** The use of AI in education involves collecting and analyzing student data, raising issues about data security, consent, and ethical data usage (Williamson & Eynon, 2020).
4. **Equity Issues:** AI-driven education could potentially widen the gap between students who have access to advanced technology and those who do not, exacerbating educational inequalities (Luckin et al., 2016).
5. **Ethical Considerations:** Ensuring that AI applications in education are used responsibly, do not reinforce biases, and promote fairness remains a significant challenge (Hwang et al., 2020).

7. RECOMMENDATION FOR OVERCOMING VARIOUS CHALLENGES: -

Addressing the challenges associated with implementing AI-driven tools in cognitive apprenticeship requires a comprehensive and strategic approach encompassing infrastructure, policy, pedagogy, and ethical considerations. The first essential step is infrastructure development, as the successful integration of AI depends heavily on reliable technological systems. Schools must invest in updated hardware, high-speed internet connectivity, and secure networks to ensure uninterrupted access to AI tools for both teachers and students (Zawacki-Richter et al., 2019). Governments and educational authorities should prioritise funding for digital infrastructure, particularly in rural and underserved regions, to reduce disparities and foster equitable learning environments. Alongside infrastructure, professional development is critical for empowering educators to effectively adopt AI technologies. Teachers need continuous training and capacity-building programs that familiarise them with AI functionalities, digital pedagogy, data interpretation, and ethical practices (Holmes et al., 2022). Professional development initiatives should combine hands-on workshops, peer mentoring, and ongoing technical support to build teachers' confidence and competence in integrating AI into cognitive apprenticeship frameworks. Another important recommendation is the implementation of robust data governance policies that regulate the collection, storage, and usage of student data. As AI systems rely on



extensive datasets, clear guidelines must be established to ensure privacy, transparency, and informed consent (Williamson & Eynon, 2020). Educational institutions should adopt secure data management protocols and collaborate with technology providers to ensure compliance with national and international data protection standards. Additionally, promoting inclusivity in AI-driven education is vital to ensure that all learners benefit from technological innovation. AI tools must be designed to accommodate diverse learning needs, including accessible interfaces for students with disabilities and adaptive features that support multicultural and multilingual populations (Luckin et al., 2016). Furthermore, policymakers should ensure equitable distribution of AI resources, subsidised devices for disadvantaged students, and inclusive curriculum frameworks that reflect varied learning contexts. Finally, establishing ethical frameworks is crucial for guiding the responsible use of AI in education. Ethical guidelines should emphasise fairness, transparency, and accountability, ensuring that AI systems do not reinforce existing biases or discriminate against particular groups (Hwang et al., 2020). Regular audits, bias-detection mechanisms, and impact assessments must be conducted to maintain ethical integrity in AI applications. Schools should also incorporate digital ethics education into their curriculum to help students understand how AI works and how their data is used. At a broader level, collaboration between educators, policymakers, technologists, and researchers is essential to develop national standards and certifications for AI tools used in schools.

- 1. Infrastructure Development:** Investing in upgrading technological infrastructure is essential to support AI applications, ensuring all students have access to necessary devices and internet connectivity (Zawacki-Richter et al., 2019).
- 2. Professional Development:** Providing comprehensive training programs for educators helps build competence and confidence in using AI tools effectively (Holmes et al., 2022).
- 3. Robust Data Policies:** Developing and enforcing strict data governance policies is crucial to protecting student information and maintaining trust in AI-powered education (Williamson & Eynon, 2020).
- 4. Promote Inclusivity:** Designing AI tools to be accessible to all students, including those with disabilities, and ensuring equitable distribution of technological resources fosters inclusivity in AI education (Luckin et al., 2016).
- 5. Ethical Frameworks:** Establishing clear guidelines for the ethical use of AI in education, including regular audits to detect and mitigate biases, is necessary to ensure fair and responsible AI integration (Hwang et al., 2020).

