How Gaming Activities Shape Lower Secondary School Pupils' Understanding of Artificial Intelligence

Magdalena Zavodna, Hana Ulrichova and Katerina Kostolanyova
University of Ostrava, Faculty of Education, Department of Information and Comunication Technologies, Ostrava, Czech Republic

Magdalena.Zavodna@osu.cz
Hana.Ulrichova@osu.cz
Katerina.Kostolanyova@osu.cz

Abstract: As artificial intelligence (AI) becomes increasingly integrated into everyday life, there is a growing need to develop not only technical skills among lower secondary school pupils, but above all an understanding of how AI works and the ability to use it critically and effectively. The aim of this study was to determine whether incorporating selected game-based activities, specifically escape rooms and activities focused on "learning" a simple artificial intelligence model related to ocean cleanup and the creation of fake news in the Canva app using AI tools, leads to a better understanding of how AI works and improves pupils' ability to use these technologies effectively. The research was conducted as a pedagogical experiment at a lower secondary school in the Czech Republic. A total of 56 pupils aged 14 to 15 were involved in the study, divided into one control group and two experimental groups. The experiment took place over three class periods as part of the computer science curriculum, with data collected through pre-tests and post-tests, analysis of pupils' outputs, and a self-evaluation questionnaire in which pupils assessed individual activities and the extent of their impact on their understanding of the subject matter and motivation to learn. The results show that the pupils in the experimental group achieved significant improvement compared to the control group. These pupils demonstrated a greater understanding of the basic principles of how artificial intelligence works, as well as an improved ability to effectively use AI tools when solving problems. At the same time, a higher level of motivation to learn was observed. The strongest motivation was identified in the activity focused on creating fake news. The findings suggest that the implementation of game elements into computer science instruction represents an effective approach to developing AI literacy in lower secondary school. The study thus contributes to expanding knowledge about the possibilities of didactically utilizing game-oriented activities in the field of artificial intelligence education and offers insights for further research and pedagogical practice.

Keywords: Pedagogical Experiment, Lower Secondary School, Artificial Intelligence, Escape Room, Educational Apps.

1. Introduction

The rapid integration of AI into society requires an urgent redefinition of basic education (UNESCO, 2021). Traditional digital literacy, which focuses on software and hardware control, is insufficient for modern algorithmic systems (Long and Magerko, 2020). Pedagogical focus must shift toward complex competencies addressing both the cognitive and ethical aspects of human-AI coexistence (Ng et al., 2021).

We live in an era where AI has ceased to be the domain of science fiction literature and specialized laboratories and has become an integral part of everyday reality (Xiaoyu et al, 2025). The younger generation interacts with these technologies constantly, often without a deeper understanding of how they work (Long and Magerko, 2020)

However, while youth intuitively consume AI technologies, they often lack a deeper understanding of how they work, their limitations, and their risks (Long and Magerko, 2020). Educational systems must transform basic technical instruction into comprehensive AI literacy that encompasses technological understanding, effective use, and critical thinking (Long and Magerko, 2020; Ng et al., 2021; Touretzky et al., 2019).

Most AI education research targets college or high school settings, leaving a shortage of studies focused on lower secondary pupils (Sanusi, 2021). Highly abstract concepts like machine learning or data bias are difficult for younger students to grasp. This problem is highly relevant to the Czech lower secondary education system, which is currently revising its Framework Educational Programs (FEP) to emphasize "new computer science." Current teaching practices lack empirical data from real-world pedagogical experiments, leaving most recommendations purely theoretical.

The aim of this research is therefore to verify the impact of activities incorporating gamification elements on pupils' understanding of AI-related content. Based on this objective, the main research question was formulated: *What impact does teaching with gamification elements have on understanding how AI works*? Subsequently, the hypothesis was established: *Teaching with gamification elements leads to a greater understanding of the*

principles of how AI works. A sub-research question further focuses on: *How do pupils perceive the motivational effect of the proposed activities*?

