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Development of an Educational Game to Enhance Students Critical Thinking Skills Assisted by the Learning Cycle 7E

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Abstract:
Critical thinking is an essential 21st-century skill. However, limited practical facilities make the teaching of Fiber Optics in the Wide Area Network (WAN) Technology subject at vocational high schools tend to be abstract and difficult for students to understand. This study aims to (1) develop an educational game to support the improvement of students' critical thinking skills, (2) determine the effectiveness of an educational game assisted by the *Learning Cycle 7E* model in improving critical thinking skills, and (3) analyze students' responses to the Fibronyc learning media. This study employed a Research and Development (R&D) approach using the ADDIE model, with a *one-group pretest-posttest* experimental design. Instrument testing involved 36 twelfth-grade TJKT students, while the implementation phase involved 37 eleventh-grade TKJT students at a vocational high school in Bandung. The media expert validation results indicated that the educational game achieved a validity score of 89.8%, categorized as Highly Feasible. Fibronyc's primary contribution lies in visualizing abstract concepts through interactive simulations that encourage students to solve problems independently. The paired-samples t-test results revealed a significant improvement in students' critical thinking skills, with the mean score increasing from 67.7 on the pretest to 88.6 on the posttest ($t = -13.56$; $p < 0.001$). The mean N-Gain score was 0.65 (Moderate), and 94.59% of students achieving Moderate to High improvement categories. Students' responses to Fibronyc were highly positive, reaching 94.49%, (Very Good). These findings indicate that the educational game assisted by the *Learning Cycle 7E* model is effective in improving students' critical thinking skills. The limitations of this study include the absence of a control group for comparison and reliance on a stable internet connection to save students' evaluation progress.

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Introduction (مقدمة)

Education plays a fundamental role in shaping the quality of human resources (Harahap, 2021). Currently, education in Indonesia is undergoing continuous reform to meet 21st-century demands, which emphasize the mastery of the 4Cs—Critical Thinking, Creativity and Innovation, Communication, and Collaboration—as essential competencies for students (Iman, 2022; Nurhayati et al., 2024; Pasaribu et al., 2025). Among these, critical thinking is one of the most vital 21st-century skills, as it enables individuals to analyze information in depth, evaluate arguments objectively, and make decisions based on logical reasoning and strong evidence (Aji & Nugraheni, 2023; Rusmin et al., 2024). Within the context of vocational education, this skill is a core workplace competency required by vocational high school (SMK) graduates to adapt to evolving industry demands, particularly in analyzing and resolving technical issues in the field (Kurniawan et al., 2021; Nurjanah et al., 2022). However, the critical thinking skills of students in Indonesia remain relatively low, largely because the curriculum tends to prioritize information delivery over fostering higher-order thinking skills (Mulyani, 2022). For instance, Fatimah (as cited in Kurniawan et al., 2021) reported that 29.44% of students at a school in Lombok Regency fell into the low category, while Hasanah et al. (2023) found that 64% of students at SMA Nurul Iman Tanjung Morawa exhibited low critical thinking abilities. A similar condition was observed by the researcher during an interview with a Computer and Network Engineering (TKJ) teacher at a school in Bandung, where student participation in asking questions, expressing opinions, and engaging in discussions remained minimal—indicating that Ennis's critical thinking indicators (as cited in Amarila et al., 2021) have not yet developed optimally.

This situation directly impacts the Wide Area Network (WAN) Technology subject, particularly the Fiber Optics topic under Phase F of the *Kurikulum Merdeka* (Independent Curriculum). Observations and interviews with the TKJ teacher revealed that practicum facilities and infrastructure remain inadequate because fiber optic equipment is relatively expensive (Arkadiantika et al., 2020; Saputra et al., 2025), thereby limiting students' opportunities for hands-on practice. The teacher also noted that the computer laboratory is shared on a rotational basis, the budget for fiber optic consumables is limited, and students tend to remain passive as they struggle to articulate their confusion. Furthermore, a preliminary study conducted among TKJ students indicated that 60.3% of respondents perceived transmission media—specifically fiber optics—as the most challenging topic in the WAN Technology subject. Within this sub-topic, 62.9% of students struggled to grasp the process of data transmission via light, and 90.4% stated that the invisible technical mechanisms were moderately to extremely difficult to understand. Fiber optics involves abstract concepts that cannot be directly observed, despite serving as a critical element of modern communication infrastructure (Sa'adah et al., 2025). Ultimately, these facility constraints and the abstract nature of the subject matter diminish student learning motivation and hinder the achievement of learning objectives (Andriani & Ramadani, 2022).

Numerous previous studies have sought to enhance critical thinking and learning outcomes through the 7E Learning Cycle model. For instance, Ayuni et al. (2025) demonstrated that the 7E Learning Cycle effectively improves students' critical thinking skills across various subjects, such as the State and Regional Budgets (APBN and APBD). These findings are further supported by Ainina and Winarsih (2020), who achieved an improvement of up to 95% using student worksheets (LKPD) on environmental pollution, as well as Saputri et al. (2024), who reported a very high effect size when integrating the model with a virtual laboratory on dynamic electricity. On the other hand, research on game-based learning (GBL) indicates that educational game media effectively boost student engagement and learning achievement. For

example, the use of interactive Wordwall games enabled 82.6–95.7% of students to meet the Minimum Mastery Criteria (KKM) (Fauziyyah & Priatna, 2024), while gamified learning has been proven to foster critical thinking and 21st-century skills through more active and exploratory learning experiences (Koten et al., 2023; Solekhah et al., 2020).

