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CONNETIC Module: CTL-Based Interactive Media to Improve Students' Logical Thinking in TCP/IP

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ABSTRACT

Logical thinking is an essential competence for vocational high school (SMK) students learning TCP/IP within the Basic Computer Network and Telecommunication Engineering (DDTJKT) subject due to its abstract, layered reasoning requirements. Preliminary findings indicate conventional instruction leaves students passive and unable to connect concepts logically. This study develops CONNETIC Module, a Contextual Teaching and Learning (CTL)-based interactive learning module built with React, TypeScript, and Supabase, to improve Grade X students' logical thinking. Employing a quantitative Research and Development (R&D) approach following the ADDIE model, a One-Group Pretest-Posttest design was applied to 36 Grade X TJKT students at SMK Negeri 4 Bandung. Data collected via tests, validation sheets, and questionnaires were analyzed using Wilcoxon signed-rank and N-Gain tests. The results show that CONNETIC Module is highly feasible based on expert validation (88.57%), significantly improved students' logical thinking ($Z = -5.22$; $p < .001$; $r = .87$) with a high overall N-Gain of .77, and achieved excellent usability (82.44%). Integrating a sequential locking mechanism and real-time feedback successfully creates an impactful, responsive learning experience.

Keywords: Contextual Teaching and Learning; Interactive Learning Module; Logical Thinking; TCP/IP; Vocational Education

Article history

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INTRODUCTION

The rapid development of the digital era requires educational institutions in Indonesia to adapt their learning processes to technological advancement. Digital literacy has become a basic competence for both teachers and students in the 21st century, as learning resources are no longer centered solely on teachers (Syahputra, 2024). One capability urgently needed to face this challenge is logical thinking, which underlies systematic problem-solving and coherent argumentation (Sumarmo et al., 2012). Logical thinking is defined as the ability to reason sensibly, correctly, and accurately based on available facts so that one's thoughts are easily understood by others (Auniyah et al., 2020), comprising three main indicators: consistency of thinking, arguing ability, and drawing conclusions (Dewi et al., 2024).

Several studies have reported low levels of students' logical thinking. Pertiwi & Putri (2024) found that monotonous learning models and insufficiently interactive media are major contributors to this weakness, compounded by instruction that fails to connect the material to students' contextual experience (Faradina & Mukhlis, 2020). Zulfickar & Oktariani (2020) further noted that low logical thinking ability stems from limited understanding of basic concepts and an inability to relate problem-solving steps to correct logical principles.

Learning in vocational high schools (SMK) is oriented toward equipping students with competencies relevant to workforce needs (Yatu et al., 2022), in line with the mandate of Law Number 20 of 2003 on the National Education System (Nasional, 2003a). Within the Computer

Network and Telecommunication Engineering (TJKT) expertise program, the Grade X Basic Computer Network and Telecommunication Engineering (DDTJKT) subject covers TCP/IP material encompassing protocol architecture, data transmission mechanisms, and IPv4/IPv6 addressing, which is inherently abstract as it requires layered understanding and binary-number operations in network addressing (Santyadiputra et al., 2024). Rahayu et al. (2024) reported that DDTJKT instruction in vocational schools remains constrained by media limited to PowerPoint slides and non-visual reading materials, leaving students unmotivated and their learning outcomes suboptimal, consistent with Lalisu et al.'s (2024) finding that interactive learning media significantly affects the learning outcomes of Grade X TJKT students in the same subject.

Technology adoption offers a relevant solution to this problem (Katili & Yassin, 2022), one of which is the Interactive Learning Module, designed with self-instructional, self-contained, stand-alone, adaptive, and user-friendly characteristics (Daryanto, 2013) that allow students to study the material at any time (Jafnihirda et al., 2023). In computer network instruction at vocational schools, simulation-based and e-learning interactive media have proven to enhance students' understanding and learning outcomes (Bunga et al., 2025). To optimize this potential, the present study applies the Contextual Teaching and Learning (CTL) model, which links learning concepts to real-life contexts to make learning more meaningful, through seven main components: constructivism, inquiry, questioning, learning community, modeling, reflection, and authentic assessment (Johnson, 2007). The effectiveness of CTL in improving both logical thinking and cognitive learning outcomes, including at the vocational education level, has been demonstrated in several prior studies (TriLaksono et al., 2025; Umah et al., 2019). Nevertheless, implementing CTL-based interactive media to enhance logical thinking still faces particular challenges, especially in designing activities that genuinely foster coherent thinking rather than merely being interactive in appearance (Adeliani et al., 2025).

