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Bridging Popular Culture and Informatics Learning: Assessing Cognitive Gains through Dr. Stone-Based Edutainment

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Abstract
Students frequently struggle with abstract informatics concepts, necessitating the use of contextual instructional media. Although the educational applications of anime are well established in other disciplines, its efficacy in informatics remains underexplored. This study evaluated Dr. Stone as a means of facilitating the comprehension of these concepts and expanding the Cognitive Theory of Multimedia Learning (CTML). A quantitative pre-experimental one-group pretest-posttest design was employed, involving 24 purposively sampled eighth-grade students at *MTs Thursina YBM PLN*. The intervention integrated anime using explicit segmentation and scaffolding guided by teachers. Data from expert-validated HOTS-based multiple-choice tests were analysed using paired-samples t-tests and N-Gain metrics. The results revealed a statistically significant improvement in the test scores ($t = 2.73$, $p = 0.012$, $d = 0.56$). However, the overall N-Gain was low ($M = 0.20$), with 62.50% exhibiting low improvement, 29.17% moderate improvement, and 8.33% high improvement. These findings indicate that visual engagement with popular media alone does not guarantee a conceptual understanding of technical subjects. Consequently, elements of popular culture improve learning outcomes only when they are explicitly integrated into structured teacher-facilitated pedagogy.

Keywords: anime; dr. stone; edutainment; ict learning; popular culture

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INTRODUCTION

The global transition toward a computationally driven society requires profound mastery of informatics, a construct distinct from basic digital literacy. While students are adept digital consumers, they fundamentally lack higher-order algorithmic thinking and system-level comprehension. Recent international data from the IEA's ICILS (2025) indicate that less than 20% of middle school students globally can independently solve complex computational logic problems (Fraillon, 2025). In Indonesia, the urgency to foster algorithmic logic is demonstrated by the rapid expansion of the Bebras Indonesia Challenge, a premier national benchmark for CT. Official statistics reveal a massive surge in participation, growing from 1,553 students in 2016 to 59,742 students across 1,648 schools in 2024 (Bebras Indonesia 2024). Notably, the middle school demographic (*Penggalang/SMP/MTs*) represents the largest single student segment, accounting for 24,872 participants in 2024. However, despite this unprecedented

national exposure to computational logic puzzles, classroom assessments confirm that students still experience severe conceptual bottlenecks when transitioning from introductory logic games to formal, abstract informatics curriculum topics, particularly Computer Systems and Data Communication (Hillman et al., 2021; Kleftodimos, 2024; Weng, 2024). Consequently, educators face an urgent challenge: translating logic-driven algorithmic materials into highly contextualised formats that support deep conceptual mastery for a visually oriented digital generation.

To address the cognitive gap in STEM education, educators have increasingly incorporated popular culture and animation into their teaching strategies (Beege & Ploetzner, 2025). A thematic synthesis of the recent literature identified several distinct trends. First, anime has been shown to significantly enhance adolescent engagement and affective interest as a motivational tool (Amodia et al., 2026; Suprapto et al., 2024; Tahir et al., 2023). Second, in terms of scientific representation, edutainment media serve effectively as visual analogies, exemplified by "Cells at Work" for illustrating biological processes (Rahmawati et al., 2026; Susanto et al., 2023). Third, narrative-based multimedia learning is recognised for its ability to contextualise complex information. Despite the well-documented affective benefits of popular media, a critical debate persists regarding its cognitive efficacy in highly technical subjects such as mathematics. Notably, whether the intrinsic engagement offered by commercial anime can extend beyond affective outcomes (motivation) to achieve measurable cognitive outcomes (conceptual mastery) in abstract, non-narrative disciplines such as computational logic remains largely unexplored.

Consequently, a complex research gap remains, rendering earlier studies inadequate in clarifying how anime aids in learning informatics. In terms of context, past edutainment research has predominantly focused on descriptive sciences such as biology or language arts (Maulina & Nurjaleka, 2020), neglecting the exploration of logic-based STEM disciplines. From a theoretical standpoint, the ways in which popular media supports the development of structural mental models for algorithmic thinking are not well understood (Kozma, 1991). Methodologically, earlier studies have mainly used qualitative methods or self-reported surveys, lacking strong experimental frameworks. Empirically, there is a significant lack of objective cognitive assessments for measuring conceptual changes. These four gaps underscore a crucial oversight: the belief that engaging with narratives naturally leads to technical understanding has yet to be scientifically validated.