Nevertheless, studies integrating the 7E Learning Cycle with virtual laboratories have predominantly focused on non-vocational subjects such as physics (Saputri et al., 2024), whereas research utilizing mind-map-assisted 7E Learning Cycles still relies on non-immersive media (Ayuni et al., 2025). Furthermore, the development of virtual laboratories for computer networking topics has largely been oriented toward improving general learning outcomes rather than reinforcing specific instructional models designed to foster critical thinking (Taufik et al., 2024). Thus, while both the 7E Learning Cycle and game-based media have independently proven beneficial, they have yet to be integrated to develop critical thinking in abstract vocational subjects constrained by limited practicum equipment. Therefore, the novelty of this study lies in the explicit integration of the structured 7E Learning Cycle instructional model with an interactive 3D educational game (*Fibronyc*) for abstract vocational content. Specifically, the *Fibronyc* educational game is designed to facilitate the *Elicit*, *Engage*, *Explore*, *Explain*, *Elaborate*, and *Evaluate* phases, providing concrete learning experiences through troubleshooting simulations without relying on expensive and scarce physical practicum tools. Meanwhile, the final phase (*Extend*) is conducted outside the game environment through guided reflection and applied case studies with the teacher, ensuring that students can transfer knowledge from virtual simulations to real-world field scenarios. In this study, critical thinking skills are measured based on Ennis's (2011) five indicators: *Elementary Clarification*, *Basic Support*, *Inference*, *Advanced Clarification*, and *Strategy and Tactics*.

Based on the aforementioned background, this study aims to develop an educational game-based learning medium—assisted by the 7E Learning Cycle model—to enhance students' critical thinking skills and deepen their understanding of the working principles and real-world applications of fiber optics. Furthermore, this study seeks to analyze its effectiveness in improving students' critical thinking skills and to evaluate student responses toward the use of this medium. To achieve these objectives, the research problems are formulated into the following research questions:

- **RQ1:** How is the educational game developed to support learning in enhancing students' critical thinking skills?
- **RQ2:** How effective is the 7E Learning Cycle-assisted educational game in improving students' critical thinking skills on the topic of Fiber Optics?
- **RQ3:** What are the students' responses toward the use of the developed 7E Learning Cycle-assisted educational game in learning Fiber Optics?

Method (منهج)

A research method is fundamentally a systematic, empirical, and objective scientific approach used to collect, process, and analyze data in order to solve a problem (Abubakar, 2021). This study employed a Research and Development (R&D) approach utilizing the ADDIE development model—comprising Analysis, Design, Development, and Implementation—as proposed by Branch (2009). The ADDIE model served as a systematic framework for developing the instructional media product, whereas the *Evaluation* process was conducted continuously at each stage to provide formative feedback for product refinement. Beyond merely producing a learning medium, this study also assessed its feasibility and

implementation outcomes in supporting the enhancement of students' critical thinking skills. Finally, the collected data were analyzed using a quantitative approach (Sugiyono, 2022).



Figure 1. The ADDIE Model of Branch (2009)

Development Procedure

The research and development procedure in this study followed the ADDIE model, which comprises the Analysis, Design, Development, Implementation, and Evaluation stages. The development process was carried out systematically, incorporating ongoing evaluations at each stage as formative feedback to determine whether the procedure could proceed to the next phase or required revision.

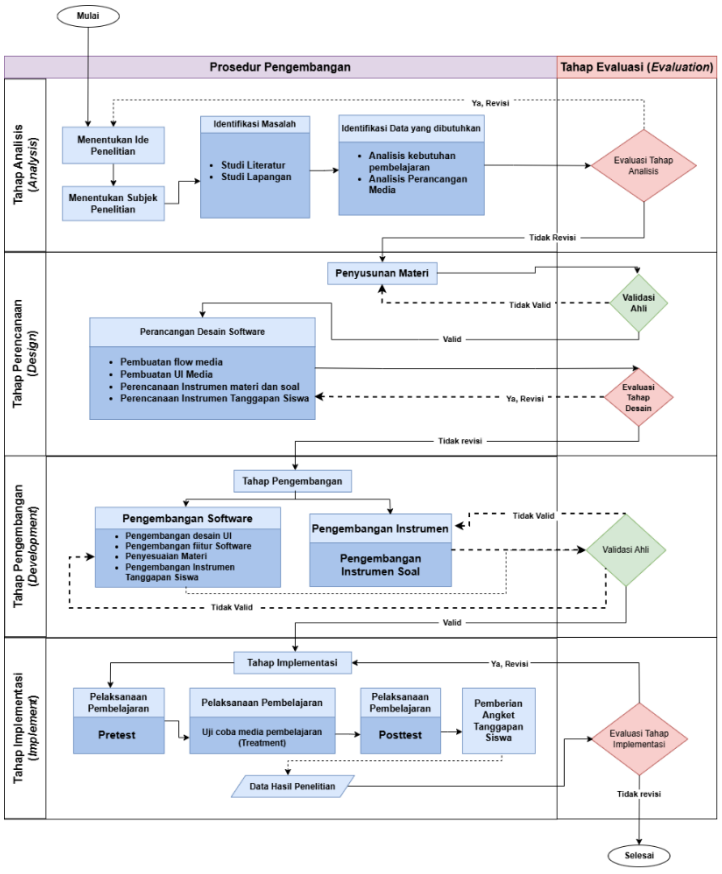


Figure 2. Development Procedure

The *Analysis* stage began by determining the research idea and selecting the research subjects. Subsequently, problem identification was conducted through a literature review and field studies to explore the instructional challenges in depth. The findings from the problem identification were then utilized to determine the required data, encompassing a learning needs analysis and a media design analysis. All outcomes from this phase underwent an *Evaluation* process. If the evaluation indicated a need for improvement, a comprehensive review was

carried out starting from the formulation of the research idea; conversely, if no revisions were required, the process proceeded to the *Design* stage.

