

Development of Gamification-Based Interactive Media to Enhance Learning Outcomes

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ABSTRACT

The objective of this research is to find out the technique of development, feasibility and efficacy of interactive learning media gamification. The Research and Development (R&D) technique linked the Lee and Owens multimedia model with the Dick and Carey instructional design paradigm in 12 phases. The product validation was done by the content, media, and instructional design experts and field testing was carried out on 30 students of grade ten at SMAN 1 Jampangtengah. Data were collected using expert validation questionnaires, student response forms, and pretest-posttest evaluations and analysed by feasibility percentage and normalised gain (N-Gain). The media feasibility was rated "Very Good" with strong validation scores from design experts (91.68%), content experts (91.67%), media experts (97.75%) and student trials (91.62%). Moreover, the media also have an important role in the results of student learning with an average N-Gain score of 0.74 (high category). Therefore, this gamification-based interactive media is valid, practical, and very successful to improve the computational thinking skills in high school Informatics learning.

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1. INTRODUCTION

We are living in an era of unavoidable technological change, and this disruption impacts all industries including education. The way humans communicate, work and even think has changed due to big data, the Internet of Things (IoT) and Artificial Intelligence (AI). Education should not only be a passive witness to these changes, but should take the initiative in training the young to adapt and master these changes. Education is to nurture the potential of pupils, transforming them into intelligent, morally upright, confident persons, who have the abilities to meet the needs of the present world.

This strategic role requires education to do more than simply transfer knowledge; it must also develop higher-order thinking skills to meet the complex and unpredictable problems of the future. The national education aims to develop the character and civilisation of the nation's dignity, as stipulated in Law No. 20 of 2003 on the National Education System. This rule necessitates the formulation of education policies and practices that can produce Indonesian citizens who are intellectually adept, exemplary in character and able to make a good contribution to national civilisation.

But the digital transformation of the 21st century and the advance of artificial intelligence have made the problems of education more difficult. With the emergence of the Industrial Revolution 4.0, the ability to think logically and systematically and to solve problems has become the paramount in the workforce. Education should not only teach pupils what is known, but also foster their thinking, learning, and adapting skills to enhance their computational thinking skills. This begs the fundamental question: what is the school system in Indonesia doing about a problem of this magnitude? Is today's curriculum geared to equip a generation that will not only consume technology but will have the ability to create it?

This is an important stage where the paradigm of education in Indonesia will be changed. The government has been proactive in issuing the Minister of Primary and Secondary Education Regulation (Permendikdasmen) No. 13 of 2025 and the Decree of the Minister of Primary and Secondary Education on Guidelines for the Implementation of Coding and Artificial Intelligence (AI) in Early Childhood, Primary and Secondary Education. Both these regulations clearly articulate a core priority of teaching computational thinking. The basic educational objectives incorporated in these changes represent a real change, not simply a change of names for subjects or a lengthening of class time.

Urgency is further strengthened by the fact that the use of interactive and adaptable learning media is a major factor in overcoming student disengagement in the classroom [1]. Today, online literacy of students entails not only the use of technical devices, but also the ability to absorb information critically and integratively [2][3]. The integration of artificial intelligence and coding is also formally integrated into the national technical Academic Paper on the new direction of primary and secondary education [4]. Globally, the trend of instructional design for online learning is leaning heavily toward technology-based simulations for problem-solving [5]. It has been demonstrated that such simulations are effective in the foundational sciences, informatics, and other exact sciences [6].

Continuing this policy, the government came out with a curricular framework to solve informatics education problems in secondary schools. The Computational Thinking strand is clearly integrated in The Informatics Learning Outcomes (Capaian Pembelajaran / CP) in the Phase E Merdeka Curriculum. This element has four fundamental pillars: decomposition, pattern recognition, abstraction, and algorithm design. The four pillars are arranged sequentially and hierarchically, showing that the skills for computational thinking are not obtained instantaneously, but rather be built systematically from the simplest talents.

It is important to point out that computational thinking is not the same as programming a computer. Computational thinking is a problem solving method based on notions from computer science. However, these strategies can be used in different fields and in daily life. A student who has computational thinking can: (1) break complicated problems into smaller problems (decomposition); (2) find patterns or similarities in seemingly random data (pattern recognition); (3) ignore irrelevant details to find the essence of the information (abstraction); and (4) create algorithms to produce logical and measurable step-by-step solutions.

