EDUCATIONAL SCIENCES: THEORY & PRACTICE eISSN: 2148-7561, ISSN: 2630-5984

Received: 12 August 2024
Revision received: 03 October 2024
Accepted: 07 November 2024

www.jestp.com

DOI 10.12738/jestp.2024.2.005 ♦ **June** 2024 ♦ 24(2) ♦ 76-87

Article

Effectiveness of Web-Based Cognitive Apprenticeship in Learning Classical Mechanics and Enhancing E-Learning Confidence in Physics Students in Iraq

Rasha Abdel Hussein Sahib Abdel Hassan
College of Basic Education, University of Misan, Iraq.
Email: rasha.a.sahib@uomisan.edu.iq
ORCID iD: https://orcid.org/0000-0003-1331-5290

Abstract

This study investigates the effectiveness of a web-based cognitive apprenticeship model in enhancing student learning of classical mechanics and their subsequent confidence in e-learning at the College of Basic Education in Iraq. Data were gathered from students through survey questionnaires, and Smart-PLS was employed to examine the relationships among the variables. The results indicate that the web-based cognitive apprenticeship model exerts a positive and significant influence on learning classical mechanics, which, in turn, is positively associated with confidence in e-learning. Furthermore, the analysis demonstrates that learning classical mechanics significantly mediates the relationship between the web-based cognitive apprenticeship and confidence in e-learning. The findings confirm that the web-based cognitive apprenticeship model serves as an effective pedagogical approach that fosters student–instructor interaction, promotes self-directed learning, and enhances academic achievement within digital learning environments.

Keywords

Web-Based Cognitive Apprenticeship, Learning Classical Mechanics, Confidence in E-Learning.

Correspondence to Rasha Abdel Hussein Sahib Abdel Hassan, College of Basic Education, University of Misan, Iraq.
Email: rasha.a.sahib@uomisan.edu.iq, ORCID iD: https://orcid.org/0000-0003-1331-5290

Citation: Hassan, R. A. H. S. A. (2024). Effectiveness of Web-Based Cognitive Apprenticeship in Learning Classical Mechanics and Enhancing E-Learning Confidence in Physics Students in Iraq. *Educational Sciences: Theory and Practice, 24*(2), 76 -87.
http://dx.doi.org/10.12738/jestp.2024.2.006

Introduction

The success of web-based e-learning is largely determined by the effectiveness of the educational models employed within it, as numerous instructional models are incorporated in web-based learning environments (Al-Kamzari & Alias, 2024). Among these is the behavioural model, which is structured around delivering educational content in an organised and cohesive manner, whereby the instructor presents and explains the material to learners. This model is primarily teacher-directed, leaving minimal opportunity for critical thinking and knowledge construction by learners. Another significant model is the constructivist model (Alyoussef, 2023), which posits that learners actively engage in constructing knowledge and generating meaning based on their personal experiences, rather than passively acquiring information. In this framework, knowledge is formed through the learner's own efforts rather than being transmitted directly by the teacher.

Furthermore, the social constructivist and cognitive model prioritizes the construction of knowledge in socially situated settings, encompassing individual learning tactics, learning through discovery, cooperative learning, project learning, and problem-solving methodologies (Hassan, 2024). Moreover, Ghosheh Wahbeh, Shweiki and Sartawi (2022) state that constructivist instructional design in e-learning is concerned with designing authentic learning environments with varied resources. It fosters social negotiation over learning outcomes, content, instructional tactics, measurements, as well as multiple perspectives exploration, ownership of the learning process by learners, promotion of metacognitive awareness, as well as introduction of cognitive dissonance for encouraging deep learning. Learners are empowered through authentic tasks for learning and constructivist tactics in formulating personal meanings, with cognitive apprenticeship being one such important instructional method (Li et al., 2024).

The cognitive apprenticeship approach, extensively utilized in web-based learning, is aimed at the cultivation of learners' metacognitive and cognitive abilities through socially supported interaction and problem-solving (Oludipe et al., 2023). It found root in the conventional system of teaching crafts and trades in the form of an apprentice system, whereby novices learned skills under observation of experienced practitioners. Conventional apprenticeships are geared towards the gradual enhancement of task-linked processes and psychomotor skills, as observed and enacted under the tutelage of experts. It entails extensive mentorship as well as experiential learning, making it possible for learning to take place through direct modelling as well as feedback (Ostovar-Namaghi, Morady Moghaddam, & Veysmorady, 2024). Inaugurating on the importance of the cognitive approach in educational settings within the virtual realm, as well as on the experience of over ten years of service in the College of Basic Education as lecturer in classical mechanics, the observed gap in students' metacognitive as well as practical capabilities has elicited the initiation of the present research study. In this research, the efficacy of utilizing the cognitive approach through the platform of the internet is tested in-order to enhance learning in classical mechanics as well as students' confidence in learning, among students at the College Basic Education Physics Department.

The central research question underpinning this investigation is as follows: To what extent is the cognitive apprenticeship model, when delivered through online platforms, effective in enhancing students' acquisition of knowledge in classical mechanics, and consequently, in improving their confidence in e-learning among physics majors at the College of Basic Education? Accordingly, the objectives of the study are threefold: (1) to assess the impact of the web-based cognitive apprenticeship model on students' comprehension and mastery of classical mechanics within the Physics Department at the College of Basic Education; (2) to determine the influence of learning classical mechanics on students' confidence in e-learning; and (3) to investigate the mediating role of classical mechanics learning in the relationship between the web-based cognitive apprenticeship model and students' confidence in e-learning.