The *Design* stage began with the preparation of instructional materials, which were immediately submitted for expert validation. If the materials were deemed *Invalid*, revisions were made to the content until they were ultimately declared *Valid*. Once the materials were validated, the next step involved Software Design Planning, which encompassed four main aspects: developing the media flow, designing the user interface (UI), planning the content and assessment instruments, and planning the student response instruments. All outcomes from this design phase then underwent an *Evaluation* process. If the evaluation indicated the need for revisions, the software design was refined accordingly. Conversely, if no revisions were required, the development procedure proceeded to the next stage.

The *Development* stage was carried out by realizing the design outputs into the *Fibronyc* educational game product and the research instruments. Software development encompassed user interface (UI) design, software feature implementation, content integration, and the development of student response instruments. During this stage, the assessment instruments were also developed. Subsequently, both the product and the instruments underwent an expert validation process. The validation results served as the basis for making revisions if any components remained invalid. Once validated, the product was ready to be deployed in the *Implementation* stage.

The *Implementation* stage was conducted by deploying the *Fibronyc* educational game in classroom learning. The activities began with a pretest, followed by the instructional media trial (treatment), a posttest, and the administration of a student response questionnaire. These activities generated research data that were subsequently evaluated during the implementation phase. This evaluation assessed the outcomes of using the medium, including improvements in students' critical thinking skills, student responses toward the medium, and challenges encountered during the learning process. The learning sessions were conducted over four meetings in the computer laboratory, with the researcher acting as the facilitator. Each phase of the 7E Learning Cycle was realized through three complementary components: the *Fibronyc* educational game, student worksheets (LKPD), and teacher guidance.

As illustrated on the right side of the development flowchart, the *Evaluation* stage did not merely serve as a final step; rather, it was integrated as a formative evaluation at the end of every phase (*Analysis*, *Design*, *Development*, and *Implementation*). This iterative evaluation mechanism functioned as a quality control measure to ensure that the outputs of each stage aligned with the development objectives before advancing to the next phase. The evaluation results were used to determine the achievement of the *Fibronyc* educational game's development goals—namely, producing a feasible educational game medium that is effective in supporting the enhancement of critical thinking skills and receives positive responses from students.

Research Design and Participants

The product implementation employed a one-group pretest–posttest design (O_1--X--O_2), in which participants were administered a pretest (O_1), received a treatment consisting of learning with the Fibronyc educational game integrated with the 7E Learning Cycle model (X), and subsequently completed a posttest (O_2). This design was selected because the research sample consisted of only a single intact class chosen in accordance with predetermined criteria. The objective of this design was to determine the effectiveness of the 7E Learning Cycle-based learning medium in enhancing students' critical thinking skills. Furthermore, the normalized gain (N-gain) analysis comparing the pretest and posttest scores indicated the extent to which the medium improved students' critical thinking in the Computer Networking subject;

consequently, a comprehensive comparative evaluation against alternative instructional models could not be fully established within this study.

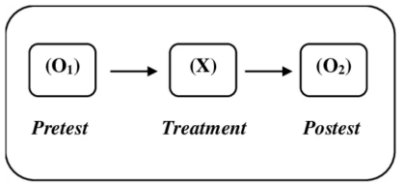


Figure 3. One-Group Pretest-Posttest Design

The population of this study comprised Grade XI (Phase F) students in the Computer and Network Engineering (TJKT) expertise program at a vocational high school (SMK) in Bandung who were enrolled in the Wide Area Network (WAN) Technology subject. The research sample was determined using purposive sampling, a sampling technique based on specific considerations or criteria aligned with the objectives and requirements of the study (Sugiyono, 2022). This technique was applied to select a group of students who met the research criteria and were suitable for receiving the instructional treatment. Based on these considerations, the sample consisted of one Grade XI TJKT class totaling 37 students.

Meanwhile, the trial of the test instrument was conducted with 36 Grade XII TJKT students to evaluate item quality prior to its use in the main study. In addition, the preliminary field study involved TKJ students as respondents for the needs analysis questionnaire and a TKJ teacher as an interview informant.

Instruments and Data Collection Techniques

This study utilized four data collection instruments: a student needs analysis questionnaire and a teacher interview guide, a media expert validation instrument, a critical thinking test, and a student response questionnaire. The needs analysis questionnaire and interview guide were used to identify subject-matter difficulties, instructional models, existing learning media, and the availability of practicum facilities. Media validation was conducted using the Multimedia Mania 2003 – Judges' Rubric, which encompasses five assessment aspects: Mechanical, Multimedia Elements, Information Structure, Documentation, and Quality of Content. Each criterion was scored on a scale of 0–4 and assigned a weight of 1–3 according to its level of importance.

The critical thinking test consisted of 70 multiple-choice items developed based on Ennis's five indicators and the Fiber Optics subject matter. The instrument was validated by expert lecturers through two rounds of expert judgment and subsequently trialed with 36 students. The analysis results indicated that 60 items were valid based on the Pearson product-moment correlation ($r_{\text{table}} = 0.329$, $df = 34$, $\alpha = 0.05$), with a Kuder-Richardson 20 (KR-20) reliability coefficient of 0.920. Subsequently, these 60 validated items were used to construct a 30-item pretest and a 30-item posttest with a balanced distribution across Ennis's five critical thinking indicators.

