



Science Forum (Journal of Pure and Applied Sciences)



Journal Homepage: <https://atbuscienceforum.com.ng/index.php/jpas>

Heuristic Discovery in Gamified Numerical Simulations and Its Relation to Mathematics Students' Algorithmic Thinking in North Central Nigerian Colleges of Education

Balarabe Mas'ud and *Yusuf Isiaka

Department of Computer Science, Umaru Sanda Ahmadu College of Education Minna

Abstract

This study investigated the effect of heuristic discovery embedded within gamified numerical simulations on the algorithmic thinking of mathematics students in Colleges of Education in North Central Nigeria. The study employed a quasi-experimental pre-test-post-test non-equivalent control group design. A total of 360 NCE II mathematics students were selected through multistage sampling, with 180 assigned to the experimental group and 180 to the control group. The experimental group was exposed to gamified numerical simulations specifically designed to foster heuristic discovery, whereas the control group received conventional classroom instruction. Data were collected using the Algorithmic Thinking Test and the Heuristic Engagement Scale. Descriptive statistics, specifically mean and standard deviation, were used to answer the research questions, while independent samples t-test, paired samples t-test, and Analysis of Covariance (ANCOVA) were employed to test the hypotheses at the 0.05 level of significance. The findings revealed that students exposed to the gamified numerical simulation approach obtained markedly higher algorithmic thinking scores ($M = 68.45$, $SD = 8.12$) than their counterparts taught using conventional methods ($M = 54.30$, $SD = 7.95$), with the difference being statistically significant, $t(358) = 12.84$, $p < .05$. Similarly, heuristic-based skills improved significantly from pre-test ($M = 52.10$) to post-test ($M = 67.65$), $t(179) = 11.27$, $p < .05$. Furthermore, the ANCOVA results indicated a significant moderating effect of prior mathematical ability on students' outcomes, $F(2, 354) = 4.75$, $p = .009$. The study concluded that heuristic discovery embedded in gamified numerical simulations significantly enhances algorithmic thinking, although its effectiveness varies across ability levels. It therefore recommends the integration of gamified numerical simulations into mathematics instruction in Colleges of Education.

Keywords

Algorithmic Thinking,
Gamified Simulations,
Heuristic Discovery,
Computational Thinking.

Introduction

The growing emphasis on computational thinking in mathematics education has positioned algorithmic thinking as a critical cognitive competence required for systematic problem solving and logical reasoning. Algorithmic thinking involves the formulation of ordered procedures, decomposition of complex problems, abstraction of essential features, and pattern recognition for generating efficient solutions. These skills are increasingly recognized as foundational for both mathematics learning and broader computational literacy required in contemporary education systems (Wing, 2006; Grover & Pea, 2013).

Within teacher education, the development of algorithmic thinking is particularly important because pre-service teachers are expected to cultivate structured reasoning and problem-solving abilities among learners. However, evidence suggests that mathematics instruction in many teacher education institutions remains dominated by procedural demonstrations and memorisation, which limits opportunities for students to develop higher-order reasoning competencies (Lye & Koh, 2014; Yusuf & Afolabi, 2010).

Recent advances in educational technology have introduced gamified learning environments as a promising approach for enhancing cognitive engagement and promoting deeper learning. Gamification involves the integration of game design elements such as scoring systems, progressive levels, challenges, and immediate feedback into instructional contexts to motivate learners and sustain participation (Deterding et al., 2011). In mathematics education, gamified numerical simulations allow learners to

manipulate variables, observe dynamic outcomes, and iteratively refine solution strategies. Such environments support exploratory learning and provide opportunities for learners to construct procedural knowledge through interaction. Empirical studies indicate that gamified learning environments can improve motivation, engagement, and academic performance when aligned with pedagogical objectives (Hamari et al., 2014; Clark et al., 2016; Subhash & Cudney, 2018). Nevertheless, concerns remain that gamification focused primarily on rewards may promote superficial engagement rather than meaningful cognitive development (Hanus & Fox, 2015).