The significance and usefulness of this study are thus evident on three key levels. The study provides empirical evidence on how game-based design (escape games, interactive simulations, creative digital production) affects both the cognitive (understanding) and affective (intrinsic motivation) components of learning. It offers an immediately applicable toolkit for computer science teachers, featuring three validated educational scenarios: a digital escape game, an AI learning simulation, and the critical creation of fake news in the Canva app. It fosters critical AI literacy, teaching pupils to deconstruct AI-generated content (e.g., recognizing fake news) to defend against disinformation, manipulation, and the loss of digital autonomy. The development of critical AI literacy is a key weapon against disinformation, manipulation, and the loss of digital autonomy. By showing how to teach pupils to deconstruct AI-generated content (e.g., recognize fake news), the study directly contributes to building society's resilience against the risks associated with the massive rise of generative models.

1.1 Artificial Intelligence in Lower Secondary Education

According to Long and Magerko (2020), "AI literacy" extends beyond programming; it is a set of competencies enabling individuals to critically evaluate, communicate with, and utilize AI as a problem-solving tool. This framework consists of three dimensions:

- Cognitive: Understanding algorithmic principles, data structures, and machine learning limits.
- Instrumental: Effectively deploying AI tools (e.g., prompt formulation).
- Ethical-critical: Reflecting on privacy, algorithmic bias, and socioeconomic impacts (Ng et al, 2021).

Critical thinking serves here as a fundamental defensive and productive mechanism. Given that generative models exhibit an inherent tendency toward so-called confabulations or hallucinations, students' ability to subject AI outputs to rigorous verification becomes a fundamental prerequisite for digital autonomy (Fulsher et al, 2026).

The integration of AI-related topics into official educational programs is undergoing significant evolution both globally and locally. International strategic frameworks, such as UNESCO's (2021) recommendations for AI in education, explicitly call on national governments to incorporate AI instruction into the core curricula of elementary and secondary schools. The goal is to eliminate the threat of a new type of digital divide that would isolate the technologically illiterate population.

In the Czech Republic, this is driving the revision of the FEP and the introduction of "new computer science" (Kostolanyova et al, 2023). This shift moves instruction away from basic user support toward computational thinking. Computational thinking acts as a pedagogical bridge; teaching machine learning is most effective when students engage empirically with datasets rather than abstract mathematical theory (Sanusi, 2021).

Students aged 12 to 15 operate within Piaget's stage of formal logical operations, allowing them to handle abstract concepts and social causality (Inhelder and Piaget, 1958). While younger children learn through anthropomorphic games (Druga et al, 2019), adolescents require authentic learning where they can actively deconstruct algorithm architectures, such as social media recommendation systems.

However, educators must overcome two distinct barriers in this age group:

- Technocentric skepticism: Believing the material is mathematically inaccessible.
- Uncritical technological optimism: Accepting AI-generated outputs without cognitive effort.

1.2 The Potential of Gamification in Education

In contemporary education, we are increasingly faced with the need to transform traditional teaching methods so that they align with digital reality and enhance students' intrinsic motivation. One of the most prominent trends addressing this need is the implementation of game principles into the educational process, in other words, gamification.

In academic settings, gamification is most commonly defined as the use of game design elements in non-game contexts (Deterding et al, 2011). In the context of education, this is not merely about "playing games" in class, but about the deliberate structuring of instruction using mechanisms such as points, badges, leaderboards, and above all, narrative, immediate feedback, and the opportunity to learn from mistakes without fatal consequences (Kapp, 2012).

According to Werbach and Hunter (2012), gamification operates on three levels:

- Dynamics: Broader concepts such as narrative, emotion, and the gradual revelation of information.
- Mechanics: Processes that drive the activity forward (challenges, cooperation, competition).
- Components: Specific tools (points, levels, tasks).

In education, gamification has a strong psychological foundation. According to self-determination theory (Ryan and Deci, 2000), game elements increase intrinsic motivation by fulfilling three basic human needs: autonomy (the ability to make choices), competence (experiencing success in overcoming challenges), and relatedness (collaboration with peers).

A specific and recently highly popular form of gamification is Educational Escape Rooms (EER). They are based on commercial escape rooms, but their primary goal is not merely entertainment, but rather the achievement of specific educational objectives (Veldkamp et al, 2020).