The significance of this research lies in several key contributions. Firstly, it provides a systematic explanation of the potential and extent to which the web-based cognitive apprenticeship model can be employed as an effective approach to digital pedagogy in higher education. Through the integration of structured and interactive online learning, this research contributes to narrowing the gap between existing pedagogical practices and more effective methods of teaching classical mechanics—widely regarded as a challenging subject for students. Furthermore, the study highlights how cognitive apprenticeship can enhance students' confidence in e-learning, making them more adaptable to digital educational environments. The research supports the combination of digital learning technology with conventional teaching pedagogies for an approach that involves direct instruction with independent learning. Secondly, this research benefits faculty development because it promotes the use of innovative, student-focused teaching methodologies through interactive web-based instruction. In terms of policy, the study outcomes are likely to guide educational institutions on how to sharpen their web learning policies as well as create effective roadmaps for designing as well as implementing digital pedagogy for different departments of study. Lastly, in emphasizing the use of cognitive apprenticeship in an online learning environment, this research opens up future studies on models for e-learning that have the capacity for future pedagogical innovation as well as instructional practice.

Literature Review

Web-based cognitive apprenticeship is an important element in learning classical mechanics, mostly because it focuses on interactivity, organised learning, and guided mentoring between learners. Cognitive apprenticeship is an educational approach that involves modelling at the level of experts, scaffolding, reflection, and collaboration, all of which are necessary for learning problems like classical mechanics (Alwafi, 2023). This form of teaching is amplified in web environments through the provision of real-time feedback, personalised learning content, as well as interactive simulations, allowing learners to visualise as well as replicate basic physical phenomena like Newtonian movement, forces, as well as energies interaction. Empirical evidence, such as the study by De Bruin (2019), highlight that web-based cognitive apprenticeship allows students to take part in problem-solving activities with experts, giving them the benefit of receiving immediate feedback that deepens their conceptual mastery as well as evaluation skills. Since classical mechanics relies heavily on learning broad principles as well as applying principles in diverse settings, cognitive apprenticeship is most suited in web teaching. Khine (2024) points out that interactive simulations, virtual labs, as well as AI-powered tutoring systems are integral components in web learning, in effect bridging the gap between theoretical as well as practical knowledge.

In addition, studies affirm that cognitive apprenticeship in online learning supports learning in a self-regulated manner by allowing students to manage their learning at their own pace, review difficult content, and repeatedly work on problem-solving together with guided feedback. Another key benefit of online cognitive apprenticeship is its ability to facilitate collaborative learning (Delaney, 2023). Such collaborative learning is particularly beneficial in the teaching of physics, where misconceptions about basic principles are frequently addressed effectively through discussion and facilitation by experts. This approach has been successful in increasing students' learning engagement, enhancing comprehension, and ensuring long-term recall of abstract classical mechanics principles. Finally, web-based cognitive apprenticeship greatly improves students' capacity for reasoning flexibly as well as applying basic principles of classical mechanics via guided mentoring as well as interactive digital resources. Therefore, this research proposes that,

H1: Web-based cognitive apprenticeship has a significant impact on learning classical mechanics.

Classical mechanics has high positive compatibility with higher levels of e-learning confidence, as it focuses on conceptual knowledge, problem-solving, and flexibility. In spite of being an abstract and mathematical topic, making it a difficult area of study, research by Sidhu et al. (2024) reveal classical mechanics students having higher levels of confidence in learning via e-learning systems. Organized instruction strengthens mental processing, deepening knowledge, as well as familiarity with digital resources, simulations, and interactive tools. Digital studies promote independent learning as well as active interaction within web-based environments (Zheng & Xiao, 2024). Research shows mastery of Newtonian mechanics, motion, and energy principles enhances digital learning self-efficacy. Mechanics' problem-solving favors the use of digital tools, feedback, as well as multiple revisions. Atashinsadaf et al. (2024) further highlight that students skilled in mechanics experience reduced anxiety and greater resilience in e-learning. Physics-based e-learning, with its interactive online content, enhances digital literacy and promotes self-adaptation, a crucial trait for effective e-learning. Integrating digital experiments and interactive exercises can bolster students' confidence in online physics learning (Aldhafeeri & Alotaibi, 2022). Successfully solving mechanics problems fosters engagement with diverse e-learning applications, building confidence in digital learning environments. Addressing complex mechanics problems reduces discomfort in virtual learning, improving academic performance and technological adaptation. The online application of physics cultivates problem-solving skills, further enhancing confidence in navigating e-learning platforms. Consequently, we hypothesise that,

H2: Learning classical mechanics has a significant positive impact on enhancing e-learning confidence.

Web-based cognitive apprenticeship is found to be highly effective in teaching classical mechanics, a topic generally considered among the most difficult for e-learners. Cognitive apprenticeship uses guided learning, modelling by experts, as well as the use of digital tools, able to support learners in acquiring highly abstract principles. Studies such as Liao, Chen and Shih (2019) shows that structured learning environments in the web ensure students gain in-depth knowledge of classical mechanics, hence are able to apply the principles in real-world scenarios. Via interactive virtual experiments as well as simulated experiments, web-based cognitive apprenticeship opens the door for learners to interact with, as well as understand, principles often difficult to grasp. As students' progress in working with classical mechanical principles, their ability in handling learning tools in the web increases, making them skilled in independent online learning (Vrgović et al., 2022). Research reveals that mastery of classical mechanical principles significantly enhances students' confidence in learning environments on the web. Web-based cognitive apprenticeship aids students in methodically approaching, as well as acquiring, difficult principles in physics, avoiding overload in the mind, as well as problem-solving capacity improvement. According to Bojović et al. (2020), learners who become competent in classical mechanics have higher levels of trusting online learning materials as well as value web-based learning sites more.