The pretest and posttest data were analyzed using the Shapiro–Wilk normality test on the difference scores (*N-gain*) because the sample size was fewer than 50 respondents. Hypothesis testing was conducted using a paired-sample *t*-test at a significance level of 0.05, whereas the improvement in critical thinking skills was calculated using the Normalized Gain (*N-gain*) formula. Meanwhile, the student response questionnaire utilized the *Multimedia Mania Student Checklist* instrument with dichotomous response options of *Yes* (1) and *No* (0). A summary of the instruments, data sources, objectives, and analytical techniques is presented in Table 1.

Table 1. Summary of research instruments

Instrument	Data Source	Objective	Analysis Technique
Needs analysis questionnaire and interview guide	TJKT students and TJKT teacher	Identify subject-matter difficulties, existing learning media, and practicum facilities	Response percentages and descriptive analysis
Media expert validation (*Multimedia Mania Judges' Rubric*)	Media experts	Assess the feasibility of the *Fibronyc* educational game	Score (0–4) × weight (1–3), percentage of ideal score, and Riduwan's (2018) categorization
Critical thinking test (70 items trialed; 30-item pretest and 30-item posttest)	36 Grade XII students (pilot test); 37 Grade XI students (implementation)	Measure Ennis's five critical thinking indicators	Item validity, KR-20 reliability, difficulty index, discrimination power; Shapiro–Wilk test, paired-sample *t*-test, and *N-gain*
Student response questionnaire (*Multimedia Mania Student Checklist*)	37 Grade XI students	Measure student responses toward the *Fibronyc* educational game	Dichotomous scoring (*Yes* = 1, *No* = 0) × weight, percentage, and response categorization

Data Analysis Techniques

Expert validation and student response scores were calculated as a percentage of the obtained score relative to the ideal score and subsequently categorized according to Riduwan's (2018) validity criteria: Very Valid (81–100%), Valid (61–80%), Moderately Valid (41–60%), Less Valid (21–40%), and Invalid (0–20%). The pretest–posttest data were analyzed using the Shapiro–Wilk normality test on the difference scores (N-gain) because the sample size was fewer than 50 (Razali & Wah, 2011), with data considered normally distributed if the significance value was greater than 0.05 ($p > 0.05$). Subsequently, a paired-sample t-test was performed at a significance level of 0.05 to examine the difference between the pretest and posttest scores. Finally, the improvement in critical thinking skills was calculated using the Normalized Gain (N-gain) formula (Hake, 1998), as follows:

$$g = \frac{posttest\ score - pretest\ score}{maximum\ score - pretest\ score}$$

he *N-gain* scores were categorized into *High*, *Medium*, and *Low*. Furthermore, the *N-gain* analysis was conducted overall, per critical thinking indicator, and per prior-ability student group namely, the upper group ($score \geq mean + standard\ deviation$), the lower group ($score \leq mean - standard\ deviation$), and the middle group (between the two thresholds).

The *N-gain* per indicator and per group was calculated from the mean pretest and posttest scores within each respective indicator or group, whereas the overall *N-gain* represented the average of individual students' *N-gain* scores; consequently, the resulting values may differ slightly. The interpretation criteria for all analyses are presented in Table 2.

Table 2. Interpretation criteria for the research data

Parameter	Interpretation Criteria
Kevalidan media (Riduwan, 2018)	81–100%: Very Valid; 61–80%: Valid; 41–60%: Moderately Valid; 21–40%: Less Valid; 0–20%: Invalid
Student response	75.00–100: Very Good; 50.00–74.99: Good; 25.00–49.99: Fair; 0.00–24.99: Poor
Item validity (Arikunto, 2021)	Valid if $r_{calculated} > r_{table}$ $(0.329;\ df = 34;\ \alpha = 0.05)$
KR-20 reliability	0.80–1.00: *Very High*; 0.60–0.79: *High*; 0.40–0.59: *Moderate*; 0.20–0.39: *Low*; 0.00–0.19: *Very Low*
Difficulty index	0.00–0.30: *Difficult*; 0.31–0.70: *Moderate*; 0.71–1.00: *Easy*
Discrimination power	0.71–1.00: *Very Good*; 0.41–0.70: *Good*; 0.21–0.40: *Satisfactory*; 0.00–0.20: *Poor*; negative: *Very Poor*
N-Gain (Hake, 1998)	$g > 0.70$: *High*; $0.30 \leq g \leq 0.70$: *Medium*; $g < 0.30$: *Low*

Result (نتائج)

Development and Feasibility of the Fibronyc Media

The needs analysis results revealed that 60.3% of students perceived transmission media (fiber optics) as the most difficult topic in the Wide Area Network (WAN) Technology subject (Figure 4). Within the fiber optics sub-topic, 62.9% of students struggled to understand the process of data transmission via light, 51.4% had difficulty grasping the functions of fiber optics and the Open Systems Interconnection (OSI) layer, and 90.4% stated that the invisible technical processes were moderately to extremely difficult to comprehend (Figure 5).