An escape room in education provides an environment where students collaborate to solve a series of puzzles and tasks within a limited time to achieve a specific goal (e.g., “escaping” the room or solving a mystery).

Fotaris and Mastoras (2019) emphasize that escape games transform the student’s role from a passive recipient of information to an active problem-solver. The main benefits of EER include:

- Development of soft skills: They significantly stimulate communication, teamwork, and critical thinking.
- Immediate feedback: Students immediately see whether their solution is correct (the key fits, the code works), which supports so-called natural learning from mistakes.
- Linking theory with practice: Tasks require the application of knowledge in a simulated but realistic context.

Combining gamification with AI instruction in lower secondary school appears to be a highly effective teaching strategy. AI concepts (such as machine learning, algorithms, or pattern recognition) are often abstract and difficult for students to grasp. As Gee (2003) notes in the context of game-based learning theory, good games create so-called “zones of proximal development,” where students are able, with modest support, to solve tasks that would be too complex for them on a purely theoretical level. An escape game or gamified activity (e.g., training a model to clean up the oceans or detect fake news) gives abstract algorithms tangible meaning. Students thus do not merely consume theory about AI, but experience its functionality in practice, which directly leads to a critical understanding of technologies, the core of digital literacy (Ng et al, 2021).

1.3 A Didactic Approach to Selected AI Concepts

The effective implementation of AI in lower secondary education requires the translation of complex algorithmic concepts into age-appropriate teaching models. Contemporary pedagogy therefore prioritizes active and game-based learning, which allows students to understand how complex systems work through experimentation and interaction.

The development of generative AI is shifting the nature of digital creation toward co-creation between humans and AI (Xiaoyu et al, 2025; Lin and Tan, 2025). The integration of generative tools into graphic editors, such as Canva, helps students overcome technical barriers and focus on the concept and content of their creations. Studies confirm that the use of text-to-image generators increases motivation, develops language and logical skills, and supports students’ creative self-efficacy (Xiaoyu et al, 2025; Lin and Tan, 2025). A key role is played by the creation of precise prompts, which guide students toward more accurate expression and work with syntax.

However, there is a risk of excessive automation in content creation and a weakening of deeper cognitive engagement. Effective teaching must therefore include reflection, critical evaluation of outputs, and discussion of ethical issues, copyright, and plagiarism (Long and Magerko, 2020; Touretzky et al, 2019).

One of the most pressing challenges today is also the misuse of generative AI to create disinformation and deepfakes. Traditional media education focused solely on text analysis is no longer sufficient (Fulsher et al, 2026). Therefore, a “prebunking” strategy is gaining traction in education, that is, preventive “vaccination” against disinformation, in which students learn the principles of manipulative content in a safe environment (Ecker et al, 2022; Fulsher et al, 2026).

Research shows that the most effective approach is the guided creation of simulated fake news by the students themselves (Fulsher et al, 2026). When creating manipulative news using AI tools, students become aware of the psychological mechanisms of disinformation and the ease with which it spreads. Subsequent fact-checking and reflection strengthen critical thinking, skepticism toward unverified information, and long-term information resilience (Ecker et al, 2022).

2. Methodology

2.1 Research Design

To achieve the study's objectives, a pedagogical experimental research design was chosen, consisting of one control group and two experimental groups. The independent variable was the type of instruction (traditional vs. instruction with gamification elements), while the dependent variable was the level of understanding of artificial intelligence principles, operationalized through a test score. The research used a pretest–posttest design, which allowed for tracking changes in pupils' knowledge before and after the intervention.

2.2 Research Sample

The research sample consisted of a total of 56 pupils aged 14 to 15. The pupils were divided into three classes. The control group (Con) consisted of 20 pupils, experimental group 1 (Ex1) consisted of 17 pupils, and experimental group 2 (Ex2) consisted of 19 pupils.

The groups were considered comparable in terms of previous performance in computer science and socioeconomic background, based on school records and the teacher's assessment.