Furthermore, as students' progress in their knowledge of physics, they are less hesitant in utilizing digital learning tools, thus enriching their entire e-learning experience. Exploring classical mechanics in web-based learning methods allows students to better adjust to digital learning environments, promoting higher independence and inherent motivation towards learning in the future (De Bruin & Merrick, 2022). Classical mechanics is used as an intermediary variable that enhances the interaction between web-based cognitive apprenticeship and higher confidence in learning via the web, affirming that students can gain the required competence necessary in coping with and meeting digital learning systems. For this purpose, this study suggests that,

H3: Learning classical mechanics mediates the relation between web-based cognitive apprenticeship and e-learning confidence.

Research Methodology and Procedures

This research aims to assess the efficacy of using the Web-Based Cognitive Apprenticeship Model (CAM) in promoting learning in Classical Mechanics as well as increasing confidence in e-learning among students pursuing Physics at the College of Basic Education (Al-Kamzari & Alias, 2024). Given the increasing reliance on digital learning, this research aims to determine if systematic and interactive learning over the web can boost students' academic performance as well as their interaction in terms of academic performance compared to traditional teaching (Gjerde, Holst, & Kolstø, 2021). For this purpose, this research embraced the use of a quantitative approach, making use of systematic questionnaires for measuring academic performance as well as confidence in web learning. This research focused on Physics students who furnished pertinent data related to the Web-Based Cognitive Apprenticeship Model as well as traditional teaching methodologies.

A quantitative research design was employed, aligning with widely accepted practices in educational research that allow for systematic comparisons of learning outcomes within controlled settings. The target population consisted of students enrolled in the General Sciences programme at the College of Basic Education, University of Maysan, during the 2022–2023 academic year. Specifically, all second-year students specialising in Physics within the General Sciences Department were included (Wang, Zulkifli, & Mohd Ayub, 2024). To ensure fairness and eliminate potential biases, random sampling was applied (Huang et al., 2024). Out of three available second-year Physics divisions, a total of 357 students were randomly selected (Ruggiero & Galante, 2020). This random selection approach ensured that participants had comparable prior academic backgrounds, abilities, and demographic profiles, thereby reducing the likelihood of confounding variables that might influence the outcomes (Ben Giaber, 2023).

In addition to this, students were direct respondents, as researchers utilized face-to-face dissemination of the questionnaires for maximum participation. While 504 questionnaires were disseminated in total, only 357 responses were collected that were valid, giving a response rate of 70.83 per cent. The study employed established scales to measure the key variables: six items were used to assess web-based cognitive apprenticeship (Lo & Tsai, 2022), five items were adopted to evaluate learning in Classical Mechanics (Guadagno et al., 2021), and six items measured confidence in e-learning (Lopes et al., 2022). Furthermore, the study utilised Smart-PLS for data analysis to examine the relationships among variables, as this method is suited for handling complex models and providing robust results (Hair Jr, Howard, & Nitzl, 2020). The research model incorporated one predictor, identified as Web-Based Cognitive Apprenticeship (WBCA), one mediating variable, Learning Classical Mechanics (LCM), and one outcome variable, Enhancing E-Learning Confidence (EELC), as illustrated in Figure 1.

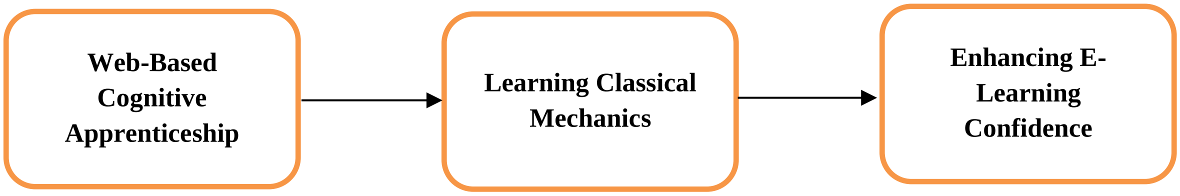

Figure 1: *Research Model.*

Data Analysis

These findings reveal that convergent validity was established, showing high amounts of correlation among the scale items. Both values of Cronbach's Alpha and Composite Reliability were higher than the cutoff level of 0.70, establishing internal consistency. Factor loadings and Average Variance Extracted (AVE) values were higher than 0.50, establishing the appropriateness of measurement representation for each factor. These findings affirm that the measure has acceptable convergent validity as well as reliability. Detailed results are presented in Table 1 and Figure 2. Furthermore, the results also demonstrate discriminant validity, indicating that the constructs are distinct from one another. Both the Fornell-Larcker criterion and cross-loadings analysis reveal that the correlations of each variable with itself are higher than the correlations with other variables, confirming that each construct measures unique aspects of the model. These outcomes highlight a low correlation between different variables, supporting the discriminant validity of the constructs. The detailed results are presented in Table 2 and Table 3.