Drawing on these theoretical and empirical perspectives, this study proposes a conceptual framework that integrates Narrative Learning Theory with Mayer's Cognitive Theory of Multimedia Learning (CTML) (Mayer & Fiorella, 2021; Sweller, 2020). The framework conceptualises these two perspectives as complementary processes through which narrative-based media can support students' cognitive engagement and conceptual learning. Narrative elements can capture and sustain students' attention while presenting complex information using coordinated visual and verbal channels. However, the limited capacity of working memory means that rapid visual transitions and other dynamic features of commercial media may impose unnecessary cognitive demands and increase the extraneous cognitive load. When these demands are controlled through appropriate instructional design, learners may be able to more effectively organise incoming information, construct meaningful schemas, and develop a deeper conceptual understanding of abstract informatics concepts.

Within this conceptual framework, *Dr. Stone* provides an optimal test case for the study. The justification for selecting this specific medium extends beyond its popularity; it is distinguished by its relatively accurate scientific representation and ability to visualise complex technological processes, step by step. By dividing the assembly of technology, such as shaping raw copper into an adder circuit or establishing a wire communication network, into sequential narrative arcs, anime naturally accommodates segmentation. These characteristics map directly

onto the targeted informatics curriculum for Computer Systems and Data Communication, providing a highly contextualised visual anchor (Da Silva & De Araujo Neto, 2024).

In this context, this study aims to explore how a Dr. Stone-inspired intervention, led by teachers, can improve students' grasp of Computer Systems and Data Communication. The effectiveness of this intervention was evaluated using objective measures of cognitive development. The study also examines how learning gains differ across various informatics concepts, aiming to pinpoint both the strengths and limitations of using narrative-based multimedia in teaching. By merging Narrative Learning Theory with the CTML, this study offers a theoretical perspective on how narrative structures and multimedia can facilitate the understanding of complex technical information. On an empirical level, this study broadens the scope of research on learning through popular media by investigating the role of commercial anime in informatics education and distinguishing between genuine cognitive improvements and mere engagement.

METHOD

This study employed a quantitative pre-experimental, one-group pretest-posttest design. Although lacking a control group, this design establishes baseline effect sizes and evaluates pedagogical feasibility prior to large-scale trials. Maturation and testing effects were mitigated by condensing the intervention into a two-week timeframe and randomising the test question sequences (Furrow, 2019).

The research was conducted at MTs Thursina YBM PLN in West Java. A priori power analysis (G*Power; power = 0.80, alpha = 0.05) required 20-24 participants. Using purposive sampling, 24 male eighth-grade students (ages 14-15) were selected. This cohort possessed uniform basic digital literacy but lacked formal computer logic training. All participants consumed anime for leisure but had no experience using it as a structured educational medium for learning English.

The intervention spanned three 80-minute meetings covering Computer Systems and Data Communication. Specific clips from *Dr. Stone* Season 1 (episodes 11, 12, 15, and 16) illustrate hardware component transformation and network data transmission. To manage cognitive load, a pause-and-discuss strategy limited viewing to 5–7-minute segments. During pauses, the teacher provided pedagogical scaffolding by mapping the on-screen animations to technical diagrams. The students simultaneously completed interactive problem-solving worksheets. An independent assessor ensured the consistent implementation of the program using fidelity checklists.

Cognitive gains were measured using a 20-item Higher Order Thinking Skills (HOTS) multiple-choice test (C4-C6), covering Computer Systems, Data Communication, and Technological Logic. A panel of three experts confirmed the content and construct validity, yielding a high Aiken's V/CVI coefficient of 0.88. The empirical reliability, tested using Cronbach's alpha, was 0.566, which is an acceptably moderate value for complex exploratory HOTS instruments.

