International Society of the Learning Sciences

The Impact of Hint Modality in Digital Game-Based Learning: A Systematic Literature Review

Mahboobeh Mehrvarz, Carnegie Mellon University, mmehrvar@andrew.cmu.edu
Samaneh Abdoli, Allameh Tabatabai University, samaneh.abdoli67@gmail.com
Esma Nur Kahveci, University of Massachusetts, ekahveci@umassd.edu
Seyedahmad Rahimi, University of Florida, srahimi@ufl.edu
Bruce M. McLaren, Carnegie Mellon University, bmclaren@andrew.cmu.edu

Abstract: Digital learning games often use hints to support learners, but the effectiveness of different hint types remains underexplored. This systematic review examines 68 empirical studies (2000–2024) on hint modalities—text, graphic, and multi-type—across educational levels. Multi-type hints were the most commonly used and showed generally positive outcomes, especially in elementary and higher education. Text-based hints had mixed results, while graphical hints, though less studied, were mostly effective. Future work should investigate the mechanisms behind hint effectiveness to optimize their design in digital learning environments.

Introduction

Digital learning games have become valuable tools for enhancing education across levels (McLaren et al., 2022; Mayer, 2019). These games combine instruction and entertainment to engage learners (McLaren & Nguyen, 2023). A major challenge in their design is balancing engagement with effective learning, especially when teacher support is unavailable (Sun et al., 2018; Lee & Chiou, 2020). Hints serve as a key scaffolding strategy to support learners, reduce dropout, and promote understanding (Rahimi et al., 2021; Anderson et al., 2022). In this study, hints are in-game supports like prompts or cues that help learners complete tasks. Learners can access them on demand or via system control. Hints help overcome challenges during gameplay, unlike feedback, which is given after completing tasks to indicate correctness. Hints guide learners without directly providing answers.

Hints vary in form—text, graphic, audio, or multi-type—and their effectiveness depends on context and learner needs (Chen et al., 2023; Hjert-Bernardi et al., 2012). While some studies show the benefits of text or visual hints, others report mixed or negative results (Lee & Chen, 2009; McLaren et al., 2022; Richey et al., 2024). While this review focuses on hint modality as a primary lens of analysis, we acknowledge that other factors—such as learner characteristics, task complexity, instructional context, and the availability of hints (e.g., on-demand vs. system-triggered)—also influence their effectiveness. This review analyzed 68 studies to explore the impact of hint modalities on learning outcomes while recognizing the importance of these broader contextual elements.

Method

Following PRISMA guidelines (Moher et al., 2009), this review used a structured process—identification, screening, eligibility, and analysis—to examine 68 studies published between 2000–2024. We addressed two research questions:

RQ1: How do different hint modalities (text, graphic, audio, multi-type) affect learning outcomes in digital games?

RQ2: How effective are these modalities across educational levels?

We searched six major databases using targeted keywords and applied inclusion criteria related to language, date, empirical focus, digital game context, and internal, individual hint use. From 2,269 initial records, 68 studies met the criteria after screening and eligibility checks (see Figure 1).

Quality was assessed using CASP and Pluye et al.'s (2009) criteria. All 68 included studies scored above 40%, indicating medium to high quality. Additionally, seven more studies were added using backward and forward snowballing (Theelen et al., 2019). (see Figure 1).

Result

This section presents findings from 68 studies examining hint use in digital learning games. Table 1 shows some examples of these studies. To address *RQ1*, we analyzed how hint modalities impact learning outcomes. *Text-based hints* showed positive results in 17 of 30 studies but varied by context—3 had no effect, 3 were negative, and 7 were mixed (e.g., Lee & Chen, 2009). *Multi-type hints* (e.g., text + graphic, audio, or video) were most effective, with 29 positive outcomes. "Text and Graphic" was the most successful combination (20 positive, 4 mixed, 1 negative). Other combinations (e.g., text + video) also showed consistently positive outcomes.

For *RQ2*, multi-type hints were particularly effective in *elementary* (n = 10) and *higher education* (n = 8). Middle school results were also strong for both text and multi-type hints (n = 7 each). High schools showed some benefit from both types.