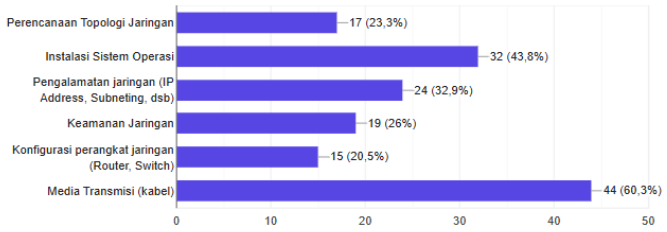
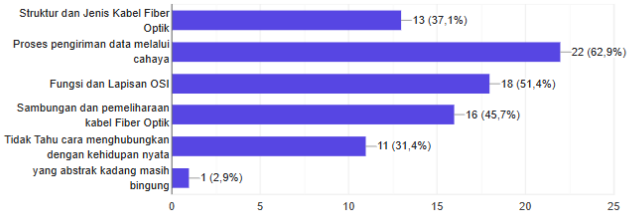


Figure 4. Students' Perceptions of the Most Challenging Topic in WAN



Technology

Figure 5. Fiber Optics Sub-Topics Perceived as Confusing by Students

Based on the needs analysis findings, the teacher observed that students tended to be passive due to difficulties in articulating their comprehension barriers and a fear of making mistakes. Furthermore, the currently utilized instructional media—such as PowerPoint and Google Classroom remained one-way and were therefore suboptimal for visualizing abstract concepts in fiber optics. The technical specifications were tailored to match the availability of school hardware. The game was designed to run on PCs or laptops operating on Windows 10/11 (64-bit) with DirectX 11 support, an Intel Core i3 or AMD Ryzen 3 equivalent processor, at least 4 GB of RAM, and 5 GB of storage space. Additionally, an internet connection was

required to upload and store student response data in the database. The game development process integrated the Unity engine, Visual Studio Code (C#), and Supabase as a cloud database to record student scores and learning progress summaries.

The *Design* and *Development* stages yielded teaching modules and student worksheets (LKPD) structured around the Phase F Learning Outcomes (*Capaian Pembelajaran*) of the *Kurikulum Merdeka* across four meetings (4×45 minutes), progressing sequentially from basic fiber optic concepts, comparisons between copper and fiber optic cables, and single-mode versus multi-mode cable types, to fault analysis and troubleshooting. The *Fibronyc* medium was designed with a structured flow comprising the main menu, control instructions, room or module selection, gameplay, and an evaluation screen. Students could explore the 3D environment, rotate and zoom in on equipment objects (splicer, cleaver, stripper), switch camera angles, follow step-by-step tutorials, and complete quizzes whose scores were automatically saved to Supabase. Black-box testing confirmed that all system functions—including menu navigation, keyboard/mouse responsiveness, splicing simulations, Supabase database connectivity, and compatibility across various computer specifications—operated as intended. Media expert validation using the *Multimedia Mania* rubric yielded a validity score of 89.8% for *Fibronyc*, falling into the *Very Valid* category and deemed *Highly Feasible* for classroom use.

The *Implementation* stage was conducted with 37 students over four meetings (4×45 minutes). A 30-item pretest was administered for 30 minutes via Google Forms, followed by instructional sessions applying the 7E syntax assisted by *Fibronyc* in the computer laboratory, and concluded with a 30-item posttest, with the researcher serving as the facilitator. Based on the researcher's observations, students demonstrated high enthusiasm and active engagement: they manipulated camera angles to inspect cable components (core, cladding, coating, strength member, and jacket), operated tools within the simulation, examined attenuation values, analyzed causes of splicing failures, and discussed potential solutions. Immediate feedback in the form of attenuation readings and quiz scores enabled students to self-correct their understanding.

Effectiveness of the Media on Critical Thinking Skills

Prior to its use in the pretest and posttest stages, the critical thinking test instrument underwent a quality assessment. Of the 70 items trialed with 36 students, 60 items were found to be valid and 10 items were invalid ($r_{calculated} < 0.329$). The Kuder-Richardson 20 (KR-20) reliability coefficient was 0.920 (Very High). The difficulty index was dominated by the Moderate category (64.29%), and all 60 valid items demonstrated discrimination power ranging from Satisfactory to Very Good, with no items falling into the Poor category (Table 3). These 60 items were subsequently divided into a 30-item pretest and a 30-item posttest, distributed according to the critical thinking indicators presented in Table 4.

Table 3. Results of the item quality analysis (n = 36; 70 items tried out)

Aspect	Results	Interpretation
Validity ($r_{table} = 0.329; df = 34$)	60 items valid; 10 items invalid	60 items used
Reliability (KR-20)	0,920	Very high
Difficulty Level (70 items)	Easy 13 (18.57%); Moderate 45 (64.29%); Difficult 12 (17.14%)	Dominated by Moderate
Discrimination Index (60 valid items)	Fair 11 (18.33%); Good 41 (68.33%); Very Good 8 (13.33%); Poor 0	Good

Table 4. Distribution of *pretest* and *posttest* items based on Ennis's (2011) critical thinking indicators

Indicator	Pretest Items	Posttest Items
Elementary Clarification	7	6
Basic Support	5	6
Inference	8	7
Advanced Clarification	3	2
Strategy and Tactics	7	9
Total	**30**	**30**

The implementation results demonstrated that the use of the *Fibronyc* educational game assisted by the 7E Learning Cycle had a significant effect on students' critical thinking skills. The Shapiro–Wilk normality test on the pretest–posttest difference (gain) scores yielded a significance value of 0.419 ($p > 0.05$), indicating that the normality assumption was met. The paired-sample *t*-test revealed a statistically significant improvement, with the mean critical thinking score increasing from 67.7 on the pretest to 88.6 on the posttest ($t = -13.56$, $p < 0.001$). The mean *N-gain* score was 0.65, which fell into the *Medium* category, with 94.59% of students achieving *Medium* to *High* levels of improvement.

Table 5. Results of the *pretest*, *posttest*, normality test, paired-samples t-test, and N-Gain (n = 37)

Parameter	Nilai	Interpretasi
Mean *Pretest*	67.7	-
Mean *Posttest*	88.6	-
Shapiro-Wilk, gain (Sig.)	0.419	Normally distributed
Paired-samples t-test (t; Sig. 2-tailed)	−13.56; p < 0.001	Significant
Mean N-Gain	0.65	Moderate
Students in the Moderate–High category	94.59%	-

By indicator, the highest *N-gain* scores were achieved in *Elementary Clarification* (0.75) and *Advanced Clarification* (0.74), followed by *Inference* (0.72), whereas *Basic Support* (0.62) and *Strategy and Tactics* (0.56) recorded the lowest gains. Examined by prior-ability group, the *N-gain* scores for the upper, middle, and lower groups were 0.68, 0.62, and 0.67, respectively Table 6.