Related studies have previously been conducted, including the application of CTL assisted by guided notes to improve logical thinking in chemistry (Umah et al., 2019), the SIBIJAK CTL-based interactive multimedia for critical thinking among high school students on networking material (Anggara et al., 2025), and mobile-based e-module learning media for the Basic TJKT subject (Lestari & Ardiyanta, 2025). These studies confirm the effectiveness of contextual approaches and interactive media, but none has specifically combined CTL with an Interactive Learning Module on TCP/IP material to improve the logical thinking of Grade X TJKT students, which constitutes the novelty of this study.

Based on the foregoing, this study aims to develop CONNETIC Module, a CTL-based interactive learning medium on TCP/IP material for the DDTJKT subject, to improve the logical thinking ability of Grade X TJKT students, as well as to analyze the improvement in this ability and students' responses to the use of the module.

METHOD

Research Procedure

This study employs the Research and Development (R&D) method with a quantitative approach, a method aimed at producing a specific product while testing its effectiveness (Sugiyono, 2022). The R&D procedure follows the ADDIE stages adapted from Branch (2009), consisting of five interrelated stages: (1) Analyze, identifying learning problems and analyzing student and teacher needs through interviews and questionnaires to obtain a picture of TCP/IP learning conditions in the field; (2) Design, designing the module content based on the Learning Outcomes (CP) and Learning Objective Flow (ATP), including mapping the material for each meeting, determining cognitive levels, and designing the module usage flow; (3) Development, developing the actual CONNETIC Module product, including content, interface, and interactive features, which was validated by media and material experts and empirically tested before use; (4) Implementation, applying CONNETIC Module to students through a pretest, module use, and a posttest, following the One-Group Pretest-Posttest design; and (5) Evaluation, evaluating the pretest-posttest results and student responses to measure the overall effectiveness and feasibility

of the module. These five stages were carried out systematically, with the evaluation results at each stage used as the basis for product refinement before proceeding to the next stage.

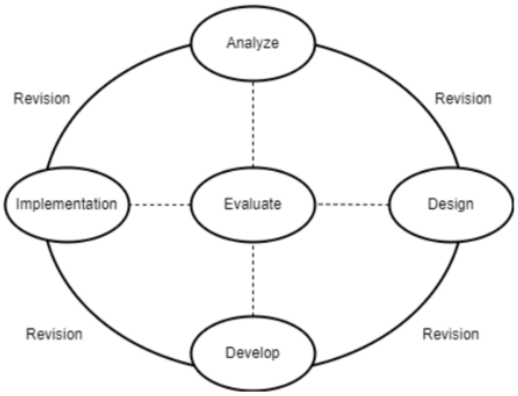


Figure 1. ADDIE Research Procedure (Branch, 2009)

Population and Sample

The population of this study comprised all Grade X students of the Computer Network and Telecommunication Engineering (TJKT) expertise program at SMK Negeri 4 Bandung enrolled in the DDTJKT subject. The sample was determined using a purposive sampling technique, namely 36 students of Grade X TJKT 2, selected based on interviews and an initial questionnaire indicating that TCP/IP material was still considered difficult and that students varied in their ability to understand abstract concepts requiring logical reasoning (Sugiyono, 2022).

Research Instruments

The research instruments comprised a field-study instrument in the form of a student-needs questionnaire using a 1–5 Likert scale (1 = Strongly Agree, 2 = Agree, 3 = Neutral, 4 = Disagree, 5 = Strongly Disagree) (Sugiyono, 2022) and teacher interviews; a logical thinking test instrument (pretest-posttest) developed based on three logical thinking indicators—consistency of thinking, arguing ability, and drawing conclusions (Dewi et al., 2024)—and validated by experts; media and material expert validation sheets adapting the Learning Object Review Instrument (LORI) version 1.5; and a student-response questionnaire on the learning media.

Data Analysis Technique

The item analysis technique included tests of validity, reliability using the Kuder-Richardson Formula 20 (KR-20), difficulty index, and discrimination index (Arikunto, 2021). Expert validation data using LORI and the student-response questionnaire were analyzed descriptively and quantitatively by calculating the feasibility percentage from the actual score divided by the maximum score multiplied by 100%, with the categories 81–100% Very Good, 61–80% Good, 41–60% Fair, and <40% Poor. Pretest-posttest data were analyzed using the Shapiro-Wilk normality test; if the data were not normally distributed, the nonparametric Wilcoxon Signed-Rank Test was used to examine differences before and after treatment (Sugiyono, 2022).