Table 1: *Convergent Validity.*

Constructs	Items	Loadings	Alpha	CR	AVE
Enhancing E-Learning Confidence	EELC1	0.764	0.845	0.883	0.556
	EELC2	0.772			
	EELC3	0.742			
	EELC4	0.750			
	EELC5	0.699			
	EELC6	0.747			
Learning Classical Mechanics	LCM1	0.832	0.820	0.875	0.584
	LCM2	0.791			
	LCM3	0.680			
	LCM4	0.777			
	LCM5	0.731			
Web-Based Cognitive Apprenticeship	WBCA1	0.882	0.922	0.939	0.720
	WBCA2	0.865			
	WBCA3	0.799			
	WBCA4	0.805			
	WBCA5	0.875			
	WBCA6	0.861			

Table 2: *Fornell Larcker.*

	EELC	LCM	WBCA
EELC	0.746		
LCM	0.654	0.764	
WBCA	0.600	0.467	0.848

Table 3: *Cross-Loadings.*

	EELC	LCM	WBCA
EELC1	**0.764**	0.542	0.444
EELC2	**0.772**	0.647	0.459
EELC3	**0.742**	0.451	0.522
EELC4	**0.750**	0.427	0.464
EELC5	**0.699**	0.349	0.384
EELC6	**0.747**	0.399	0.405
LCM1	0.598	**0.832**	0.374
LCM2	0.492	**0.791**	0.289
LCM3	0.456	**0.680**	0.298
LCM4	0.513	**0.777**	0.452
LCM5	0.416	**0.731**	0.352
WBCA1	0.553	0.420	**0.882**
WBCA2	0.539	0.431	**0.865**
WBCA3	0.508	0.403	**0.799**
WBCA4	0.468	0.355	**0.805**
WBCA5	0.502	0.386	**0.875**
WBCA6	0.475	0.372	**0.861**

The outcomes further validate discriminant validity via the Heterotrait-Monotrait (HTMT) ratio analysis, for all values captured below the criterion of 0.90. These outcomes confirm that there is a low level of association between variables, in support of the uniqueness of each construct in the model. Additional HTMT details are captured in Table 4. Further, the outcomes affirm that there is a positive impact of WBCA on LCM, thereby supporting and accepting hypothesis H1. Further, the findings reveal that LCM is significantly related to EELC, thereby accepting hypothesis H2. In addition, the research substantiates that there is significant mediation of the relationship between WBCA and EELC via LCM, thereby accepting hypothesis H3. These relations are outlined in Table 5 and illustrated in Figure 3.

Table 4: *Heterotrait Monotrait Ratio.*

	EELC	LCM	WBCA
EELC			
LCM	0.746		
WBCA	0.671	0.530	

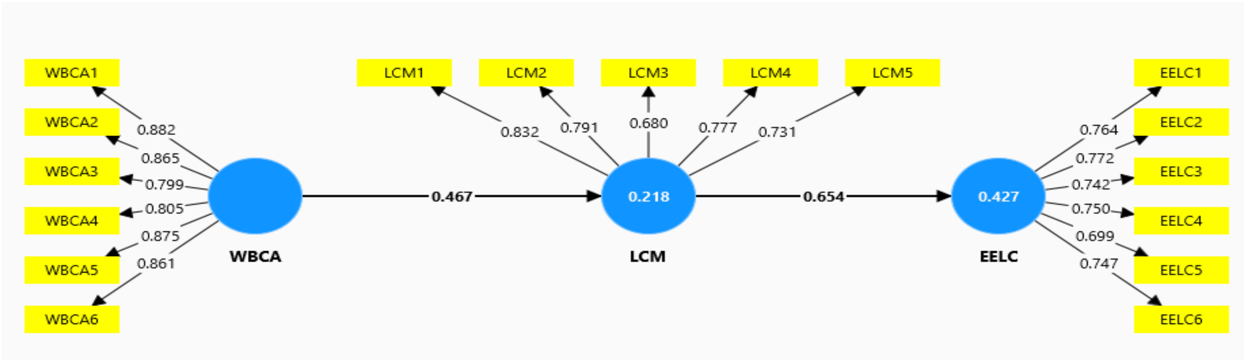

Figure 2: *Measurement Model Assessment.*

Table 5: *Path Analysis.*

Relationships	Beta	Standard Deviation	T Statistics	P Values
LCM -> EELC	0.654	0.036	17.989	0.000
WBCA -> LCM	0.467	0.050	9.401	0.000
WBCA -> LCM -> EELC	0.305	0.043	7.019	0.000