8. MAJOR FINDINGS: -



The analysis of existing literature and AI applications in secondary education reveals several key findings regarding the enhancement of cognitive apprenticeship through AI-driven tools. First, the study found that AI significantly strengthens core components of cognitive apprenticeship—modelling, coaching, scaffolding, articulation, reflection, and exploration—by providing personalised instruction and real-time adaptive feedback. Intelligent tutoring systems, AI-integrated LMS platforms, and virtual simulations effectively replicate expert guidance, making complex thinking processes visible and accessible for learners. This promotes deeper cognitive engagement and enhances higher-order skills such as problem-solving, reasoning, and metacognition. Second, AI tools were found to substantially improve learner engagement and motivation. Interactive digital environments, gamified platforms, and immersive VR simulations support authentic learning experiences that mirror real-world contexts, thereby increasing relevance and student interest. AI-powered analytics also help teachers monitor learner progress more accurately, enabling targeted support and differentiated instruction. Third, the study highlights a growing reliance on AI-based tools to support academic writing, research, and collaborative learning. Tools such as Grammarly, Scite, and Elicit assist students in structuring arguments, locating credible sources, and refining writing quality, thereby strengthening the articulation and reflection phases of cognitive apprenticeship. However, the findings also identify critical barriers, including disparities in technological access, lack of teacher preparedness, and ethical concerns involving data privacy and algorithmic bias. These challenges indicate the need for system-level reforms and comprehensive policy frameworks. Overall, the findings affirm that while AI has immense potential to enhance cognitive apprenticeship in secondary schools, thoughtful implementation supported by adequate infrastructure, teacher training, and ethical safeguards is essential to maximise its educational impact.

9. CONCLUSION: -

The integration of Artificial Intelligence into secondary education marks a transformative shift in how teaching and learning occur, particularly through the cognitive apprenticeship model. This study demonstrates that AI-driven tools provide powerful opportunities to enhance modelling, coaching, scaffolding, reflection, articulation, and exploration the foundational phases of cognitive apprenticeship. Through adaptive tutoring systems, AI-integrated learning management platforms, immersive virtual simulations, and intelligent feedback mechanisms, students are able to access personalised and context-rich learning experiences that were previously limited to traditional expert-novice interactions. A key conclusion of this study is that AI strengthens instructional effectiveness by making expert thinking visible and accessible. AI systems can diagnose misconceptions, provide instant corrective feedback, and



adjust learning pathways to meet individual needs. This level of adaptability not only promotes mastery learning but also supports the development of independent problem-solvers capable of applying skills across diverse contexts. The integration of conversational AI tools enables learners to articulate their reasoning more effectively, while VR and simulation-based tools deepen conceptual understanding through experiential learning. These improvements collectively highlight AI's capacity to modernise and enrich cognitive apprenticeship in secondary schools. However, the study also identifies significant challenges that must be addressed for AI to be implemented safely, ethically, and effectively. Issues such as inadequate technological infrastructure, the digital divide, teacher skill gaps, and concerns about data privacy pose real barriers to equitable adoption. Without strategic planning and investment, AI has the potential to widen existing educational inequalities rather than bridge them. Ethical concerns including algorithmic bias and lack of transparency further underscore the need for clear accountability mechanisms and responsible governance. Therefore, the successful integration of AI into cognitive apprenticeship requires a holistic approach. Policymakers must prioritise digital infrastructure and equitable access to technology. Teachers need continuous professional development to develop digital and AI literacy. Educational institutions must adopt robust data governance policies and ethical frameworks to ensure that AI tools are used responsibly. Collaborative efforts among educators, technology developers, researchers, and policymakers are essential to establish standards that safeguard fairness, transparency, and student well-being. In conclusion, AI-driven tools hold tremendous promise for transforming secondary education by strengthening the cognitive apprenticeship model. When supported by sound policies, ethical safeguards, and teacher readiness, AI has the potential to make learning more personalised, engaging, reflective, and effective. By combining the strengths of traditional pedagogy with the power of intelligent technologies, schools can create dynamic and future-ready learning environments that prepare students for the demands of the 21st century.

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