Table 6. N-Gain by critical thinking indicator and students' initial ability group

Analysis Category	N-Gain	Improvement Category
Elementary Clarification	0.75	High
Basic Support	0.62	Moderate
Inference	0.72	High
Advanced Clarification	0.74	High
Strategy and Tactics	0.56	Moderate
Upper group	0.68	Moderate
Lower group	0.67	Moderate
Middle group	0.62	Moderate

Student Responses Toward the Fibronyc Educational Game

The responses of the 37 students toward the Fibronyc educational game, measured using the Multimedia Mania Student Checklist, yielded a total score of 874 out of a maximum score of 925, or an average percentage of 94.49%, falling into the Very Good category. All assessment aspects achieved percentages above 87%, with the Information Structure (87.84%) and Mechanical (89.86%) aspects scoring slightly lower than the other dimensions Table 7.

Table 7. Students' responses to the Fibronyc educational media by assessment aspect

Aspect	Percentage	Category
Mechanical	89.86%	Very Good
Multimedia Elements	95.95%	Very Good
Information Structure	87.84%	Very Good
Documentation	100%	Very Good
Quality of Content	96.88%	Very Good
Overall student response (5 aspects)	**94.49%**	**Very Good**

Discussion (مناقشة)

Development of the Fibronyc Educational Game Assisted by the 7E Learning Cycle Model

The needs analysis findings confirm that the primary challenge in Fiber Optics instruction does not lie in the inherent complexity of the subject matter itself, but rather in the lack of concrete learning experiences capable of supporting the visualization of abstract processes, aligning with the high proportion of students who struggled to comprehend invisible technical phenomena. This condition is understandable given the limited availability of fiber optic practicum equipment in vocational high schools (SMK) in general, rendering the need for alternative media that do not rely on physical hardware urgent. While the use of PowerPoint and Google Classroom has aided content delivery, these platforms have not fully facilitated student exploration. Moreover, concepts such as cable structure, cable-type characteristics, light propagation, and transmission impairments are difficult to grasp through verbal explanations alone. This scarcity of practicum facilities further reinforces the demand for an alternative medium capable of visualizing these concepts. Consequently, *Fibronyc* was developed as a PC-based educational game that integrates instructional content, component visualization, simulations, interactive activities, and learning evaluations.

The selection of an educational game was grounded in game characteristics that foster enjoyment (fun), tiered challenges, and immediate feedback mechanisms to encourage active student participation (Sartika et al., 2026; Solekhah et al., 2020). As an edutainment medium, *Fibronyc* combines Fiber Optics subject matter with interactive simulations and challenges, enabling abstract concepts to be presented more concretely and visually (Fauziyyah & Priatna, 2024; Fitriani et al., 2025; Pratiwi et al., 2026). This approach also aligns with the findings of Koten et al. (2023) and Solekhah et al. (2020), who demonstrated that gamified learning supports the development of critical thinking skills through active and exploratory learning experiences. Thus, the game format serves as a complementary instructional element that reinforces the implementation of the 7E Learning Cycle model.

The integration of the 7E Learning Cycle within *Fibronyc* was achieved through the synergy of the game medium, student worksheets (LKPD), and teacher guidance. The *Elicit* phase was conducted through teachers' prompting questions to uncover students' prior knowledge, whereas the *Engage* phase was realized through stimuli within the medium to spark

interest in the topic. During the *Explore* phase, students observed the learning materials, visualizations, and simulations provided in *Fibronyc*. Subsequently, the *Explain* phase afforded students the opportunity to present their exploration findings and articulate the concepts learned. The *Elaborate* phase was implemented by solving problem-based tasks in the LKPD, while the *Evaluate* phase was carried out through in-game quizzes. Finally, the *Extend* phase involved follow-up activities outside the medium to connect Fiber Optics concepts to real-world applications. This integration demonstrates that *Fibronyc* does not function merely as a standalone game, but rather operates as an integral component of an instructional process that retains the teacher's role as a facilitator. The integration of the 7E Learning Cycle phases into learning with the *Fibronyc* educational game is outlined below.

Table 8. Integration of the Learning Cycle 7E stages in the Fibronyc educational media

7E Stage	Student Activities	Supporting Components
Elicit	Expressing prior knowledge about computer networks and fiber optics	Fibronyc educational game
Engage	Observing visual displays and the *problem statement* to build interest.	Fibronyc educational game
Explore	Observing the cable structure and exploring the simulation, for example rotating the camera and trying the splicer, cleaver, and stripper tools	Fibronyc educational game
Explain	Presenting observation results and understanding	Fibronyc educational game, LKPD
Elaborate	Applying concepts to solve cases, including analyzing attenuation values and performing *troubleshooting*	Fibronyc educational game
Evaluate	Completing evaluation quizzes and independent reflection	Quiz in Fibronyc and reflection sheet
Extend	Connecting fiber optic concepts with their application in real networks	LKPD and teacher

The features and activities within *Fibronyc* were also designed to support critical thinking indicators as conceptualized by Ennis (2011). Content presentation and component introduction assist students in identifying relevant information (*Elementary Clarification*), whereas observing visualizations and simulations reinforces foundational skills in acquiring and evaluating evidence (*Basic Support*). Activities involving the comparison of cable characteristics and distinguishing between single-mode and multi-mode fiber types correspond to the ability to draw valid conclusions (*Inference*). Subsequently, articulating exploration findings supports the capacity to provide deeper elaboration (*Advanced Clarification*), while troubleshooting tasks afford students opportunities to formulate and evaluate problem-solving strategies (*Strategy and Tactics*). These linkages demonstrate that the in-game activities are oriented not merely toward content comprehension, but also toward engaging students in identification, observation, comparison, reasoning, and decision-making processes.