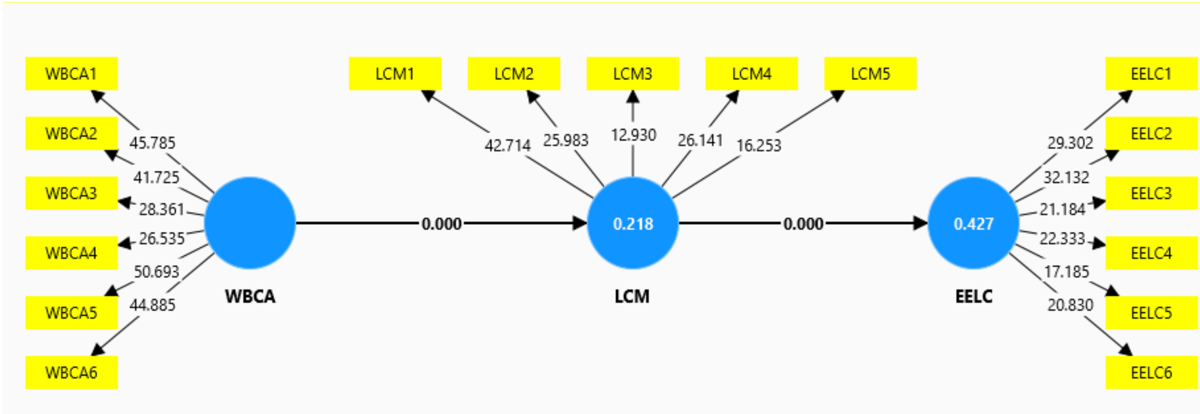

Figure 3: *Structural Model Assessment.*

Discussion of Results

This research confirms the hypothesis that web-based cognitive apprenticeship enhances students' independent learning of classical mechanics, as posited by Alwafi (2023). Such an instructional method creates an interactive learning environment in which students learn through modelling, scaffolding, and guided exploration, reinforcing and establishing conceptual understanding. In addition, this confirms the views of May, Jahnke and Moore (2023), who aver that web tools in the form of simulations, virtual experiments, and problem-solving exercises enhance students' understanding of abstract mechanical concepts. In the same line, this research finds that as students interact within the organized digital learning platform—wherein they interact and enhance their learning—students perform better in physics. According to Tsai, Ong and Chen (2023), dynamic visual models' interaction, coupled with immediate feedback, strengthens problem-solving abilities, enabling students to better apply theoretical concepts. In addition, web-based cognitive apprenticeship avails students with a flexible, independent learning experience, protecting students from the challenges entailed in learning classical mechanics and eventually achieving better learning outcomes.

Furthermore, classical mechanics is central in boosting students' efficacy in e-learning. Notably, this is especially true for students of physics, as mechanics is abstract as well as mathematical in nature, such that mastery would require a robust conceptual basis to interact confidently in virtual learning environments. Dorfner and Zakerzadeh (2021) through mastery of the concepts in mechanics, students feel successful, thus minimizing fear towards virtual learning as it increases the facility in using digital learning environments. For instance, Abbott (2019) found that there is high correspondence between digital learning confidence and performance in intricately demanding problem-solving tasks, these being central in the teaching as well as the examination of mechanics. Additionally, Whalley et al. (2021) claimed that virtual implementation of the laws of physics not only increases students' flexibility but it also increases their frequent use of digital environments for learning. It is observed that there is correspondence between the knowledge of the topic as well as digital learning efficacy in that the mastery of classical mechanics is key in enhanced digital learning performance overall.

Learning classical mechanics is thereby also an intermediary variable between web-based learning through cognitive apprenticeship and academic confidence in electronic learning. According to the research findings, web-based teaching allows learners to receive systematic instruction that organises learning in topics in mechanics in a structured fashion, thus leading to higher confidence in the use of electronic tools. Students who effectively learn basic principles of classical mechanics through electronic sources are more likely to have faith in electronic learning and use digital media in their academic progress. As argued by van Lankveld et al. (2019), c cognitive apprenticeship is designed in such a way that it is not only for effective mastery of content in physics but is aimed at helping learners become increasingly independent learners able to take command of their own learning in digital environments as well. Similarly, Chu et al. (2021) assert that problem-oriented content in mechanics, as supported through the use of cognitive apprenticeship in virtual environments, draws benefits for learners in web-focused learning while at the same time enhances their academic confidence in this type of learning as well. Cai et al. (2021) support this in the same line by positing that as learners get engaged in practicing theoretical learning for actual problems in physics in virtual setups, their perception of their competency in learning through electronic channels is considerably boosted. Mediating effect of learning classical mechanics, as reflected in mastery of content, implies that instructional methods utilised in electronic learning spaces are better converted into learners' academic confidence, thus leading towards enhanced academic performance as well as academic interaction.

The research corroborates that the Web-Based Cognitive Apprenticeship Model successfully improved students' academic performance in classical mechanics as well as their efficacy in e-learning. Students' academic performance, as measured through achievement tests as well as surveys of their confidence in both experimental and control groups, showed significant improvement (Wang et al., 2024). Improvement in the experimental group students' mean scores showed that interactive online learning environments are beneficial for learning outcomes. Utilization of virtual experiments, instructional videos, as well as practice activities engendering interaction, allowed students to better understand abstract concepts. In addition, incorporating cognitive apprenticeship methods—such as modelling, coaching, as well as scaffolding—coupled with immediate feedback opportunities worked towards better development in students' problem-solving capacity as opposed to standard pedagogy.

Students' confidence in using digital technologies and learning platforms improved, promoting familiarity with digital learning. Outcomes revealed that the experimental group had higher levels of interaction with digital material as well as instructors in comparison with the control group. This reflects the invaluable contribution of persistent interaction towards building academic confidence. Aspects like immediate feedback as well as adaptive accessibility of learning resources promoted students' motivation in independent learning. These outcomes fall in line with earlier findings on the effectiveness of cognitive apprenticeship in electronic learning environments. Studies show interactive learning enhances information recall up to 60% in contrast with conventional lectures. In addition, the findings support earlier research on digitalization in teaching, which established that student interaction in electronic learning environments promoted learning comprehension by 40% in comparison with conventional teaching (Smith, 2022).