The policy requires a radical adjustment in the teaching paradigm. Curriculum modifications alone will not lead to real improvements in the quality of education unless they are accompanied by changes in instructional practices. The traditional teacher-centered, one-way expository approach has to be replaced by engaging, inspirational and student-centered approaches. In this new paradigm, teachers are no longer the exclusive source of knowledge, but they are facilitators, who encourage and build learning settings that enable students to find, construct and apply their own knowledge.

Policy makers often disregard the realities of dynamics in the classroom. In education, the gap between *das Sollen* (what ought to be) and *das Sein* (what actually is) has been a long time coming. This gap, if left untreated, represents a big concern. Field experience data demonstrates a wide gap between student learning and curricular goals.

During the requirements assessment at SMAN 1 Jampangtengah, Sukabumi Regency, serious problems were detected in informatics instruction, especially in the area of computational thinking. An analysis of the performance of tenth-grade students in the academic year of 2025-2026 showed that class X-9 only earned an average score of 66 in Computational Thinking, which was far from the Learning Goal Attainment Criteria that had been set. Table 1 offers detailed data.

Table 1. Distribution of Computational Thinking Scores among Class X-9 Students

Score Range	Category	Frequency	Percentage
55–59	Very Low	1	3%
60–64	Low	11	31%
65–69	Moderate	21	58%
70–74	High	3	8%
	(Unmastered)		
75–100	Mastered	0	0%
Total		36	100%

As shown in Table 1, none of the students reached learning mastery (minimum passing score of 75) and 15 out of 36 students (41.7%) scored below the class average. Students have difficulty with algorithmic logic, pattern identification and issue decomposition. No student met the minimum proficiency required. The highest score was 72 which is still far below the KKTP.

Interviews with informatics teachers on December 17, 2025, showed that expository instruction and static modules (PDFs/worksheets) are still the prevailing teaching approaches. Teachers tried to employ gaming media based on blocks, but they admitted that “the existing media only address individual student interests” and does not visualise abstract ideas like algorithms and abstraction. Teachers also commented that the two most difficult pillars for students were abstraction and algorithm design, since students “get stuck unless provided with initial scaffolding examples.”

The needs survey conducted to 57 tenth-grade students of SMAN 1 Jampangtengah showed that the majority of them were not pleased with conventional techniques and want to have instructional modification. Table 2 Student Preferences Regarding Learning Media Formats

Table 2. Student Preferences for Learning Media Formats

Media Type	Number of Students	Percentage
Mobile Applications	15	0,26
Learning Websites	13	0,23
Interactive Games	13	0,23
Interactive Simulations	8	0,14
Animated Videos	4	0,07
Quizzes with Instant		
Feedback	3	0,05
Printed Modules	1	0,02

The most common key phrases from the open-ended and multiple-choice replies were “engaging challenges/missions” (chosen by nearly all participants), “points/rewards for task completion,” “levels (easy to hard),” and a desire to “learn through fun game-like experiences.” Of 57 pupils, 48 (84%) indicated that badges and levelling elements would greatly enhance their motivation. The findings suggest that kids need dynamic, relevant and stimulating media interventions. Therefore, the main basis for the development of gamification-based interactive media in this study is the empirical insights.

The aim of this research is to build interactive media using gamification tactics based on the Moodle Learning Management System (LMS). Here gamification is not about just fun but it is a pedagogical intervention that uses game design elements like points, badges, leaderboards, and levels to improve student motivation, engagement and learning results. The reason why gamification is chosen is that it is directly related to the cognitive requirements of computational topics. Within gamification, the levelling process is based on the notion of decomposition, where complicated problems are divided into digestible chunks. This also stimulates iterative learning, with quick feedback in the form of points and incentives. Finally, scaffolded tasks assist lower cognitive load while promoting a growth mentality.

Therefore, this study aims to: (1) explore the development technique of gamification-based interactive media; (2) analyse the viability of this instructional strategy; and (3) assess its usefulness in increasing student learning outcomes in computational thinking.

1.1. Models for Development of Learning Media

One of the educational technologies is a creation of learning media. Educational technology is a study and ethical practice of supporting learning and enhancing performance by creating, using, and managing appropriate technological processes and resources [7]. The development domain [8] is the process of transforming design specifications into physical form, and its implementation must adhere to a systematic and measurable Research and Development (R&D) framework [9].