Text hints had no effect in 4 studies and negative outcomes in 3, mostly in middle and mixed-level settings. In contrast, multi-type hints consistently outperformed others across all levels.

These results suggest that multi-type hints are the most robust strategy for enhancing learning outcomes across educational stages (see Figure 2).

Figure 1

Adapted PRISMA Flow Chart

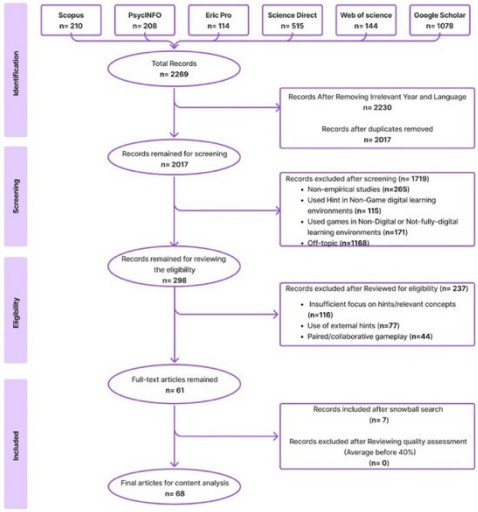

Figure 2

Distribution of Hint Types and Their Educational Levels Across Different Outcomes

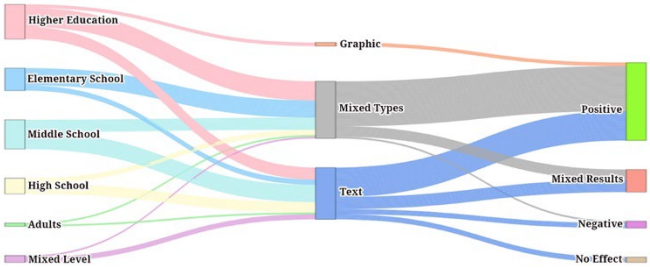

Table 1

A Sample of Selected Studies in this Systematic Review (N = 68)

Authors & Year	Game Name	Educational Levels	Type of Hint	Outcomes
Dai et al. (2023)	E-Rebuild	Higher Education	Text, Graphic	Positive
Kao et al. (2017)	Crayon Physics Deluxe	High School	Graphic, Video	Positive
McLaren et al. (2022)	Decimal Point	Middle School	Text	No effect
Rahimi et al. (2021)	Physics Playground	High School	Text, Vedio	Mixed

Discussion and conclusion

The findings suggest that hints generally lead to positive outcomes, aligning with Vygotsky's theory of the Zone of Proximal Development (1978), which emphasizes guided learning support.

Focusing on multi-type hints, the study identified strategies to improve student outcomes across educational levels. Multi-type hints showed the most positive results, demonstrating broad applicability (Chen & Tang, 2023; Easterday et al., 2017; Chen & Hwang, 2015). For instance, Chen and Hwang (2015) found that combining text, graphics, and video significantly improved learning achievement, motivation, and flow.

Although multi-type hints are generally effective, their impact varies by context and educational level. Higher education benefited from both text-based and multi-type hints, while elementary schools showed stronger results with multi-type hints. Across age groups, multi-type hints proved effective at all levels. Text hints also showed promise, especially in middle schools and higher education, though results varied. Negative and null outcomes in some cases—particularly in middle schools—highlight the importance of thoughtful design, so hint strategies should be adapted to the learner's age, prior knowledge, and the complexity of the task. For example, a simple text hint may be effective in a logic puzzle for college students but less helpful for younger learners struggling with abstract math concepts. Designers should consider these contextual elements alongside modality when developing hint systems in educational games. Future research should explore how adaptive or personalized hint systems can respond to learner needs in real time and how different hint types function in various instructional and game design contexts. In conclusion, while multi-type hints tend to yield stronger results, effectiveness

depends on context. A meta-analysis is recommended to quantify these effects and better understand the role of educational level and other contextual factors.

References

Anderson, C. G., Goeke, M., Hussein, B., Carpenter, Z., Salehi, S., & DeLiema, D. (2022). Baba is Hint-Designing a Scaffolding Guidebook for Game-Based Learning.