Recommendations and Suggestions for Future Research

According to the findings, it is recommended that WBCAM be utilized in other fields like Mathematics, Engineering, and Applied Sciences. Training students for enhanced digital literacy is necessary to facilitate greater preparedness for e-learning. Utilizing a hybrid model integrating digital as well as face-to-face learning is recommended to balance the format. Faculty members are recommended to be encouraged towards adopting cognitive apprenticeship tactics through proper training support. It is recommended that studies comparing WBCAM with instructional models like Project-Based or Problem-Based Learning be undertaken in the future. Future studies need to investigate the applicability of WBCAM across additional fields as well as investigate the long-term impact on learning, problem-solving, as well as on building confidence.

It is important to investigate if students persist in using cognitive strategies at later academic levels or professional life. Future studies should explore how ongoing use of digital learning influences independent learning, technological flexibility, as well as independent research abilities. Intercomparison studies between Cognitive Apprenticeship and other e-learning models, for example, Project-Based Learning, Problem-Based Learning, Flipped Classroom, as well as AI-powered Adaptive Learning, are advisable to ascertain the most appropriate ways for increasing engagement, motivation, as well as academic achievement. In addition, research on hybrid constructs that combine cognitive apprenticeship with inquiry learning, teamwork, as well as gamification is advisable. Studies can investigate how AI systems tailor the Cognitive Apprenticeship Model according to students' learning rates, strengths, and weaknesses. Studies on AI tutors' ability to provide immediate feedback in human-like dialogue form, as well as adaptive algorithms that check on students' progress while adjusting, are necessary for improving learning outcomes.

Future studies need to investigate psychological variables such as intrinsic motivation, self-efficacy, cognitive load, and digital literacy that drive students' engagement and persistence in CAM in digital learning contexts. The impact of peer support, online communities, and virtual mentoring on motivation should be explored too. Research studies should measure blended learning models integrating web-based CAM with on-campus instruction, comparing their effectiveness with entirely online and face-to-face methods to determine the optimal methods. Teacher attitudes towards procedures in blended CAM should be studied, as should challenges in implementation. Research should also measure the impact of the model on different age groups, learning preferences, and academic backgrounds, removing the obstacle of students with poor digital competency through specifically designed pre-training intervention. Gender, socio-economic status, and cultural effects on digital learning uptake should be tested as well.

Effective workshops and training for teachers on how to implement CAM in online environments should be established, in conjunction with determining challenges within making the switch in teaching practices from conventional teachings to digital ones. Critical thinking as well as problem-solving abilities in digital CAM environments should be researched, having tools designed to assess mental progress. CAM-trained students' problem-solving performance in real-life settings should be compared with that of control groups. In addition, how CAM can be incorporated in university curriculums as well as the policy shifts, budgeting, as well as technological standards required for its implementation in higher educations on a broad scale should be examined. Ultimately, the effects of successful digital learning implementation in premier institutions on academic achievement as well as student involvement should be determined.

Conclusion

These findings present strong evidence that the WBCA enhances students' conceptual understanding of classical mechanics significantly as well as their confidence in tackling learning through e-learning substantively. In addition, the findings highlight that enriching virtual learning environments through guided support, dynamic discussion, and active learning methods bring about significant improvement in academic performance, problem-solving ability, and student engagement in virtual learning environments. Students who undergo the cognitive apprenticeship mode demonstrate higher scores in terms of academic performance as well as higher levels of confidence as compared to their peers in the control group, thus establishing the efficacy of this mode in achieving enhanced conceptual thinking as well as independent learning. However, while carried out within a flexible, technology-mediated learning environment that accommodated geographically diverse educational requirements, this research suffered certain limitations as well. These include technical as well as operational impediments, coupled with students' familiarity limitations with virtual learning tools as well as face-to-face interaction preferences. To address such drawbacks, future applications should engross strong support in terms of robust scaffolding mechanisms, enable peer collaboration, as well as ensure constructive as well as timely feedback on the part of instructors, thus supporting an enhanced student-centric approach favouring enhanced critical thinking, flexibility, as well as independent learning. Moreover, considering growing momentum toward blended learning models using both bricks-and-mortar as well as digital forms of instruction, higher learning institutions should step up their attempts in providing interactive, Personalised, as well as effective learning experiences. Future studies should aim at researching the effects of applying cognitive apprenticeship across durations, across different fields, as well as on varied learning modalities. Moreover, implementing cutting-edge technologies like AI-driven as well as adaptive learning systems could possibly enhance the impact of web-based learning even further. These findings highlight the need for ongoing pedagogical reform as well as the implementation of cutting-edge technological solutions to build stimulating, flexible, as well as high-quality learning environments as per the changing requirements of modern higher learning.

Research Limitations

Several limitations exist in this study that should be noted. First, the study is restricted to testing the efficacy of the CAM only in learning classical mechanics and building students' confidence in learning in this manner, without testing it in other areas of study or aspects of teaching high school physics. Secondly, the study is based on students belonging only to the Physics branch at the College of Basic Education, hence restricting the applicability of the findings in other areas of study or other learning environments. Moreover, the study is based on topics in classical mechanics as per the students' curriculum, which may not exhaustively reflect the applicability of the model in learning other advanced or varied content in physics. In addition, the teaching method is restricted to web-based teaching using CAM without other blended or hybrid teaching models that may affect learning in varying ways. Further, the study is carried out over a single term, which hampers the examination of the long-term effect as well as the retention of the learning improvement. Finally, students' knowledge acquisition as well as students' confidence in learning is evaluated only using smart-PLS without the use of qualitative indicators or other learning evaluation tools that may provide richer feedback on students' learning aspects.