Dick and Carey Development Model The systems approach is one of the most complete instructional design frameworks. According to [10], instruction is a systematic process that is designed to attain desired learning objectives through interrelated components. It is a process orientated model, with focus on the development of instructional strategies and analysis of student's characteristics and needs. This model is very ideal for implementation due to its precise and systematic stages [11].

The Dick and Carey model is comprised of ten systematic steps: (a) identify instructional goals; (b) conduct instructional analysis; (c) analyse learners and contexts; (d) write performance objectives; (e) develop assessment instruments; (f) develop instructional strategy; (g) develop and select instructional materials; (h) design and conduct formative evaluation; (i) revise instruction; and (j) design and conduct summative evaluation. The main benefit of this strategy is its comprehensive instructional analysis and systematic objective creation [12].

Lee and Owens Development Model: In Multimedia-Based Instructional Design, [13] declare that the major objective of their development model is to offer a consistent, reproducible, and effective framework for multimedia-based learning. The model has five major phases, (a) assessment/analysis phase (covering needs, front-end, audience, technology, situational, task, and media analysis), (b) design phase, (c) development phase, (d) implementation phase, and (e) evaluation phase. The Lee and Owens model is quite adequate to build interactive e-learning systems since it has a complete technical framework, as shown by [14]. [15] confirmed that its stages consistently support e-learning module development.

Model Integration in Research: This research merges the Dick & Carey and Lee & Owens models. Dick & Carey are strong in pedagogical rigour (content structure, objective formulation, instructional analysis) while Lee & Owens are strong in technical multimedia design (interface design, digital content development, system implementation). Both together give a balanced development process. The rationale for this choice is the assessment of other models, namely the ADDIE model, which pays attention to linear systems [16] [17], the Borg & Gall model, which pays attention to macro-scale empirical validation [18] [19], and the ASSURE model, which pays attention to classroom media utilisation [20] [21]. Synthesis of Dick & Carey and Lee & Owens best meets pedagogical and technical requirements of multimedia.

1.2. Interactive learning medium

In the current educational paradigm, interactive learning media is not only visual assistance, but it emphasises learner control [22]. Unlike linear media such as static movies, students can choose the sequence of content, repetition and pacing. Multi-tiered testing (small and large scale) [23] is the key to product feasibility. Traditional methods are less effective than context-based interactive media to improve student results [24]. Validation by experts in design and material is very important to guarantee didactic quality before being put into practice [25].

The quality of interaction dictates knowledge transfer. It is therefore important that the design of the media be rigorous as unguided game-based interactions might lead to cognitive overload [26]. [27] extends the interaction to the social arena, where the good media arouses collective attention and interaction. This success depends on the integration of web-based interactive media with active learning models [28]. Modular LMS solutions, such as Moodle, provide for flexibility in adjusting features without licensing limits [29], and also encourage logical thinking through asynchronous discussion forums [30].

1.3. Gamification in education

Gamification is a process of applying game design principles in non-game environments to enhance engagement and motivation [31]. There are two types of gamifications: structural gamification (adding game elements without changing the content) and content gamification (changing content to be game-like). Recent empirical studies suggest that gamification of online learning greatly enhances the learning drive over conventional techniques [32] and gamified digital quizzes boost student engagement and literacy [33].

According to [34] the success of gamification is contingent on a strong theoretical basis. Gamification and immersive technology can foster supportive virtual environments [35]. However, [36] caution about the "novelty effect" where the initial engagement decreases with time, underlining the significance of the "familiarisation effect" for long-term design. Theoretically, levelling is consistent with cognitive hierarchy methods [37], rapid feedback is consistent with behaviourist reinforcement [38], and scenario design is consistent with long-term motivation [39].

1.4. Computational Thinking.

Computational thinking is the heart of informatics education. [40] Conceptual process of creating issues and solutions in such a way that they may be executed by human or computer agents. It involves decomposition, pattern recognition, abstraction and algorithm design. Sequences, loops and conditionals can be taught successfully [41]. Computational thinking and active learning models improve critical thinking and problem-solving skills [42], enabling structured logical reasoning [43].