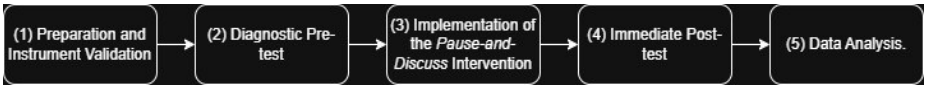

Figure 1. Research workflow diagram outlining the sequential steps from preparation to data analysis

Data were analysed using IBM SPSS Statistics ($\alpha = 0.05$). The analytical procedure included the Shapiro-Wilk normality test, followed by a paired-samples t-test to assess statistical significance. The magnitude of the treatment was quantified using Cohen's d. Conceptual improvement was evaluated using Hake's Normalised Gain (N-Gain), categorised

as high ($g > 0.70$), moderate ($0.30 \leq g \leq 0.70$), and low ($g < 0.30$) (Nissen et al., 2018). The actual calculated outcomes of these measurements are presented comprehensively in the Results section of this paper. The research workflow is illustrated in Figure 1. Institutional ethical consent was obtained prior to the study, and the data were strictly de-identified. Normalised gain scores were categorised as high ($g > 0.70$), moderate ($0.30 \leq g \leq 0.70$), and low ($g < 0.30$). Institutional consent was obtained before the study, and all participant data were deidentified to meet research ethics standards.

$$g = \frac{Post - Pre}{Max - Pre} \quad (1)$$

RESULTS AND DISCUSSION

Results

The main objective of this study was to evaluate cognitive conceptual gains in abstract informatics concepts following the *Dr. Stone* anime intervention. To provide a comprehensive empirical evaluation, the data were systematically analysed using descriptive statistics, prerequisite normality testing, hypothesis testing, and normalised gain analysis. The analysis used data from 24 students ($n = 24$). Prior to inferential testing, descriptive statistics were calculated to map data distribution. The initial pre-test revealed a mean score of 52.92 ($SD = 16.54$, $SE = 3.38$), a median of 50.00, an estimated interquartile range (IQR) of 25.00, and a 95% Confidence Interval (CI) of [45.94, 59.90], with scores ranging from a minimum of 10 to a maximum of 80. Following the intervention, the post-test mean score increased to 62.92 ($SD = 21.16$, $SE = 4.32$), with a median of 70.00, an IQR of 35.00, and a 95% CI of [53.99, 71.85], ranging from 10–90.

A critical prerequisite for conducting a parametric paired-samples t-test is the normal distribution of paired differences (post-test minus pre-test). The Shapiro-Wilk test yielded a statistical value of $W = 0.94$, with an exact p-value of 0.158. As the p-value exceeded the 0.05 significance level, the assumption of normality was met, rigorously justifying the use of parametric hypothesis-testing.

A paired-samples t-test was performed to determine whether the differences in scores were statistically significant. The analysis revealed a significant increase in raw scores, with $t(23) = 2.73$ and an exact p-value of 0.012. The mean score difference between the post- and pre-test was 10.00 ($SE\ Diff = 3.66$), and the 95% confidence interval was [2.42, 17.58]. Cohen's d was calculated to be 0.56, indicating a medium effect size. This suggests that the educational intervention resulted in a moderate change in students' overall raw scores. A detailed statistical summary is presented in Table 1.

Table 1. Summary of paired sample t-test and effect size

Variable	n	Pre-test Mean (SD)	Post-test Mean (SD)	Mean Diff (SE)	95% CI of Diff	t(df)	exact p	Cohen's d
Informatics Score	24	52.92 (16.54)	62.92 (21.16)	10.00 (3.66)	[2.42, 17.58]	2.73 (23)	0.012	0.56

Figure 2 presents a boxplot showing the distribution of students' total scores before and after the multimedia intervention. The chart highlights an increase in both the median and interquartile range (IQR), suggesting a statistically significant enhancement in the overall performance. However, the main empirical value of the chart lies in its variance. The vertical

spread or height of the box is notably larger in the post-test than in the pre-test, whereas the lowest score remains unchanged at the bottom. This pattern provides an important educational insight: although the anime intervention increased the class average, it did not consistently reduce the comprehension gaps. The media's engaging qualities benefited some students more than others, leaving some still struggling with the content. This supports the theoretical assertion of this study that narrative edutainment alone is not an educational equaliser. This demonstrates that effectively managing extraneous cognitive load in abstract informatics topics necessitates highly tailored, teacher-guided scaffolding rather than just media exposure.