2.3 Course of the Intervention

The experiment took place over three consecutive 45-minute computer science classes. The individual groups differed in the extent and form of gamification elements used; see Table 1. The control group underwent traditional instruction based primarily on lecture-style teaching and independent student work without gamification elements (lecture + worksheets). The experimental groups further differed from one another in the versions of the activities used. In the Ex1 group, only partial gamification was implemented in the form of an online escape game; however, the "ocean cleanup" activity was carried out here in the same way as in the Con group, namely in the form of a worksheet. The Ex2 group underwent fully gamified instruction (all activities in an interactive format). This arrangement made it possible to compare different levels of gamification in instruction.

Table 1: Comparison of the activities used in all groups

Activity	Control Group (Con)	Experimental Group 1	Experimental Group 2
Escape game	lecture-style teaching	✓	✓
AI learning simulation	worksheet	worksheet	✓
The creation of fake news	✓	✓	✓

The first class began with a pre-test to assess the pupils' initial level of knowledge and skills in the field of AI. This was followed by an activity called "AI Lab," in which pupils were tasked with completing an online escape game. In the first part of the second lesson, pupils tried their hand at AI training using the HourOfCode web app in an activity focused on "Cleaning Up the Ocean," or completed a worksheet on the same topic. In the second part of the lesson, pupils were given a final assignment: working in pairs, they were to create a "fake news" newspaper article in the Canva app using AI tools to generate fake images. In the final lesson, pupils had time to complete their own fake news piece and then took a post-test and a motivational questionnaire. The instruction for all groups aligned with the theme "How New Technologies Work Around Me" according to the current FEP and School Educational Program.

2.4 Description of the Activities Used

The intervention program in the experimental groups was based on the pedagogical concept of game-based learning and consisted of three key thematic activities, each supported by a specific software tool.

2.4.1 Digital Escape Game "AI Lab"

The first activity focused on introducing basic AI terminology and concepts. For this purpose, an educational escape game was created in the Genially app. During the game, pupils completed individual tasks focused on how AI works, detecting AI outputs, and prompt engineering. For correctly solving each task, pupils received a piece of code. At the end of this activity, they were prompted to unlock the final phase of the game (stabilizing the AI in the lab) and, by entering the code, they discovered whether they had made any mistakes while completing the individual tasks.

2.4.2 Machine Learning Simulation "Cleaning Up the Ocean"

The HourOfCode educational app was used to help pupils understand the principles of training AI models and the issue of data bias. Pupils took on the role of AI programmers and manually classified objects on the screen (fish vs. trash), thereby creating a training dataset for AI machine learning. They then analyzed the success of their model and deliberately tested how insufficient or one-sidedly biased data (e.g., training only on plastic bottles) would affect AI's ability to correctly identify other types of trash. This activity directly visualized the AI learning process.

2.4.3 Creating "Fake News"

The final activity linked the technical functioning of generative AI with the development of critical thinking and media literacy. Pupils were tasked with creating believable-looking fake news in the Canva graphic editor using integrated AI image generators. In the final phase of the activity, a guided deconstruction of these outputs took place, during which pupils analyzed specific artifacts of the generated content (e.g., syntactic anomalies, anatomical errors in the generated images) and discussed the ethical risks associated with the misuse of AI.

2.5 Research Tools

Pupils' cognitive knowledge was measured using an identical pretest and posttest consisting of 10 items (7 multiple-choice questions and 3 open-ended questions requiring a brief response). This was a knowledge test focused on understanding the principles of AI, recognizing AI outputs, and basic application skills. The content validity of the test was verified through expert assessment by two experts in computer science education.

The research also included a questionnaire that pupils completed at the end of the final class session. The questionnaire contained 7 items on a 5-point Likert scale (strongly disagree to strongly agree) and 3 closed-ended questions with yes/no options. The questionnaire assessed the pupils' level of motivation, the subjective benefits of the given game elements for learning, the clarity of the activities, and their preferred type of activities.

2.6 Data Processing

Quantitative data from the pretests and posttests were analyzed statistically using the PAST4 software. First, the normality of the data distribution was tested using the Shapiro-Wilk test. Since the data were normally distributed, a parametric paired t-test was used to compare the results across groups (Con, Ex1, Ex2).