Chen, C. H., & Hwang, G. J. (2015, July). Improving learning achievements, motivations and flow with a progressive prompt-based mobile gaming approach. In *2015 IIAI 4th international congress on advanced applied informatics* (pp. 297-302). IEEE.

Chen, M. Y., & Tang, J. T. (2023). Developing a digital game for excel skills learning in higher education-a comparative study analyzing differences in learning between digital games and textbook learning. *Education and Information Technologies*, 28(4), 4143-4172.

Dai, C. P., Ke, F., Pan, Y., & Liu, Y. (2023). Exploring students' learning support use in digital game-based math learning: A mixed-methods approach using machine learning and multi-cases study. *Computers & Education*, 194, 104698.

Easterday, M. W., Aleven, V., Scheines, R., & Carver, S. M. (2017). Using tutors to improve educational games: A cognitive game for policy argument. *Journal of the Learning Sciences*, 26(2), 226-276.

Hjert-Bernardi, K., Melero, J., & Hern'ndez-Leo, D. (2012, July). Comparing the effects on students' behavior of two hint techniques embedded in a digital game-based learning tool. *In 2012 IEEE 12th International Conference on Advanced Learning Technologies* (pp. 138-140). IEEE.

Kao, G. Y. M., Chiang, C. H., & Sun, C. T. (2017). Customizing scaffolds for game-based learning in physics: Impacts on knowledge acquisition and game design creativity. *Computers & Education*, 113, 294-312.

Lee, C. Y., & Chen, M. P. (2009). A computer game as a context for non-routine mathematical problem solving: The effects of type of question prompt and level of prior knowledge. *Computers & Education*, 52(3), 530-542.

Lee, M. J., & Chiou, J. (2020). Animated hints help novices complete more levels in an educational programming game. *Journal of computing sciences in colleges*, 35(8).

Mayer, R. E. (2019). Computer games in education. *Annual review of psychology*, *70*(1), 531-549.

McLaren, B. M., Richey, J. E., Nguyen, H., & Hou, X. (2022). How instructional context can impact learning with educational technology: Lessons from a study with a digital learning game. *Computers & Education*, 178, 104366.

McLaren, B. M., & Nguyen, H. A. (2023). Digital learning games in Artificial Intelligence in Education (AIED): A review. *Handbook of Artificial Intelligence in Education*, 440-484.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & PRISMA Grup*, T. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Annals of internal medicine, *151*(4), 264-269. https://doi.org/10.1136/bmj.b2535.

Pluye, P., Gagnon, M. P., Griffiths, F., & Johnson-Lafleur, J. (2009). A scoring system for appraising mixed methods research, and concomitantly appraising qualitative, quantitative and mixed methods primary studies in mixed studies reviews. *International journal of nursing studies*, 46(4), 529-546.

Rahimi, S., Shute, V., Kuba, R., Dai, C. P., Yang, X., Smith, G., & Fernández, C. A. (2021). The use and effects of incentive systems on learning and performance in educational games. *Computers & Education*, 165, 104135.

Richey, J. E., Nguyen, H. A., Mehrvarz, M., Else-Quest, N., Arroyo, I., Baker, R. S., ... & McLaren, B. M. (2024, July). Understanding Gender Effects in Game-Based Learning: The Role of Self-Explanation. *In the International Conference on Artificial Intelligence in Education* (pp. 206-219). Cham: Springer Nature Switzerland.

Sun, C. T., Chen, L. X., & Chu, H. M. (2018). Associations among scaffold presentation, reward mechanisms and problem-solving behaviors in game play. *Computers & Education*, 119, 95-111.

Theelen, H., Van den Beemt, A., & den Brok, P. (2019). Classroom simulations in teacher education to support preservice teachers' interpersonal competence: A systematic literature review. *Computers & Education*, 129, 14-26.

Vygotsky, L. S., & Cole, M. (1978). Mind in society: Development of higher psychological processes. *Harvard university press*.

Acknowledgments

We would like to acknowledge the assistance of ChatGPT-4 for providing language editing and proofreading support. The content and ideas presented in this paper are entirely our own.