Heuristic discovery provides a theoretical framework for understanding how learners develop structured reasoning within exploratory environments. Heuristic problem solving emphasises flexible strategies such as analogy, pattern detection, trial-and-error, and iterative refinement when explicit algorithms are not readily available. This perspective originates from the work of Pólya (1945), who emphasised discovery-oriented approaches to mathematical reasoning. Subsequent research demonstrates that heuristic-based learning promotes conceptual understanding by encouraging learners to actively construct knowledge through exploration and feedback (Koedinger & Alevan, 2007; Bruner, 1961).

When embedded in simulation-based environments, heuristic discovery supports iterative reasoning processes that gradually evolve into formal algorithmic procedures. This connection suggests that heuristic engagement may play a critical role in

developing algorithmic thinking within digital learning environments.

The integration of gamified simulations and heuristic discovery therefore presents a theoretically coherent instructional approach. Gamified numerical simulations provide interactive platforms for experimentation, while heuristic discovery guides learners toward systematic reasoning. Through repeated interaction, learners transform exploratory strategies into structured algorithms. Studies on simulation-based learning indicate that interactive environments improve problem-solving performance and conceptual understanding in STEM disciplines (de Jong & van Joolingen, 1998; Wouters et al., 2013).

However, limited empirical research has examined the specific relationship between heuristic discovery within gamified simulations and the development of algorithmic thinking, particularly among pre-service mathematics teachers. This gap limits understanding of how these pedagogical approaches jointly influence structured reasoning skills.

Within the Nigerian teacher education context, the need for innovative instructional approaches is particularly pronounced. Although digital technologies are increasingly recognised as essential for improving educational quality, implementation in Colleges of Education remains constrained by inadequate infrastructure, limited training, and reliance on traditional teaching methods (Yusuf & Afolabi, 2010; Omoniyi & Quadri, 2019). Consequently, students often experience teacher-centred instruction that emphasises procedural knowledge rather than problem-solving and analytical reasoning. This

instructional pattern may hinder the development of algorithmic thinking, which requires active engagement, exploration, and iterative refinement of solution strategies. Moreover, research focusing on computational thinking and gamified learning within Nigerian Colleges of Education remains limited, creating a need for context-specific empirical evidence.

Another important consideration is the role of prior mathematical ability in shaping learning outcomes. Learners with stronger foundational knowledge are more likely to benefit from exploratory learning environments because they possess cognitive resources necessary for abstraction and problem decomposition. Conversely, students with weaker backgrounds may experience cognitive overload when interacting with complex simulations. Research indicates that prior knowledge significantly influences learning outcomes in technology-enhanced environments and may moderate the effectiveness of discovery-based learning approaches (Mayer, 2004; Hattie, 2009). Investigating this moderating effect is therefore necessary to determine whether gamified heuristic learning benefits all learners equally.

Despite growing interest in computational thinking, gamification, and heuristic learning, these constructs have largely been examined independently within mathematics education research. Studies on computational thinking primarily focus on programming and problem decomposition, while gamification research emphasises motivation and engagement, and heuristic learning studies centre on discovery-based reasoning processes (Grover & Pea, 2013; Hamari et al., 2014; Koedinger & Alevan, 2007). Consequently, limited empirical work has integrated these constructs within a

unified framework to explain how heuristic discovery embedded in gamified simulations influences algorithmic thinking. Furthermore, context-specific studies within Nigerian Colleges of Education remain scarce, with most local research focusing on ICT integration or computer-assisted instruction rather than algorithmic reasoning development (Yusuf & Afolabi, 2010; Omoniyi & Quadri, 2019). This gap necessitates empirical investigation into the combined effect of gamified numerical simulations and heuristic discovery on algorithmic thinking among pre-service mathematics teachers. The present study therefore examines the effect of heuristic discovery in gamified numerical simulations on mathematics students' algorithmic thinking, while also investigating the moderating role of prior mathematical ability.