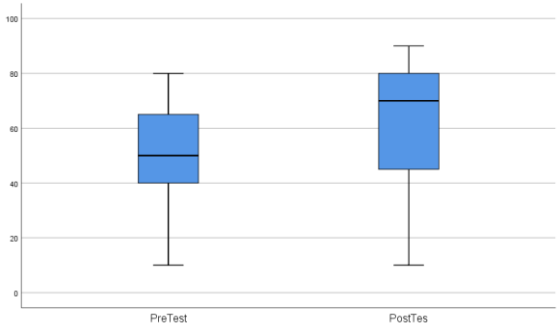

Figure 2. Boxplot distribution of pre-test and post-test scores

An in-depth examination using cognitive question indicators revealed notable differences in conceptual development across various subjects. As shown in Table 2, Data Communication experienced the most significant average increase (+14.30), whereas Computer Systems achieved the greatest normalised improvement proportion (N-Gain = 0.28). Both areas nearly reached moderate levels. In contrast, Technological Logic consistently showed the smallest score increase (+2.90) and the least conceptual growth, resulting in a minimal N-Gain of 0.07.

Table 2. Average scores and n-gain based on learning indicators

Indicator	n	Pre-test Mean	Post-test Mean	Mean Diff (SE)	95% CI of Diff	N-Gain	Category
Computer Systems	24	55.40	68.20	12.80 (4.50)	[3.49, 22.11]	0.28	Low
Data Communication	24	51.20	65.50	14.30 (5.10)	[3.75, 24.85]	0.25	Low
Technological Logic	24	52.16	55.06	2.90 (3.20)	[-3.71, 9.51]	0.07	Low

(**Note**: The N-Gain categorisation is interpreted as High ($g > 0.70$), Moderate ($0.30 \leq g \leq 0.70$), and Low ($g < 0.30$)).

Figure 3 displays a paired line plot depicting each student's overall score trajectory from the pre-test to the post-test, with the mean increase represented by a solid red line. This visualisation has two primary empirical significances. First, it visually confirms the statistically significant main effect of the intervention, as most individual trajectories exhibit a clear upward trend. Second, and of greater theoretical importance, the relatively parallel nature of these lines suggests a uniform, short-term performance enhancement rather than a substantial conceptual restructuring. The multimedia intervention effectively elevated baseline scores universally; however, it did not function as a cognitive equaliser, as students generally retained their relative-performance rankings. This visual evidence supports the study's central argument:

while popular culture media can enhance surface-level recall and short-term engagement, it does not inherently address individual disparities in mastering complex, abstract computational logic without targeted, differentiated scaffolding.

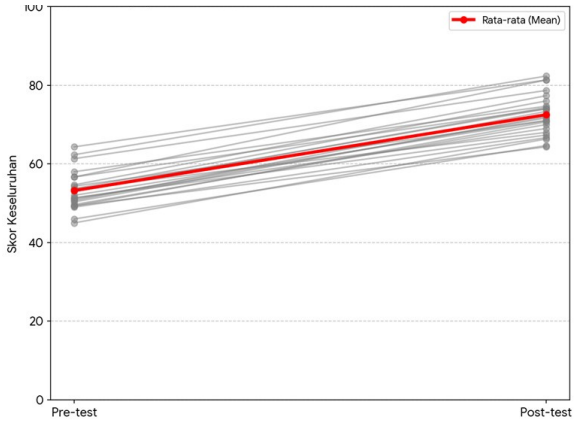

Figure 3. Paired line plot showing individual student changes

The normalised gain (N-Gain) was used to assess overall conceptual growth, resulting in an average of 0.20 (SD = 0.36, SE = 0.07), with a 95% confidence interval ranging from 0.05 to 0.35, categorising it as low. Examination of the variance in individual N-Gain scores indicated a broad range among participants: 62.50% of students (n = 15) demonstrated low improvement, 29.17% (n = 7) showed moderate improvement, and only 8.33% (n = 2) achieved significant improvement in their post-test scores.