3. Results

3.1 Comparison of Pretests and Posttests

Before proceeding to the actual testing of the null hypotheses, basic descriptive statistics (sample means and standard deviations) were calculated for the pretest and posttest results, as well as for the absolute educational gain (defined as the difference between the posttest and pretest scores). The research sample consisted of a total of 56 respondents divided into three groups: experimental group 1 (N = 17), experimental group 2 (N = 19), and the control group (N = 20). The maximum possible score on both tests was 10. A detailed descriptive overview is summarized in Table 2.

Table 2: Average score

Group	Pretest M (SD)	Posttest M (SD)	Average Profit (SD)
Ex1	5,82 (1,29)	8,94 (1,30)	+3,12 (1,93)
Ex2	5,05 (1,61)	8,42 (1,12)	+3,37 (1,77)
Con	5,75 (1,68)	8,00 (1,56)	+2,25 (2,38)

To select the appropriate statistical method (parametric vs. nonparametric tests), the normality of the distribution of differences (gains) was tested for each group using the Shapiro-Wilk test. The significance level was set at the standard 0.05. If $p > 0.05$, the data are normally distributed. No statistically significant deviation from a normal distribution was found in any of the three groups (see Table 3). The normality of the data was thus confirmed, and a paired t-test could be used for further analysis (see Tables 4, 5, and 6).

Table 3: Data normality test

Group	Ex1	Ex2	Con
N	17	19	20
Shapiro-Wilk W	0,9498	0,9392	0,9051
p(normal)	0,4526	0,2555	0,05148

Table 4: Ex1 paired t-test

t test			
Mean difference:	3,1176	95% conf.:	(2,1239 4,1113)
t:	-6,651	p (same mean):	5,57E-06
Exact:	-	p (same mean):	0,00012207

Table 5: Ex2 paired t-test

t test			
Mean difference:	3,3684	95% conf.:	(2,5151 4,2218)
t:	-8,2931	p (same mean):	1,46E-07
Exact:	-	p (same mean):	3,81E-06

Table 6: Con paired t-test

t test			
Mean difference:	2,25	95% conf.:	(1,115 3,385)
t:	-4,1491	p (same mean):	0,00054513
Exact:	-	p (same mean):	0,0014038

The aim of the main phase of the analysis was to verify whether respondents in the individual groups demonstrated a demonstrable increase in knowledge compared to the control group after completing the experimental instruction. For the Ex1 group, the average score increased from 5.82 on the pretest to 8.94 on the posttest. A paired t-test (Table 4) confirmed that this average increase of +3.12 points is statistically highly significant ($t = 6.65$; $p < 0.001$). The calculated Cohen's d value of 1.61 indicates, according to standard criteria, an extremely large effect of the intervention. In the case of the second experimental group (Ex2), a shift was recorded from a baseline value of 5.05 to a final score of 8.42 points. This average gain of +3.37 points proved to be statistically the most significant based on a paired t-test (Table 5) ($t = 8.29$; $p < 0.001$). Cohen's $d = 1.90$ indicates an exceptionally strong scientific effect of the applied method. This finding indicates a strong influence of gamification activities on pupils' acquired knowledge.

In the control group (Con), the mean shifted from 5.75 to 8.00 points (average gain of +2.25). Based on a paired t-test (Table 6), a statistically significant improvement was also observed in this group. Although the effect size expressed by Cohen's $d = 0.94$ still represents a significant effect, it is evident that it is lower than in both experimental groups.

The hypothesis that teaching incorporating gamification elements leads to better mastery of the subject matter and a better understanding of how AI works was confirmed by the results from both experimental groups.

3.2 Evaluation Questionnaire

All pupils in the Ex2 group unanimously agreed that they would like to use this type of activity more often in class. In the Ex1 group, however, this figure was “only” 70.6% of pupils.

Creating their own "fake news" in the Canva app was successful across all groups, with the strongest motivational effect observed in the partially gamified group Ex1 (76.5%) and the fully gamified group Ex2 (68.4%), while in the control group without a gaming context, only 55% of pupils found it enjoyable.