Statement of the Problem

Algorithmic thinking is a fundamental competence required for systematic problem solving in mathematics, yet evidence indicates that students in teacher education institutions often demonstrate weak performance in decomposition, abstraction, and pattern recognition due to predominantly procedural and teacher-centred instructional approaches (Grover & Pea, 2013; Lye & Koh, 2014). Although gamified learning environments have been reported to improve engagement and participation, their implementation frequently emphasises motivation rather than structured cognitive development, limiting their effectiveness in promoting algorithmic reasoning (Hamari et al., 2014; Hanus & Fox, 2015).

Heuristic discovery has been identified as a strategy capable of supporting structured problem solving through exploration, iterative

testing, and refinement of solution procedures, yet empirical evidence examining its integration within gamified numerical simulations remains limited, particularly among pre-service mathematics teachers (Koedinger & Alevan, 2007; Mayer, 2004).

In addition, prior mathematical ability may influence how learners benefit from exploratory technology-enhanced environments, with stronger students more likely to translate heuristic exploration into formal algorithms (Hattie, 2009; Mayer, 2004).

Furthermore, studies investigating algorithmic thinking within Nigerian Colleges of Education are scarce, with most local research focusing on ICT integration rather than structured reasoning development (Yusuf & Afolabi, 2010; Omoniyi & Quadri, 2019). This gap necessitates empirical investigation into whether heuristic discovery embedded in gamified numerical simulations can enhance mathematics students' algorithmic thinking in North Central Nigerian Colleges of Education, while also examining the moderating role of prior mathematical ability.

Aim and Objectives of the Study

The aim of this study is to examine the effect of heuristic discovery in gamified numerical simulations on the algorithmic thinking of mathematics students in North Central Nigerian Colleges of Education.

The specific objectives of the study are to:

1. determine the effect of gamified numerical simulations on students' algorithmic thinking;
2. examine the effect of heuristic discovery on students' heuristic-based skills;

3. compare the algorithmic thinking performance of students exposed to gamified numerical simulations and those taught using conventional instructional methods;
4. examine the moderating effect of prior mathematical ability on the relationship between gamified heuristic learning and students' algorithmic thinking.
2. Heuristic discovery does not have a significant effect on students' heuristic-based skills.
3. Prior mathematical ability does not significantly moderate the effect of gamified numerical simulations on students' algorithmic thinking.

Research Questions

The following research questions guided the study:

1. What is the effect of gamified numerical simulations on students' algorithmic thinking?
2. What is the effect of heuristic discovery on students' heuristic-based skills?
3. What difference exists in the algorithmic thinking performance of students exposed to gamified numerical simulations and those taught using conventional instructional methods?
4. How does prior mathematical ability moderate the effect of gamified heuristic learning on students' algorithmic thinking?

Research Hypotheses

The following null hypotheses were formulated to guide the study:

1. There is no significant difference in the mean algorithmic thinking scores of students exposed to gamified numerical simulations and those taught using conventional instructional methods.

Scope and Delimitations of the Study

This study examined the effect of heuristic discovery in gamified numerical simulations on the algorithmic thinking of mathematics students in North Central Nigerian Colleges of Education. The study was limited to NCE II students enrolled in Mathematics education programmes in selected Colleges of Education within the North Central geopolitical zone of Nigeria, comprising Kwara, Kogi, Niger, Benue, Plateau, Nasarawa States, and the Federal Capital Territory. The content scope was restricted to numerical problem-solving tasks embedded within gamified simulation environments designed to promote heuristic discovery and algorithmic reasoning. The intervention was conducted during the 2024/2025 academic session and lasted eight weeks.

The study excluded students from other academic levels, disciplines, and institutions outside the North Central zone. Other forms of digital instructional strategies beyond gamified numerical simulations were not considered. Although prior mathematical ability was examined as a moderating variable, additional learner characteristics such as gender, socio-economic status, learning styles, and digital literacy were not included. Institutional variables such as instructor differences and infrastructure variability were also not controlled beyond those directly

related to the implementation of the intervention.