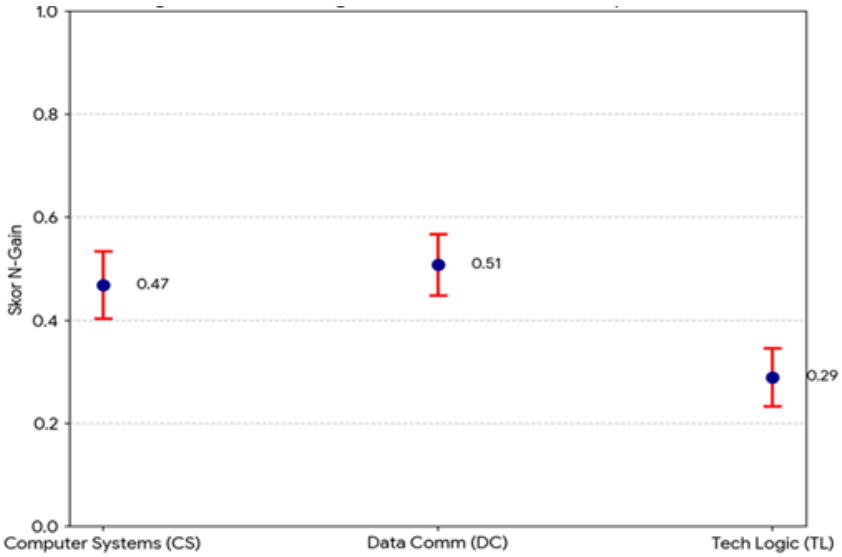

Figure 4. Individual n-gain distribution and error bars across indicators

Figure 4 presents the mean conceptual improvement scores (N-Gain) with 95% Confidence Intervals for the three learning indicators. The graph reveals a notable disparity in knowledge acquisition between the two groups. The Data Communication (DC) and Computer Systems (CS) indicators demonstrated moderate improvements, with mean scores of 0.51 and 0.47, respectively. In contrast, the Technological Logic (TL) indicator exhibited the lowest performance, with a mean score of 0.29, categorising it as low. The critical aspect of this visualisation is the red error bar. The confidence interval for the TL indicator did not overlap with those of the other two domains, providing strong statistical evidence of a significant

comprehension deficit in this logical domain. This empirical pattern underscores the limitations of narrative-based edutainment: while commercial anime effectively anchors tangible, structural, and descriptive concepts (such as computer hardware and networks), it struggles to support cognitive schema construction for abstract, sequential algorithmic reasoning without intensive teacher-led pedagogical scaffolding.

Discussion

The findings of this study provide a nuanced interpretation of the effectiveness of anime-based edutainment in informatics learning. The intervention resulted in a statistically significant improvement in students' learning outcomes, reflected by an average increase of 10.00 points and a medium effect size (Cohen's d = 0.56). However, the relatively low normalised gain (g = 0.20) indicates that the improvement represents modest conceptual development rather than substantial restructuring of knowledge. This distinction is important because statistical significance does not necessarily indicate educational significance; therefore, measurable improvement should be interpreted together with the magnitude of learning gains and the extent to which students achieve a deeper conceptual understanding (Nissen et al., 2018). These results suggest that *Dr. Stone*-based learning can support informatics achievement, but its contribution should be understood as a facilitating mechanism rather than a standalone solution for developing complex cognitive skills.

The findings extend previous research on multimedia and popular culture-based learning by demonstrating that the educational value of anime depends on instructional integration rather than media exposure. Previous studies have shown that multimedia learning can improve understanding when learners are supported in constructing meaningful connections between verbal and visual representations (Mayer and Fiorella, 2021). Similarly, research on educational animation indicates that animated representations are effective when learners are guided to interpret relevant features and connect visual information to conceptual knowledge (Ploetzner et al., 2020). In the present study, *Dr. Stone* provided contextual visualisation and narrative coherence that potentially supported students' initial understanding of informatics concepts. However, the limited normalised gain suggests that visual engagement and narrative context alone are insufficient to guarantee deeper conceptual mastery in learning.