The media expert validation yielded a validity score of 89.8%, falling into the *Very Valid* or *Highly Feasible* category. This result indicates that *Fibronyc* has met the feasibility criteria across technical aspects, multimedia elements, information structure, and content quality. The assessment of content quality also demonstrated alignment among the subject matter, learning activities, and established learning objectives. Furthermore, validator feedback regarding the branching mechanisms for *Copper/Fiber Optic* and *Single-mode/Multi-mode* pathways was addressed prior to media implementation. This demonstrates that the ADDIE development

process did not merely proceed sequentially, but also incorporated iterative evaluation and refinement to ensure product alignment with instructional needs. Consequently, *Fibronyc* is feasible for use as a supplementary learning medium in Fiber Optics instruction, integrating an educational game with the 7E Learning Cycle model to facilitate students' critical thinking activities.

Effectiveness of the Fibronyc Educational Game in Enhancing Critical Thinking Skills

The research findings demonstrate that the use of the *Fibronyc* educational game assisted by the 7E Learning Cycle model supports the enhancement of students' critical thinking skills in Fiber Optics instruction. This is evidenced by an increase in the mean score from 67.7 on the pretest to 88.6 on the posttest. The paired-sample *t*-test revealed a statistically significant difference between the two test scores ($t = -13.56$, $p < 0.001$), with a mean *N-gain* score of 0.65, falling into the *Medium* category. Furthermore, 94.59% of students achieved improvements in critical thinking skills within the *Medium* to *High* categories..

This improvement is closely linked to the implementation of the 7E Learning Cycle phases within the instructional process utilizing the *Fibronyc* educational game. The *Elicit* phase was carried out through teacher-facilitated introductory activities aimed at uncovering students' prior knowledge. Subsequently, the *Engage* phase was implemented by providing stimuli within the *Fibronyc* educational game to spark students' interest in the Fiber Optics topic. During the *Explore* phase, students investigated the learning materials and simulations available in *Fibronyc*. Findings from these exploratory activities were then reinforced during the *Explain* phase, in which students comprehended and articulated the concepts they had learned. In the *Elaborate* phase, students applied their understanding through in-game activities and challenges. Next, the *Evaluate* phase was conducted via quizzes to measure students' mastery of the subject matter. Finally, the *Extend* phase was facilitated by the teacher through follow-up activities outside the medium to expand the application of concepts to broader contexts and problems.

This sequence of phases afforded students the opportunity to progressively construct their conceptual understanding of Fiber Optics while cultivating systematic thinking skills in problem-solving. Through exploration and simulation activities, students were encouraged to identify problems, gather information, comprehend concepts, and apply acquired knowledge. Furthermore, the challenge and quiz activities provided opportunities for students to apply and evaluate their understanding. Consequently, the *Fibronyc* educational game functions not merely as a content-delivery medium, but also supports active learning processes through trial-and-error experiences within a simulated environment without relying entirely on hands-on practice with physical hardware.

Examined by critical thinking indicator, the highest improvements occurred in *Elementary Clarification* with an *N-gain* score of 0.75 and *Advanced Clarification* at 0.74, followed by *Inference* at 0.72, all of which fell into the *High* category. Meanwhile, *Basic Support* obtained an *N-gain* of 0.62 and *Strategy and Tactics* recorded 0.56, both falling into the *Medium* category, with *Strategy and Tactics* exhibiting the lowest gain.

Several complementary explanations account for why *Strategy and Tactics* yielded the lowest improvement. This indicator demands higher cognitive complexity because students must not only comprehend the problem, but also determine appropriate resolution steps, select suitable strategies, and weigh alternative solutions along with their consequences (Ennis, 2011; Hmelo-Silver, 2004). Developing such competencies generally requires repeated practice across a broader range of problem variations than the four meetings allocated in this study.

Furthermore, the troubleshooting scenarios within *Fibronyc* were still limited to specific fault types, providing fewer opportunities for students to compare multiple strategic alternatives and test them under varying conditions compared to activities targeting other indicators. Additionally, during the learning process, students still tended to rely on teacher guidance, indicating that their capacity for autonomous strategic decision-making requires further reinforcement.

Beyond indicator-specific factors, the overall improvement may also have been influenced by external variables beyond the game medium itself. Because this study lacked a control group, the effect of *Fibronyc* could not be isolated from the contributions of the student worksheets (LKPD), classroom discussions, teacher guidance, and repeated content exposure across the four meetings, nor from the impact of pretest administration on posttest performance (*testing effect*) and student enthusiasm toward a novel medium (*novelty effect*) (Campbell & Stanley, 1963; Shadish et al., 2002). The dual role of the researcher serving simultaneously as the facilitator may also have influenced student engagement. Therefore, the magnitude of the observed improvement (effect size $d = 2.23$ and *N-gain* $= 0.65$) cannot be attributed solely to the educational game, and future studies employing a control or comparison group are warranted to disentangle the effect of the game from that of the 7E Learning Cycle syntax. Subsequent development could focus on enriching the variety and complexity of network fault scenarios so that students gain more opportunities to analyze problems, compare alternative solutions, determine appropriate actions, and evaluate the outcomes of their chosen strategies.