The paradigm shift from ICT to informatics emphasises the development of system logic rather than software literacy [44]. This is consistent with the cognitive learning taxonomies [45], 21st-century critical thinking [46], constructivist knowledge building [47], STEM skill acquisition [48], social knowledge validation [49], and adapting to various learning styles [50].

2. METHOD

Study explanation in chronological order, encompassing study design, research technique, test administration and data collecting [51] [52]. The process of research description should be backed by references so that the explanation is scientifically acceptable [7] [8].

2.1. Research Design and Approach

This study used Research and Development (R&D) technique [52] to design interactive learning media based on gamification and to test the effectiveness of the media. The research methodology was an embedded experimental mixed-method design, the quantitative data were the primary data source, and qualitative data were used to develop the product. The media effectiveness was evaluated using the pre-experimental one-group pretest-posttest design based on the pattern $O_1 \rightarrow X \rightarrow O_2$ is the pretest, O_1 is the treatment (instruction with the gamification-based interactive media), and O_2 is the posttest [51].

2.2. Research Site and Subjects

The research was conducted at SMAN 1 Jampangtengah, Sukabumi Regency, West Java. The location was purposively sampled to determine the study site. The research site was based on the preparedness of computer laboratory infrastructure and the implementation of the Phase E Curriculum. The research was carried out for six months, starting in December 2025 and ending in May 2026, during the even semester of the academic year 2025/2026. The research subjects were 30 students of class X-9 tenth grade with a sufficient level of digital literacy proficiency.

2.3. Development Procedure

The development process involved the Dick and Carey instructional design paradigm [10] and the Lee and Owens multimedia development model [13] in 12 methodical phases as follows:

2.3.1. Front-End Analysis (Needs Assessment) Teacher interviews, student surveys, and documentation studies to identify learning gaps.

- 2.3.2. Instructional Analysis: Classification of the hierarchy of Computational Thinking content into three stages (decomposition, pattern recognition & abstraction, and algorithm creation).
- 2.3.3. Learner and Context Analysis: looking at students' characteristics, their degrees of online literacy, and the presence of technical infrastructure.
- 2.3.4. Formulating Specific Learning Objectives: Developing 15 performance indicators following the ABCD framework.
- 2.3.5. Development of Assessment Instruments Construction of the pretest and posttest instruments (30 multiple-choice items) to be tested for validity and reliability.
- 2.3.6. Instructional Strategy Development: Design of gamification mechanics and learning scenarios (points, badges, leaderboards and levels).
- 2.3.7. Selection of Instructional Materials: curating and organising Computational Thinking Learning Content
- 2.3.8. Storyboard Development: Mapping the system architecture (flowchart) and UI design.
- 2.3.9. Interactive Media Development : Moodle 5.1 setup, Gamification plugin integration (Level Up!, Stash), Digital learning asset creation
- 2.3.10. Expert Validation: Three field experts (instructional design, content and media experts) provided formative evaluation.
- 2.3.11. User Testing: One-to-one trials ($n = 3$), small-group trials ($n = 15$), and large-group field testing ($n = 30$)
- 2.3.12. Summative Evaluation: Assessing product effectiveness using the pretest-posttest method and normalised gain (N-Gain) analysis

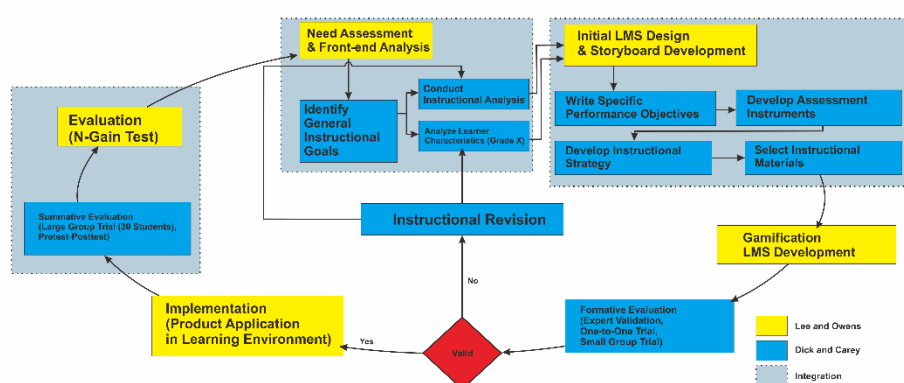


Figure 1. Integrated Dick & Carey and Lee & Owens development model flowchart

2.4. Data Collection Instruments

Data were collected using the following structured instruments:

2.4.1. Teacher Interview Instrument

Semi-structured interview technique with 30 questions spread across eight analytical domains (audience, task, critical-incident, situational, objective, technology, media and extant-data analysis).