References

Abbott, D. (2019). Game-based learning for postgraduates: An empirical study of an educational game to teach research skills. *Higher Education Pedagogies, 4*(1), 80-104. https://doi.org/10.1080/23752696.2019.1629825

Al-Kamzari, F., & Alias, N. (2024). Exploring the readiness of high school physics students for project-based hybrid learning in the Sultanate of Oman. *EURASIA Journal of Mathematics, Science and Technology Education, 20*(2), em2404. https://doi.org/10.29333/ejmste/14241

Aldhafeeri, F. M., & Alotaibi, A. A. (2022). Effectiveness of digital education shifting model on high school students' engagement. *Education and Information Technologies, 27*(5), 6869-6891. https://doi.org/10.1007/s10639-021-10879-4

Alwafi, E. M. (2023). The impact of designing an online learning environment based on cognitive apprenticeship on students' critical thinking and interaction in CSCL. *Educational Technology Research and Development, 71*(2), 441-457. https://doi.org/10.1007/s11423-022-10180-2

Alyoussef, I. Y. (2023). Acceptance of e-learning in higher education: The role of task-technology fit with the information systems success model. *Heliyon, 9*(3), e13751. https://doi.org/10.1016/j.heliyon.2023.e13751

Atashinsadaf, A., Ramezani-badr, F., Long, T., Imanipour, M., & Amini, K. (2024). Facilities, challenges, attitudes, and preferences of nursing students related to e-learning in the Covid-19 pandemic in Iranian context: a cross-sectional study. *BMC Medical Education, 24*(1), 5-110. https://doi.org/10.1186/s12909-024-05029-6

Ben Giaber, R. (2023). Libyan teachers as transitionalist pragmatists: conceptualising a path out of the peacebuilding narrative in conflict-affected contexts. *London Review of Education, 21*(1), 15. https://doi.org/10.14324/lre.21.1.15

Bojović, Ž., Bojović, P. D., Vujošević, D., & Šuh, J. (2020). Education in times of crisis: Rapid transition to distance learning. *Computer Applications in Engineering Education, 28*(6), 1467-1489. https://doi.org/10.1002/cae.22318

Cai, S., Liu, C., Wang, T., Liu, E., & Liang, J. C. (2021). Effects of learning physics using Augmented Reality on students' self-efficacy and conceptions of learning. *British Journal of Educational Technology, 52*(1), 235-251. https://doi.org/10.1111/bjet.13020

Chu, S. K. W., Reynolds, R. B., Tavares, N. J., Notari, M., & Lee, C. W. Y. (2021). *21st century skills development through inquiry-based learning from theory to practice*. Springer. https://doi.org/10.1007/978-981-10-2481-8

De Bruin, L., & Merrick, B. (2022). Creative Pedagogies with Technology: Future Proofing Teaching Training in Music. In D. Henriksen & P. Mishra (Eds.), *Creative Provocations: Speculations on the Future of Creativity, Technology & Learning* (pp. 143-157). Springer International Publishing. https://doi.org/10.1007/978-3-031-14549-0_10

De Bruin, L. R. (2019). The use of cognitive apprenticeship in the learning and teaching of improvisation: Teacher and student perspectives. *Research Studies in Music Education, 41*(3), 261-279. https://doi.org/10.1177/1321103X18773110

Delaney, B. (2023). Designing and delivering experiential journalism tasks in online environments: A framework grounded in cognitive apprenticeship theory. *Journalism Studies, 24*(1), 128-151. https://doi.org/10.1080/1461670X.2022.2150263

Dorfner, N., & Zakerzadeh, R. (2021). Academic games as a form of increasing student engagement in remote teaching. *Biomedical Engineering Education, 1*, 335-343. https://doi.org/10.1007/s43683-021-00048-x

Ghosheh Wahbeh, D. M., Shweiki, S. N., & Sartawi, A. F. (2022). The Role of an Instructional Design Model Integrated with OERS in Developing Teachers' Competencies to Adopt E-Learning. In D. Burgos & S. Affouneh (Eds.), *Radical Solutions in Palestinian Higher Education: Research from An-Najah National University* (pp. 101-118). Springer Singapore. https://doi.org/10.1007/978-981-19-0101-0_9

Gjerde, V., Holst, B., & Kolstø, S. D. (2021). Integrating effective learning strategies in basic physics lectures: A thematic analysis. *Physical Review Physics Education Research, 17*(1), 010124. https://doi.org/10.

1103/PhysRevPhysEducRes.17.010124

Guadagno, R. E., Gonzenbach, V., Puddy, H., Fishwick, P., Kitagawa, M., Urquhart, M., et al. (2021). A usability study of classical mechanics education based on hybrid modeling: Implications for sustainability in learning. *Sustainability*, *13*(20), 11225. https://doi.org/10.3390/su132011225

Hair Jr, J. F., Howard, M. C., & Nitzl, C. (2020). Assessing measurement model quality in PLS-SEM using confirmatory composite analysis. *Journal of Business Research*, *109*, 101-110. https://doi.org/10.1016/j.jbusres.2019.11.069

Hassan, N. M. H. (2024). Using an Online Collaborative Learning Program Based on the Cognitive Apprenticeship Model for Developing Student Teachers' EFL Argumentative Writing and Critical Thinking Skills. *Sohag University International Journal of Educational Research*, *10*(10), 147-184. https://doi.org/10.21608/suijer.2024.369245