The online escape game was also a big hit with pupils in the experimental groups; 70.6% of pupils in group Ex1 enjoyed it, and 63.2% of pupils in group Ex2 enjoyed it. In group Ex2, however, of all three activities, pupils enjoyed teaching AI about ocean cleanup the most, at 78.9%.

Pupils in the fully gamified environment (Ex2) rated the activities as highly understandable (78.9%) and easy to complete (68.4%). A full 73.7% of them reported that these games helped them understand the material better, and 57.9% believe they will remember it longer as a result. In the Ex1 group, which had a lower level of interactivity, this subjective effect was not as pronounced. 58.8% of pupils rated the activities as understandable, and 52.9% as easy to complete. Only 41.2% of pupils reported that these activities helped them better understand the subject matter and remember it longer (52.9%).

4. Conclusion

The main research hypothesis, that teaching incorporating gamification elements leads to a better understanding of how AI works, was unequivocally confirmed by the results of the pedagogical experiment. The data clearly show that both experimental gamified teaching methods demonstrate high and consistent effectiveness. The implementation of both types of interventions (Ex1 and Ex2) led to a demonstrable and robust increase in pupils’ knowledge, as evidenced by the extremely high effect sizes. When comparing Ex1 and Ex2, the collected data do not allow us to designate either method as statistically superior. The Ex2 group did show a slightly higher growth rate (net gain), which could have been caused by a higher number of gamification activities or simply by knowledge differences among pupils. However, all these minor deviations are fully within the limits of natural sampling variability. From a pedagogical perspective, both experimental methods can be considered comparably successful alternatives that demonstrably outperform the standard growth observed in the control group.

From the perspective of pedagogical practice, a key finding is that, based on the collected data, no statistically significant difference in performance was found between partial (Ex1) and full (Ex2) gamification. Minor deviations in growth are fully within the bounds of natural sample variability. For teachers, this leads to an optimistic conclusion: even the inclusion of just one game element (e.g., online escape games) can dramatically increase the effectiveness of instruction compared to conventional lectures with worksheets.

The sub-research question focused on how pupils perceive the motivational effect of the proposed activities. The results confirmed that the implementation of game elements has a strong psychological impact on intrinsic motivation, comprehension of the material, and the integration of theory and practice. The activity focused on machine learning simulation, “Ocean Cleanup,” became the absolute favorite of the fully gamified Ex2 group. This simulation clearly visualized the AI learning process and the risks associated with one-sided, biased data for the pupils.

Teaching with gamification elements also had a significant motivational effect in the experimental groups and a positive influence on easier comprehension of the subject matter and its longer retention, which is also confirmed by data from other studies focused on game-based learning (e.g., Veldkamp et al., 2020; Gee, 2003; Kapp, 2012).

The study offers an immediately applicable toolkit for computer science teachers, directly supporting the Czech Republic's “new computer science” curricular shift toward developing computational thinking. By creating simulated fake news in a safe classroom environment, pupils uncover the psychological triggers of disinformation and learn to rigorously verify AI outputs, building long-term societal resilience against generative models. Integrating game elements and digitally relevant scenarios into lower secondary instruction allows

adolescents to successfully deconstruct complex technological concepts. This shifts them from naive consumers into critical editors of their own informational reality.

This study also has its limitations, including, for example, a small sample size (56 pupils) from a single school, their specific age range (14–15 years), the short duration of the intervention, and the absence of a follow-up assessment, which made it impossible to objectively verify long-term retention of the material; instead, only the immediate improvement in knowledge and the pupils' subjective opinions could be assessed.

Ethics Declaration

The research was conducted in a lower secondary school setting with prior written informed consent obtained from the parents or legal guardians of participating pupils. No additional formal ethical clearance was required for this research.

AI Declaration

ChatGPT was used solely for language editing and grammatical refinement. The ideas, structure, interpretations, and conclusions presented in this manuscript are entirely the authors' original work.