2.4.2. Student Needs Questionnaire

15-item questionnaire covering five analytical dimensions (audience, task, critical incident, situational and media).

2.4.3. Method

Study Protocol. This includes comprehensive investigation of student grade archives, syllabi, instructional modules and computer laboratory facilities.

2.4.4. Expert Validation Questionnaires

40 items using a 1-5 Likert scale to assess the characteristics of Instructional Design, Content and Media.

2.4.5. Student Response Questionnaire

A 15-item measure of media practicality and usability in user trials.

2.4.6. Learning Achievement Test

A 30-item multiple choice test based on Computational Thinking cognitive levels (C_2 – C_5). The post-trial item analysis found 20 valid items ($r_{calculated} > 0.361$) with a good internal consistency reliability ($KR - 20 = 0.832$).

2.5. Data Analysis Techniques

Qualitative data gathered from field notes, interviews, and open-ended feedback sections were analyzed using the interactive data analysis model [53], involving data reduction, data display, and conclusion drawing/verification.

Quantitative data analysis comprised the following methods:

2.5.1. Validity and Practicality Analysis

Calculated using the percentage formula:

$$\text{Feasibility Percentage (\%)} = \frac{\text{Total Score Obtained}}{\text{Maximum Score}} \times 100\%$$

The resulting percentages were categorized using the standard evaluation criteria: 90%–100% (Very Good), 75%–89% (Good), 65%–74% (Fair), 55%–64% (Poor), and 0%–54% (Very Poor).

2.5.2. Effectiveness Analysis (N-Gain)

Student learning gains were measured using the normalized gain formula:

$$g = \frac{\text{Posttest Score} - \text{Pretest Score}}{\text{Maximum Score} - \text{Pretest Score}}$$

The g values were classified as: High ($g > 0.7$), Moderate ($0.3 \leq g \leq 0.7$), and Low ($g < 0.3$). The effectiveness percentage was interpreted as: $> 76\%$ (Effective), $56\% - 75\%$ (Fairly Effective), $40\% - 55\%$ (In-effective), and $< 40\%$ (Ineffective).

3. RESULTS AND DISCUSSION

3.1. Development of Interactive Media Procedure

With twelve interconnected phases, we have managed to complete the development process effectively. A major instructional gap was observed during the needs assessment phase. The average score of students was only 66 (below the passing criterion/KKTP of 75) with a 0% mastery rate. The discussions with teachers indicated that the two most difficult computational pillars are abstraction and algorithms. Also, the student poll results showed that 84% of students wanted gamification aspects.

Hence, an interactive media platform based on the Moodle Learning Management System (LMS) and gamification plugins (Level Up! for the point system and Stash for badges) was built. The computational materials were organised in a three-tier hierarchy:

3.1.1. Level 1 (Decomposition)

Students are taught how to reduce complicated issues into smaller, more manageable pieces. This level contains 5 learning exercises, an interactive drag & drop pre-quiz mission and an end of level quiz.

3.1.2. Level 2 (Pattern Recognition & Abstraction)

Students learn to recognise patterns and filter relevant information. It contains case study (financial report analysis) and analytical assignment of “Juragan Seblak”.

3.1.3. Level 3 (Algorithms)

Students are introduced to flowcharts and basic coding in Python to design logical stages. This level includes 7 learning exercises, coding simulations, and programming assignments. It also has asynchronous discussion boards, an anonymous leader board that updates in real time, and quick feedback on every quiz. The development approach was revised three times based on comments from validators and user trials.

3.2. Interactive Media Feasibility

3.2.1. Expert Validation Results

The validation results from the three experts are presented in Table 3.