Huang, S.-F., Kuo, H.-C., Chen, Z., Yang, X., Yang, C.-H. H., Tsao, Y., et al. (2024). Detecting the Undetectable: Assessing the Efficacy of Current Spoof Detection Methods Against Seamless Speech Edits. In *2024 IEEE Spoken Language Technology Workshop (SLT)* (pp. 652-659). IEEE. https://doi.org/10.1109/SLT61566.2024.10832200

Khine, M. S. (2024). AI in Teaching and Learning and Intelligent Tutoring Systems. In M. S. Khine (Ed.), *Artificial Intelligence in Education: A Machine-Generated Literature Overview* (pp. 467-570). Springer. https://doi.org/10.1007/978-981-97-9350-1_4

Li, W., Pea, R., Haber, N., & Subramonyam, H. (2024). Tutorly: Turning Programming Videos Into Apprenticeship Learning Environments with LLMs. *arXiv preprint arXiv:2405.12946*, 23. https://doi.org/10.48550/arXiv.2405.12946

Liao, C.-W., Chen, C.-H., & Shih, S.-J. (2019). The interactivity of video and collaboration for learning achievement, intrinsic motivation, cognitive load, and behavior patterns in a digital game-based learning environment. *Computers & Education*, *133*, 43-55. https://doi.org/10.1016/j.compedu.2019.01.013

Lo, S.-C., & Tsai, H.-H. (2022). Perceived effectiveness of developing a Mobile system of formative test with handwriting revision to devise an instruction design based on cognitive apprenticeship theory. *Sustainability*, *14*(4), 2272. https://doi.org/10.3390/su14042272

Lopes, C., Bernardes, Ó., Gonçalves, M. J. A., Terra, A. L., da Silva, M. M., Tavares, C., et al. (2022). E-learning enhancement through multidisciplinary teams in higher education: students, teachers, and librarians. *Education Sciences*, *12*(9), 601. https://doi.org/10.3390/educsci12090601

May, D., Jahnke, I., & Moore, S. (2023). Online laboratories and virtual experimentation in higher education from a sociotechnical-pedagogical design perspective. *Journal of Computing in Higher Education*, *35*(2), 203-222. https://doi.org/10.1007/s12528-023-09380-3

Oludipe, O. S., Olayanju, M. O., Akindoju, O. G., & Lameed, S. N. (2023). Is cognitive apprenticeship a gender nonchauvinistic instructional strategy for improving pre-service Integrated science teacher's cognitive achievement towards knowledge economy. *International Journal of Innovative Research and Advanced Study*, *10*(10), 1-8. https://www.ijiras.com/2023/Vol_10-Issue_10/paper_1.pdf

Ostovar-Namaghi, S. A., Morady Moghaddam, M., & Veysmorady, K. (2024). Empowering EFL learners through cognitive apprenticeship: A pathway to success in IELTS speaking proficiency. *Language Teaching Research*, 13621688241227896. https://doi.org/10.1177/13621688241227896

Ruggiero, M. L., & Galante, L. (2020). Online Tutoring in Introductory Physics Courses: a Lockdown Experience. *Physics Educatio*, 8. https://doi.org/10.48550/arXiv.2011.13315

Sidhu, M. S., Mousakhani, S., Lee, C. K., & Sidhu, K. K. (2024). Educational impact of Metaverse learning environment for engineering mechanics dynamics. *Computer Applications in Engineering Education*, *32*(5), e22772. https://doi.org/10.1002/cae.22772

Smith, C. (2022). *Understanding Middle School Teachers' Use of Instructional Practices for Online Reading Comprehension* [Doctoral Dissertation, Walden University]. https://scholarworks.waldenu.edu/cgi/viewcontent.cgi?article=14126&context=dissertations

Tsai, M.-L., Ong, C. W., & Chen, C.-L. (2023). Exploring the use of large language models (LLMs) in chemical engineering education: Building core course problem models with Chat-GPT. *Education for Chemical Engineers*, *44*, 71-95. https://doi.org/10.1016/j.ece.2023.05.001

van Lankveld, W., Maas, M., van Wijchen, J., Visser, V., & Staal, J. B. (2019). Self-regulated learning in physical therapy education: a non-randomized experimental study comparing self-directed and instruction-based learning. *BMC Medical Education*, *19*(1), 50. https://doi.org/10.1186/s12909-019-1484-3

Vrgović, P., Pekić, J., Mirković, M., Anderla, A., & Leković, B. (2022). Prolonged emergency remote teaching: sustainable E-learning or human capital stuck in online limbo? *Sustainability*, *14*(8), 4584. https://doi.org/10.3390/su14084584

Wang, R., Zulkifli, N. N., & Mohd Ayub, A. F. (2024). Investigating the impact of the stratified cognitive apprenticeship model on high school students' math performance. *Education Sciences*, *14*(8), 898. https://doi.org/10.3390/educsci14080898

Whalley, B., France, D., Park, J., Mauchline, A., & Welsh, K. (2021). Towards flexible personalized learning and the future educational system in the fourth industrial revolution in the wake of Covid-19. *Higher Education Pedagogies*, *6*(1), 79-99. https://doi.org/10.1080/23752696.2021.1883458

Zheng, Y., & Xiao, A. (2024). A structural equation model of online learning: investigating self-efficacy, informal digital learning, self-regulated learning, and course satisfaction. *Frontiers in Psychology*, *14*, 1276266. https://doi.org/10.3389/fpsyg.2023.1276266