The observed learning pattern can be explained through the principles of the CTML and Cognitive Load Theory. According to CTML, meaningful learning requires learners to actively select relevant information, organise it into coherent mental models, and integrate it with their prior knowledge (Mayer & Fiorella, 2021). Meanwhile, Cognitive Load Theory emphasizes that instructional materials must manage the limited capacity of working memory by reducing unnecessary cognitive demands and directing attention toward essential information (Sweller 2020). Although animation and narrative media can provide useful representations, complex visual transitions, simultaneous audiovisual information, and narrative elements may increase extraneous cognitive processing when they are not carefully structured (Skulmowski & Xu, 2022). Therefore, the moderate effect size observed in this study may be partly explained by the teacher-guided scaffolding strategy, which helped students connect anime representations with formal informatics concepts.

The differences in learning gains across informatics indicators provide additional insight into the boundary conditions of anime-based multimedia learning. Data Communication showed the highest absolute improvement, whereas Computer Systems achieved the highest normalised gain, and Technological Logic demonstrated the lowest improvement. This pattern suggests that narrative multimedia may be more suitable for concepts involving observable processes, sequential transformations, and concrete representations than abstract representations. Such concepts can be visually represented through narrative events, allowing students to establish connections between the depicted processes and scientific principles.

Conversely, abstract computational reasoning requires learners to construct internal relational structures that cannot be developed through visual observation alone. Therefore, topics involving algorithmic logic may require additional instructional strategies, including worked examples, explanation activities, problem-solving tasks, and opportunities for generative learning (Fiorella and Mayer, 2015).

These findings contribute to the broader discussion of edutainment by challenging the assumption that popular media automatically produces cognitive benefits for its consumers. Previous studies on anime-based learning have generally emphasised improvements in motivation, engagement, and conceptual understanding within specific disciplines, such as biology and science education (Amodia et al., 2026; Rahmawati et al., 2026; Susanto et al., 2023). However, the current findings indicate that the effectiveness of anime as an educational resource is conditional on the relationship between media characteristics, instructional design, and the cognitive demands of the learning objectives. This interpretation is consistent with Kozma's (1991) argument that media do not influence learning independently; rather, learning outcomes emerge from the interaction between representational features, learner cognition, and the instructional context.

Theoretically, this study provides empirical support for the complementary roles of Narrative Learning Theory and CTML in explaining how popular culture-based multimedia may facilitate learning in Informatics education. Narrative structures can provide contextual coherence, causal relationships, and meaningful learning contexts that support students' engagement with unfamiliar concepts (Green and Brock, 2000). However, CTML explains why narrative coherence alone may not be sufficient for advanced conceptual learning, as learners must actively process and integrate information to construct durable knowledge structures (Mayer and Fiorella, 2021). Thus, the contribution of *Dr. Stone* lies not merely in its entertainment value but in its ability to function as a contextual scaffold that supports conceptual entry points when combined with appropriate pedagogical interventions.

Several limitations should be considered when interpreting these findings. The one-group pretest-posttest design restricts causal conclusions because improvements may also be influenced by testing effects, maturation, or other classroom-related factors. Additionally, the small sample size and single educational context limit the generalisability of the results. Furthermore, although this study measured cognitive achievement using a HOTS-based assessment, it did not directly examine cognitive load, learner engagement, mental model development, or knowledge transfer. Future studies should employ controlled experimental designs with larger samples and incorporate additional measures such as delayed post-tests, transfer assessments, concept mapping, and cognitive load instruments. Such investigations would clarify the conditions under which anime-based multimedia can produce more sustained and transferable learning outcomes in informatics education.

CONCLUSION

This study suggests that narrative-based multimedia can support students' informatics learning, as reflected in the significant improvement in their post-test performance. However, the relatively low normalised gain indicates that the improvement was modest and varied across learning topics, suggesting that narrative media alone may not be sufficient for demanding conceptual content. The findings also highlight the complementary roles of Narrative Learning Theory and CTML, where narratives provide context and coherence, and multimedia design supports the processing and integration of verbal and visual information. Given the one-group pretest–posttest design, small sample size, and limited assessment measures, the findings should be interpreted cautiously, particularly regarding causal effects and deeper conceptual learning. Future studies should use controlled designs, larger samples, and additional measures of conceptual understanding, cognitive load, retention, and knowledge transfer to establish

when and how narrative-based multimedia can provide more sustained learning benefits for students.

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