Table 3. Summary of Expert Validation Results

Validator	Assessed Aspect	Percentage	Qualification
Instructional Design Expert	Instructional Design Appropriateness	0,92	Very Good
	Content-Curriculum Alignment	0,87	Good
	Media Interactivity	0,96	Very Good
	Average	91.68%	Very Good
Content Expert	Instructional Design Appropriateness	0,9	Very Good
	Content-Curriculum Alignment	0,95	Very Good
	Media Interactivity	0,9	Very Good
	Average	91.67%	Very Good
Media Expert	Instructional Design Appropriateness	0,97	Very Good
	Media Interactivity	0,99	Very Good
	Average	97.75%	Very Good

The validators' revision notes were: (1) develop more clear and measurable learning objectives aligned with the ABCD framework; (2) include visual features on the pretest-posttest items; (3) remove instructional language; and (4) resynchronise media navigation flow. All modifications were strictly done before the field trials.

3.2.2. User Trial Results

Table 4. Summary of User Trial Results

Trial Phase	Number of Subjects	Percentage	Qualification	Decision
One-to-One	3 students	85.19%	Good	Revised as necessary
Small Group	15 students	85.62%	Good	Revised as necessary
Large Group	30 students	91.62%	Very Good	No revision needed

3.3. Interactive Media Effectiveness

3.3.1. Pretest and Posttest Results

The effectiveness test was conducted by administering a pretest prior to the treatment and a posttest after the students engaged with the gamification-based interactive media for 5 sessions. The results are detailed in Table 5.

Table 5. Pretest and Posttest Scores

Description	Pretest	Posttest
Highest Score	83.33	100.00
Lowest Score	20.00	76.67
Average Score	47.56	87.56
Standard Deviation	16.24	6.78

The data demonstrate highly significant academic progress. The average pretest score (47.56) surged to 87.56 in the posttest, falling into the "High" category. This forty-point increase indicates that the media intervention substantially enhanced the students' conceptual understanding.

3.3.2. N-Gain Analysis

The N-Gain calculation for each student yielded an average N-Gain of 0.74 (74%). The distribution of the N-Gain categories is presented in Table 6.

Table 6. Distribution of N-Gain Categories

Category	Range	Number of Student s	Percentag e
High	$g > 0.7$	20	66.7%
Moderate	$0.3 \leq g \leq 0.7$	10	33.3%
Low	$g < 0.3$	0	0%

Based on the table it can be seen that 20 students (66.7%) obtained the high category and 10 students (33.3%) obtained the moderate category. None of the students were in the low category. This medium is rated as “Fairly Effective” to “Effective” (average 74%) on the effectiveness interpretation scale.

One interesting result is that students with very low starting pretest scores (between 20 and 30) can successfully attain posttest scores above 80, producing an N-Gain between 0.75 and 0.92. This indicates how useful gamified interactive media are for students with lesser initial abilities, since they get the basic principles step-by-step, with quick feedback and a scaffolding technique (levelling).

3.4. Discussion

3.4.1. Advantages of the Developed Media

The advantages of the produced interactive media with gamification are as follows. Firstly, there is no question that structured gameification, i.e. the use of points, badges, leaderboards and levels, dramatically boosts student engagement and learning outcomes. The results are consistent with the results of [54] and [55]. Second, the progressive material hierarchy (Level 1: decomposition; Level 2: patterns and abstraction; Level 3: algorithms) effectively reduces students' cognitive load [41]. Third, the synchronous multimedia design which incorporates images, audio, text and video helps to visualise abstract concepts. Fourth, students might learn anytime anywhere by cloud-based access, thereby facilitating autonomous learning.

Because of its large scalability and open source nature, Moodle being a cloud based platform is vital to the requirements of educational institutions. Moodle has been demonstrated to be better than other commercial e-learning platforms [56] [57]. The interface of Moodle has, from its very beginnings, been underpinned by a social constructivist theory, which allows learners to construct their own meaning [58]. Still the ideal choice for structuring independent and remote learning in the current post-pandemic age [59].

3.4.2. Media Success Factors

The success of this media can be ascribed to a number of key aspects. First, the systematic development process, integrating the models from Dick & Carey and Lee & Owens, made sure that all the technical and pedagogical components were covered in depth. Second, the product underwent extensive professional validation (design, content and media) before going live to guarantee quality. Third, the multi-level user testing approach (one-to-one, small group, and big group) supported the incremental detection and resolution of usability issues. Fourth, the educational infrastructure such as internet connectivity, computer laboratories and proper electronic literacy of the pupils aided the implementation.