Significance of the Study

Findings from this study will be significant in the following ways:

1. It will provide empirical evidence on the effectiveness of heuristic discovery embedded in gamified numerical simulations for improving algorithmic thinking among pre-service mathematics students;
2. It will guide lecturers in Colleges of Education on the use of heuristic-based instructional strategies to promote structured problem solving and algorithmic reasoning;
3. It will inform curriculum developers and educational policymakers on the relevance of technology-enhanced learning environments for improving higher-order thinking skills in teacher education;
4. It will assist teacher educators in designing adaptive instructional approaches that account for differences in students' prior mathematical ability.
5. It will contribute to existing literature by providing context-specific evidence on gamified heuristic learning within North Central Nigerian Colleges of Education;

Research Methodology

This study adopted a quasi-experimental pre-test post-test non-equivalent control group design to examine the effect of heuristic discovery in gamified numerical simulations on students' algorithmic thinking. The study was conducted in selected Colleges of Education in the North Central geopolitical zone of Nigeria.

Ethical approval for the study was obtained from the Research Ethics Committees of the participating institutions. Participants were informed about the purpose of the study and provided informed consent prior to participation. Confidentiality and anonymity of responses were ensured, and participants were informed of their right to withdraw at any stage without penalty. The population of the study comprised all NCE II mathematics students in Colleges of Education within North Central Nigeria.

A sample of 360 students was selected using multistage sampling. In the first stage, six Colleges of Education were selected using stratified sampling based on state representation. In the second stage, intact classes were randomly assigned to experimental and control groups. The experimental group consisted of 180 students, while 180 students formed the control group. The experimental group was exposed to gamified numerical simulations designed to promote heuristic discovery, while the control group received conventional lecture-based instruction. The intervention lasted eight weeks with three instructional sessions per week, each lasting 45 minutes.

The gamified simulation modules were developed using the GeoGebra platform and structured into progressive levels. The modules covered numerical problem-solving tasks including linear relationships, numerical sequences, iterative approximation, optimisation problems, and structured algorithm development. Game elements incorporated into the modules included point-based scoring, progressive levels, timed challenges, immediate feedback, and achievement badges. Students in the

experimental group engaged in heuristic discovery processes such as pattern identification, decomposition of problems, trial-and-error exploration, and refinement of solution procedures. The control group was taught using teacher explanation, worked examples, and guided practice without gamified features.

Data were collected using two instruments: Algorithmic Thinking Test (ATT) and Heuristic Engagement Scale (HES). The ATT consisted of 20 structured items measuring decomposition, abstraction, pattern recognition, and algorithm design. The HES comprised eight Likert-scale items assessing students' engagement in heuristic discovery processes. Content validity of the instruments was established through expert review by three specialists in mathematics education and educational technology.

Construct validity was determined using exploratory factor analysis, which confirmed a four-factor structure for the ATT and a unidimensional structure for the HES. Factor loadings ranged from 0.61 to 0.84 for the ATT and 0.58 to 0.79 for the HES. A pilot study was conducted using 40 NCE II mathematics students outside the study sample. Cronbach's alpha reliability coefficients obtained were 0.82 for the ATT and 0.78 for the HES. For the main study, internal consistency

coefficients were 0.86 for the ATT and 0.81 for the HES. Test-retest reliability conducted over a two-week interval produced coefficients of 0.80 for the ATT and 0.76 for the HES. These values indicated acceptable reliability of the instruments. Data collection involved administering the pre-test to both experimental and control groups prior to the intervention. Following the eight-week instructional period, the post-test was administered using the same instruments. Prior mathematical ability was determined using students' previous semester mathematics scores and categorised into high, moderate, and low ability levels. Data were analysed using descriptive statistics of mean and standard deviation to answer the research questions. Independent samples t-test was used to test the difference between experimental and control groups. Paired samples t-test was used to examine improvement in heuristic-based skills. Analysis of Covariance (ANCOVA) was employed to determine the moderating effect of prior mathematical ability while controlling for pre-test scores. All hypotheses were tested at 0.05 level of significance. Effect sizes were computed using Cohen's *d* for t-tests and partial eta squared for ANCOVA. Assumptions of normality, homogeneity of variance, and homogeneity of regression slopes were tested prior to inferential analysis.