Findings disaggregated by prior-ability group revealed that the lower group achieved an *N-gain* of 0.67, which was nearly equivalent to that of the upper group (0.68) and higher than that of the middle group (0.62). These results demonstrate that all three groups experienced improvements in critical thinking skills within the *Medium* category. This outcome indicates that learning with the *Fibronyc* educational game assisted by the 7E Learning Cycle model provides equitable learning opportunities for students across varying levels of prior ability. Repeatable object visualizations and simulations, accompanied by student worksheets (LKPD) and teacher guidance, enabled students to re-explore the material and construct their understanding progressively. Consequently, the improvement observed in the lower prior-ability group should be understood as the outcome of an integrated instructional sequence combining digital media, structured learning activities, and teacher facilitation. These findings align with prior studies applying the 7E Learning Cycle in other subjects that similarly reported gains in critical thinking (Ainina & Winarsih, 2020; Ayuni et al., 2025; Sari et al., 2022), while extending this body of literature to abstract vocational subjects with limited practicum facilities. Furthermore, Koten et al. (2023) and Solekhah et al. (2020) confirmed that gamified instructional models (gamified Project-Based Learning and Group Investigation) as well as educational game media significantly enhance students' critical thinking and 21st-century skills (creativity, collaboration, and communication) by fostering more active, responsive, and exploratory learning experiences.

Consequently, game-based learning media that integrate structured instructional models such as the 7E Learning Cycle hold potential as an alternative solution to the scarcity of fiber optic practicum facilities in vocational high schools (SMK), while simultaneously promoting equitable learning outcomes within the classroom.

Student Responses Toward the Fibronyc Educational Game

Student responses toward the Fibronyc medium were analyzed using the Multimedia Mania Student Checklist, administered to 37 students. The analysis yielded a total score of 874 out of a maximum score of 925, corresponding to an average percentage of 94.49% and falling

into the Very Good category. These results indicate that Fibronyc received positive feedback as a supplementary learning medium for Fiber Optics instruction. Furthermore, all assessment aspects scored above 87%, demonstrating that the medium was favorably evaluated across technical aspects, multimedia elements, information structure, documentation, and content quality.

Examined by individual assessment dimension, *Documentation* achieved the highest percentage at 100%, followed by *Quality of Content* at 96.88% and *Multimedia Elements* at 95.95%. These results indicate that the user guidelines, content presentation, and multimedia components within *Fibronyc* received highly favorable evaluations from students. Presenting the subject matter through visualizations and simulations enabled students to interact directly with Fiber Optics concepts that are otherwise difficult to observe firsthand, such as cable structures, data transmission processes, and the distinctions between single-mode and multi-mode fiber types. Furthermore, the game-based activities are replayable, affording students the flexibility to re-explore the instructional materials and learning tasks at their own pace and according to their individual needs.

Meanwhile, the *Mechanical* aspect obtained a percentage of 89.86% and *Information Structure* recorded 87.84%. Although both remained within the *Very Good* category, these percentages were relatively lower than those of the other dimensions. This indicates that technical execution and information organization still leave room for further refinement. During implementation, technical issues were identified, including a bug in the gameplay branching flow and frame rate lag while students completed the quizzes. These glitches have the potential to disrupt interaction fluidity and user comfort, and therefore warrant attention in subsequent iterations.

The high overall student response rate of 94.49% also aligns with the media expert validation results and the critical thinking improvements discussed earlier. This finding reinforces the interpretation that interactive learning experiences facilitated through visualizations and simulations help students comprehend subject matter more contextually. Rather than passively receiving theoretical information, students actively engage with the objects and problem scenarios presented within the medium. Overall, *Fibronyc* achieved very positive reception as a supplementary learning medium for Fiber Optics instruction.

Conclusion (خاتمة)

Based on the results of this study on the development and implementation of the Fibronyc educational game assisted by the Learning Cycle 7E model to support the improvement of students' critical thinking skills in the Fiber Optics topic, the following conclusions can be drawn:

This study successfully developed the Fibronyc educational game assisted by the *Learning Cycle 7E* model, using the ADDIE development model, as a medium supporting the learning of Fiber Optics. The media developed combine visualization, simulation, and interactive activities. The media expert validation obtained a percentage of 89.8%, in the very valid and highly feasible category, so Fibronyc is considered feasible for use in learning Fiber Optics.

The application of Fibronyc in learning assisted by the *Learning Cycle 7E* model showed an improvement in students' critical thinking skills. This is shown by the increase in the mean score from 67.7 on the *pretest* to 88.6 on the *posttest*, with the *paired sample t-test* showing a significant difference ($t = -13.56$; $p < 0.001$). The N-Gain analysis showed a moderate improvement, with 94.59% of students improving their critical thinking skills in the moderate to high categories. These findings indicate that the use of Fibronyc in a learning sequence assisted

by *Learning Cycle 7E* has the potential to support the improvement of students' critical thinking skills in the Fiber Optics topic.

Students' responses to the use of Fibronyc reached 94.49%, in the very good category, based on the *Multimedia Mania Student Checklist* administered to 37 students. These results show that Fibronyc received a positive response as a learning support medium. Nevertheless, further improvement is still needed, particularly in fixing the bug in the game branching and improving the quiz responsiveness so that use of the media becomes more optimal.

Overall, the Fibronyc educational game assisted by the Learning Cycle 7E model can be an alternative interactive learning medium to support the learning of Fiber Optics and the improvement of students' critical thinking skills. This medium can also help provide learning experiences through visualization and simulation, particularly when direct practice is limited by facilities.

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