References

Deterding, S., Dixon, D., Khaled, R. and Nacke, L. (2011). From Game Design Elements to Gamefulness: Defining Gamification. In *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments*, pp 9–15. https://doi.org/10.1145/2181037.2181040

Druga, S., Vu, S. T., Likhith, E., and Qiu, T. (2019). Inclusive AI literacy for kids around the world. In *Proceedings of FabLearn 2019*, pp 104–111. https://doi.org/10.1145/3311890.3311904

Ecker, U. K., Lewandowsky, S., Cook, J. et al. (2022). The psychological drivers of misinformation belief and its resistance to correction. *Nature Reviews Psychology*, pp 13–29. https://doi.org/10.1038/s44159-021-00006-y

Fotaris, P. and Mastoras, T. (2019). Escape Rooms for Learning: A Systematic Review. In *13th European Conference on Games Based Learning*, pp 235–243, https://doi.org/10.34190/GBL.19.179

Fulsher, A., Pagkratidou, M., Kendeou, P. (2026). GenAI and misinformation in education: A systematic scoping review of opportunities and challenges. *AI and Society*, Vol 41, No. 1, pp 1373–1385. https://doi.org/10.1007/s00146-025-02536-y

Gee, J. P. (2003). What Video Games Have to Teach Us About Learning and Literacy. *Computers in Entertainment*, pp 1–4. https://doi.org/10.1145/950566.950595

Inhelder, B., & Piaget, J. (1958). *The growth of logical thinking from childhood to adolescence*. Basic Books. https://doi.org/10.1037/10034-000

Kapp, K. M. (2013). T*he gamification of learning and instruction: Game-based methods and strategies for training and education*. John Wiley & Sons Inc.

Kostolanyova, K., Cirus, L., Javorcik, T., Simonova, I. (2023). A New Concept of the Informatics Curriculum in the Czech Republic: Teacher Reflection on the First Year of the Transition Period. *Sustainability*, Vol 15, No. 5, pp 1–19. https://doi.org/10.3390/su15054091

Long, D. and Magerko, B. (2020). What is AI literacy? Competencies and design considerations. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, pp 1–16. https://doi.org/10.1145/3313831.3376727

Lin, X. and Tan, H. (2025). A Systematic Review of Generative AI in K–12: Mapping Goals, Activities, Roles, and Outcomes via the 3P Model. *Systems*, Vol 13, No. 10, pp 840–865. https://doi.org/10.3390/systems13100840

Ng, D. T. K., Leung, J. K. L., Chu, S. K. W and Qiao, M. S. (2021). Conceptualizing AI literacy: An exploratory review. *Computers and Education: Artificial Intelligence.* Vol 2, No. 1*,* pp 1–11. https://doi.org/10.1016/j.caeai.2021.100041

Ryan, R. M. and Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology*. Vol 25, No. 1, pp 54–67. https://doi.org/10.1006/ceps.1999.1020

Sanusi, I. T. (2021). Teaching machine learning in K-12 education. In *Proceedings of the 17th ACM Conference on International Computing Education Research*, pp 395–397. https://doi.org/10.1145/3446871.346976

Touretzky, D., Gardner-McCune, C., Martin, F. and Seehorn, D. (2019). Envisioning AI literacy for K-12 What Should Every Child Know about AI?. *Communications of the ACM*, Vol 33, No. 1, 9795–9799. https://doi.org/10.1609/aaai.v33i01.33019795

UNESCO. (2021). *AI and education: Guidance for policy-makers.* United Nations Educational, Scientific and Cultural Organization. https://doi.org/10.54675/PCSP7350

Veldkamp, A., Daemen, J., Teekens, S. et al. (2020). Escape boxes: Bringing escape room experience into the classroom. *British Journal of Educational Technology,* Vol 51, No. 4, pp 1220–1239. https://doi.org/10.1111/bjet.12935

Werbach, K. and Hunter, D. (2012). *For the Win: How Game Thinking can Revolutionize your Business*. Wharton Digital Press.

Xiaoyu, W., Zainuddin, Z., and Hai Leng, C. (2025). Generative Artificial Intelligence in Pedagogy: A Systematic Review of Empirical Studies (2022–2024). *Cogent Education,* Vol 12, No. 1, https://doi.org/10.1080/2331186X.2025.2485499