The efficacy of this R&D product [60] is dependent on comprehensive instructional preparation from the beginning phases. The model of instruction employed can be fitted to the peculiarities of the audience. This is in line with the success of the ASSURE model in IT-based media design [20] or the circular approach of the Kemp model which emphasises total curriculum structuring [61]. The use of organised routes, much like the flexibility of the ADDIE framework,

provided an objective approach for validation. Furthermore, the scaffolding or instructional advice included in the media [62] permitted constructive alignment of game aspects with the key curricular objectives. This directly affects students' autonomy and deep learning [63]. This is also supported by the fact that traditional methods cannot have a deeper cognitive impact than carefully planned interactive media [64].

3.4.3. Research Limitations

The research findings are highly successful, however there are some limitations that should be taken into account. Firstly, the trial was done in only one school with a small sample of thirty students within a fairly short period of one semester. Second, the effectiveness assessment was done only using the cognitive learning outcomes disregarding the psychomotor and affective domains. Third, 33.3% of the students (10 persons) were in the moderate range (N-Gain 0.3–0.7), indicating that the media has not entirely accommodated the entire spectrum of student cognitive capacities. Fourth, because of time constraints, item difficulty and discrimination indices were not analysed in-depth.

Nonetheless, these restrictions provide useful opportunities for further research. We advocate that future gamified system designs should integrate smart chatbot technologies as virtual assistants to minimise declines in student motivation while facing coding problems [65]. The use of simulations based on a realistic five-step instructional design can be viewed as an advanced evaluation framework to promote higher-order thinking skills [16].

4. CONCLUSION

Based on the research findings and discussion, the following conclusions can be drawn:

4.1. The development procedure for the gamification-based interactive media was successfully executed through 12 integrated phases utilizing the Dick & Carey and Lee & Owens models. This procedure commenced with a needs assessment (revealing a performance gap with an average score of $66 < \text{KKTP } 75$ and a 0% mastery rate), instructional analysis, learner and context analysis, formulation of specific learning objectives (15 indicators), development of assessment instruments (20 valid items with a reliability of $\text{KR-20} = 0.832$), development of gamification-based instructional strategies, selection of instructional materials, storyboard development, interactive media development on the Moodle LMS (integrating *Level Up!* and *Stash* plugins), expert validation, user trials (one-to-one, small group, and large group), and concluded with a summative evaluation. This procedure proved to be systematic, structured, and highly replicable by other researchers or educators in similar instructional contexts.

4.2. The feasibility level of the gamification-based interactive media was categorized as very good and declared highly feasible for use. The expert validation results yielded excellent percentages: instructional design expert at 91.68% (with 96% for the interactivity aspect), content expert at 91.67%, and media expert at 97.75% (with 99% for the interactivity aspect). User trials demonstrated a steady increase in practicality from the one-to-one trial (85.19% / Good) to the small group trial (85.62% / Good), culminating in the large group trial at 91.62% with a "Very Good" qualification. The highest indicators in the large group trial were the content-curriculum alignment (94%) and the synchronization of text, video, and images (averaging 4.70–4.80). Consequently, this media fulfills Nieveen's three criteria for product quality: validity, practicality, and effectiveness.

4.3. The effectiveness level of the gamification-based interactive media falls into the high category, with an average N-Gain score of 0.74 (74%). The media significantly increased the students' average score from 47.56 (very low category) in the pretest to 87.56 (very high category) in the posttest, marking a substantial 40-point increase. A total of 20 out of 30 students (66.7%) achieved a high N-Gain category ($g > 0.7$), while 10 students (33.3%) were in the moderate category ($0.3 \leq g \leq 0.7$). A pivotal finding is that students with very low initial pretest scores (20–30) successfully attained posttest scores above 80 (N-Gain 0.75–0.92), demonstrating that this media is highly beneficial in assisting students with low baseline abilities to progressively build their conceptual understanding of Computational Thinking.

In conclusion, the developed gamification-based interactive learning media is proven to be valid, practical, and effective in enhancing high school students' computational thinking skills in

Informatics subjects. It is recommended that this media be implemented more broadly and further developed by integrating Artificial Intelligence (AI)-based adaptive features. Future studies should also evaluate its effectiveness across a larger population utilizing a quasi-experimental design.

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