Results

Table 1: Mean and Standard Deviation of Students' Algorithmic Thinking Scores by Group

| SN | Group | N | Mean | Standard Deviation |
|----|--------------------|-----|-------|--------------------|
| 1 | Experimental Group | 180 | 68.45 | 8.12 |
| 2 | Control Group | 180 | 54.30 | 7.95 |

Table 1 shows that students exposed to gamified numerical simulations recorded a higher mean algorithmic thinking score ($M = 68.45$, $SD = 8.12$) than students taught using conventional instructional methods ($M = 54.30$, $SD = 7.95$). The difference in mean scores indicates that students in the experimental group demonstrated better algorithmic thinking performance than those in the control

group. The relatively close standard deviations for both groups suggest comparable variability in scores, indicating that the observed difference in mean performance is attributable to the instructional treatment rather than dispersion in scores. This result implies that exposure to gamified numerical simulations improved students' algorithmic thinking.

Table 2: Mean and Standard Deviation of Heuristic-Based Skills (Pre-test and Post-test)

| SN | Variable | N | Mean | Standard Deviation |
|----|-----------|-----|-------|--------------------|
| 1 | Pre-test | 180 | 52.10 | 8.05 |
| 2 | Post-test | 180 | 67.65 | 7.88 |

Table 2 shows that the mean score for heuristic-based skills increased from 52.10 ($SD = 8.05$) at pre-test to 67.65 ($SD = 7.88$) at post-test. The higher post-test mean indicates that students demonstrated improved heuristic-based skills after exposure to the gamified numerical simulations. The standard deviations for both pre-test and

post-test scores are relatively close, suggesting that the improvement occurred across most students rather than being limited to a small proportion. The observed increase in mean score indicates that heuristic discovery embedded within the gamified simulations enhanced students' ability to engage in heuristic processes.

Table 3: Independent Samples t-test Comparing Algorithmic Thinking Scores

| Group | N | Mean | SD | Mean Diff | t-value | df | Sig. (2-tailed) |
|--------------------|-----|-------|------|-----------|---------|-----|-----------------|
| Experimental Group | 180 | 68.45 | 8.12 | | | | |
| Control Group | 180 | 54.30 | 7.95 | 14.15 | 12.84 | 358 | 0.000 |

Table 3 shows that students in the experimental group obtained a higher mean score ($M = 68.45$, $SD = 8.12$) compared to those in the control group ($M = 54.30$, $SD = 7.95$), resulting in a mean difference of 14.15. The independent samples t-test produced a t-value of 12.84 with 358 degrees of freedom and a significance value of .000, which is less than the 0.05 level of significance. This indicates

that there is a statistically significant difference in algorithmic thinking scores between students exposed to gamified numerical simulations and those taught using conventional instructional methods. The result implies that the use of gamified numerical simulations significantly improved students' algorithmic thinking.

Table 4: ANCOVA Summary Showing Moderating Effect of Prior Mathematical Ability

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|-----------------|-------------------------|-----|-------------|-------|-------|
| Group | 4820.35 | 1 | 4820.35 | 35.62 | 0.000 |
| Prior Ability | 3915.20 | 2 | 1957.60 | 14.48 | 0.000 |
| Group * Ability | 1285.75 | 2 | 642.88 | 4.75 | 0.009 |
| Error | 48350.10 | 354 | 136.59 | | |

Table 4 shows that the main effect of group is significant, $F(1, 354) = 35.62, p < .05$, indicating that students exposed to gamified numerical simulations performed significantly better in algorithmic thinking than those taught using conventional methods after controlling for pre-test scores. The result also shows a significant main effect of prior mathematical ability, $F(2, 354) = 14.48, p < .05$, indicating that students' performance differed based on their ability levels. The interaction effect between group and prior mathematical ability is significant, $F(2, 354) = 4.75, p = .009$, indicating that prior mathematical ability moderated the effect of gamified heuristic learning on students' algorithmic thinking. This implies that the effectiveness of the gamified numerical simulations varied across ability levels.

Discussion of Findings

The results from Tables 1-4 collectively indicate that heuristic discovery embedded in gamified numerical simulations improved students' algorithmic thinking. Table 1 showed that students exposed to the gamified simulations obtained a higher mean score in algorithmic thinking than those taught using conventional instructional methods. This descriptive difference was confirmed in Table 3, where the independent samples t-test revealed a statistically significant difference between the experimental and control groups. The agreement between the descriptive and

inferential results indicates that the improvement in algorithmic thinking was associated with exposure to the gamified numerical simulations. This finding supports earlier studies which reported that simulation-based and gamified learning environments enhance higher-order thinking and structured problem-solving skills (Clark et al., 2016; Wouters et al., 2013). The improvement in algorithmic thinking suggests that interactive environments that allow learners to manipulate variables, receive feedback, and refine solution strategies promote procedural reasoning and systematic problem solving.

The improvement observed in algorithmic thinking is further explained by the results in Table 2, which showed an increase in heuristic-based skills from pre-test to post-test. The increase in mean scores indicates that students developed stronger abilities in heuristic processes such as decomposition, pattern recognition, and iterative testing.

The development of these heuristic-based skills provides a plausible explanation for the improved algorithmic thinking reported in Tables 1 and 3. This relationship suggests that heuristic discovery within the gamified simulations supported learners in constructing stepwise procedures for solving problems. This finding aligns with research indicating that discovery-oriented learning environments promote deeper conceptual understanding and

structured reasoning when learners actively engage in exploration and feedback-driven refinement (Koedinger & Aleven, 2007; Mayer, 2004).

The moderating role of prior mathematical ability reported in Table 4 further clarifies the pattern observed across Tables 1-3. The significant interaction effect indicates that the improvement in algorithmic thinking varied across ability levels, suggesting that students with stronger mathematical backgrounds benefited more from the gamified heuristic learning environment. This implies that while the intervention improved performance overall, the magnitude of improvement differed depending on students' prior knowledge. This finding is consistent with previous studies which identified prior knowledge as a key determinant of learning effectiveness in exploratory and technology-enhanced environments (Hattie, 2009; Mayer, 2004). Students with higher prior ability are more likely to interpret feedback, identify patterns, and translate heuristic exploration into structured algorithmic procedures.

Taken together, the findings from Tables 1-4 demonstrate that gamified numerical simulations enhanced heuristic-based skills, which in turn improved algorithmic thinking, while prior mathematical ability influenced the extent of improvement. The consistency between descriptive and inferential results strengthens the validity of the findings and suggests that combining gamification with heuristic discovery provides an effective approach for developing algorithmic thinking. These results agree with studies that reported positive effects of simulation-based and discovery-oriented learning environments on problem-solving and cognitive development

in mathematics and related disciplines (Clark et al., 2016; Wouters et al., 2013; Koedinger & Aleven, 2007).

Conclusion

This study examined the effect of heuristic discovery embedded in gamified numerical simulations on mathematics students' algorithmic thinking in North Central Nigerian Colleges of Education. The findings from Tables 1-4 showed that students exposed to gamified numerical simulations demonstrated higher algorithmic thinking scores than those taught using conventional instructional methods, and this difference was statistically significant.

The improvement in performance was accompanied by increased heuristic-based skills, indicating that engagement in heuristic discovery processes contributed to the development of structured problem-solving abilities. The results further revealed that prior mathematical ability significantly moderated the effectiveness of the intervention, with students of higher ability benefiting more from the gamified heuristic learning environment. Overall, the study concludes that integrating heuristic discovery within gamified numerical simulations is an effective instructional approach for enhancing algorithmic thinking among pre-service mathematics students, although its effectiveness varies across ability levels.

Recommendations

Based on the findings of this study, the following recommendations are made:

1. Lecturers in Colleges of Education should integrate gamified numerical simulations into mathematics instruction to enhance students'

algorithmic thinking, as the findings showed improved performance among students exposed to the gamified learning environment.

2. Mathematics educators should incorporate heuristic discovery strategies such as pattern identification, problem decomposition, and iterative testing into classroom activities to strengthen students' heuristic-based skills that support algorithmic reasoning.
3. Management in Colleges of Education should provide training programmes for lecturers on the design and implementation of gamified heuristic learning environments to facilitate effective integration into mathematics teaching.
4. Educational administrators should support the provision of technological infrastructure such as computer laboratories and simulation software to enable the implementation of gamified numerical simulations.
5. Future studies should investigate additional moderating variables such as digital literacy, gender, and learning styles to further explain variations in students' algorithmic thinking in gamified heuristic learning environments.

Reference

- Bruner, J. S. (1961). The act of discovery. *Harvard Educational Review*, 31(1), 21-32.
- Clark, D. B., Tanner-Smith, E. E., & Killingsworth, S. S. (2016). Digital games, design, and learning: A systematic review and meta-analysis. *Review of Educational Research*, 86(1), 79-122.
<https://doi.org/10.3102/0034654315582065>
- de Jong, T., & van Joolingen, W. R. (1998). Scientific discovery learning with computer simulations of conceptual domains. *Review of Educational Research*, 68(2), 179-201.
<https://doi.org/10.3102/00346543068002179>
- Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From game design elements to gamefulness: Defining gamification. In *Proceedings of the 15th International Academic MindTrek Conference* (pp. 9-15). ACM.
<https://doi.org/10.1145/2181037.2181040>
- Grover, S., & Pea, R. (2013). Computational thinking in K-12: A review of the state of the field. *Educational Researcher*, 42(1), 38-43.
<https://doi.org/10.3102/0013189X12463051>
- Hamari, J., Koivisto, J., & Sarsa, H. (2014). Does gamification work? A literature review of empirical studies. In *Proceedings of the 47th Hawaii International Conference on System Sciences* (pp. 3025-3034). IEEE.
<https://doi.org/10.1109/HICSS.2014.377>
- Hanus, M. D., & Fox, J. (2015). Assessing the effects of gamification in the classroom. *Computers & Education*, 80, 152-161.
<https://doi.org/10.1016/j.compedu.2014.08.019>
- Hattie, J. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. Routledge.

- Koedinger, K. R., & Aleven, V. (2007). Exploring the assistance dilemma in experiments with cognitive tutors. *Educational Psychology Review*, 19(3), 239-264. <https://doi.org/10.1007/s10648-007-9049-0>
- Lye, S. Y., & Koh, J. H. L. (2014). Review on teaching and learning of computational thinking. *Computers in Human Behavior*, 41, 51-61. <https://doi.org/10.1016/j.chb.2014.09.012>
- Mayer, R. E. (2004). Should there be a three-strikes rule against pure discovery learning? *American Psychologist*, 59(1), 14-19. <https://doi.org/10.1037/0003-066X.59.1.14>
- Omoniyi, T., & Quadri, K. (2019). ICT integration in Nigerian Colleges of Education: Challenges and prospects. *Journal of Education and Practice*, 10(12), 45-52.
- Subhash, S., & Cudney, E. A. (2018). Gamified learning in higher education: A systematic review. *Computers in Human Behavior*, 87, 192-206. <https://doi.org/10.1016/j.chb.2018.05.028>
- Wing, J. M. (2006). Computational thinking. *Communications of the ACM*, 49(3), 33-35. <https://doi.org/10.1145/1118178.1118215>
- Wouters, P., van Nimwegen, C., van Oostendorp, H., & van der Spek, E. D. (2013). A meta-analysis of the cognitive and motivational effects of serious games. *Journal of Educational Psychology*, 105(2), 249-265. <https://doi.org/10.1037/a0031311>
- Yusuf, M. O., & Afolabi, A. O. (2010). Effects of computer assisted instruction on secondary school students' performance in biology. *Turkish Online Journal of Educational Technology*, 9(1), 62-69.