The improvement in students' logical thinking ability, both overall and per indicator, was calculated using the Normalized Gain (N-Gain) test, as shown in the following equation (Hake, 1999):

$$g = \frac{posttest\ score - pretest\ score}{maximum\ score - pretest\ score} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

The results were then matched against the following gain interpretation criteria: (a) $g > .7$ was categorized as High; (b) $.3 \leq g \leq .7$ was categorized as Moderate; and (c) $g \leq .3$ was categorized as Low.

FINDINGS AND DISCUSSION

Findings

Needs Analysis Results (Analyze Stage)

The preliminary study was conducted through interviews with the DDTJKT subject teacher and a questionnaire administered to Grade XI TKJ students at SMK Negeri 4 Bandung. Based on the interview results, the teacher currently applies the Problem-Based Learning model using lectures, discussions, and case practice, yet the learning media remain limited to conventional teaching modules and PowerPoint slides considered unappealing and inadequate for accommodating students' visual, auditory, and kinesthetic learning styles. School facilities (computer laboratory, internet access) were deemed adequate to support interactive media-based learning. A summary of the student questionnaire results is shown in Table 1.

Table 1. Summary of Needs Analysis Questionnaire Results

Aspect Measured	Mean Score	Mean Response
TCP/IP Material Difficulty	2.83	Neutral
Logical Thinking Indicator	2.25	Agree
Learning Media	2.26	Agree
Learning Model (CTL)	2.00	Agree

The mean scores across the four aspects ranged from 2.00 to 2.83, falling between the Agree and Neutral categories. The highest score (2.83, close to the Neutral category) was found for the TCP/IP material difficulty aspect, indicating that students were not entirely confident they could easily understand the material, suggesting that it is fairly difficult for them. Scores for the logical thinking indicator (2.25) and learning media (2.26) aspects fell within the Agree category, consistent with students' acknowledgment that their logical thinking ability was not yet optimal and that the learning media currently used remained inadequate. The lowest score, on the CTL learning model aspect (2.00, Agree category), indicated that students most strongly agreed that the implementation of CTL components in daily instruction remained minimal. The specific difficulties most frequently reported by students included converting and calculating binary numbers, subnetting, determining IP classes, dividing networks, and memorizing the CIDR table. The teacher had, in fact, attempted to implement several CTL elements (relating material to real contexts, peer tutoring, closing reflection), yet students perceived this implementation as not yet optimal. Both the teacher and students displayed strong enthusiasm for and support of the planned development of CONNETIC Module, with the only identified obstacle being technical aspects of module design rather than infrastructure readiness or user acceptance.

Module Design Results (Design Stage)

The needs analysis results were translated into the content design and usage flow of CONNETIC Module. Material design referred to the Merdeka Curriculum Learning Outcomes (CP) for Phase E, Media and Telecommunication Networks element, which states that by the end of Phase E, students should understand the basic principles of IPv4/IPv6 systems, TCP/IP, Networking Services, Telecommunication Network Security Systems, Cellular Systems, Microwave Systems, VSAT IP Systems, Optical Systems, and WLAN Systems (Kemendikbudristek, 2022). This CP was elaborated into a Learning Objective Flow (ATP) and mapped across four meetings: Meeting 1 TCP/IP Fundamentals (8 learning objectives), Meeting 2 TCP Mechanism (7 learning objectives), Meeting 3 IPv4 (8 learning objectives), and Meeting 4 IPv6 (7 learning objectives), with Bloom's Taxonomy cognitive levels designed to progressively increase from C2 (Understanding) in the early meetings to C5 (Evaluating) in the final meeting, tailored to the logical thinking ability of Grade X students. Each meeting integrated Contextual Teaching and Learning (CTL) components through real case studies and inquiry-based exercises to stimulate students' logical thinking indicators.

The module usage flow was designed to be linear with a sequential locking mechanism, as shown in Figure 2. Students access the landing page and log in to enter the dashboard, complete the pretest, then proceed through Meeting 1 to Meeting 4 in sequence each meeting consisting of Brief Material, Activities, Exercises, and Summary before completing the posttest and viewing

the evaluation results page. This mechanism prevents students from skipping ahead to the next meeting before completing all sub-stages and quizzes in the preceding meeting, so that the coherence of students' logical reasoning is built progressively.

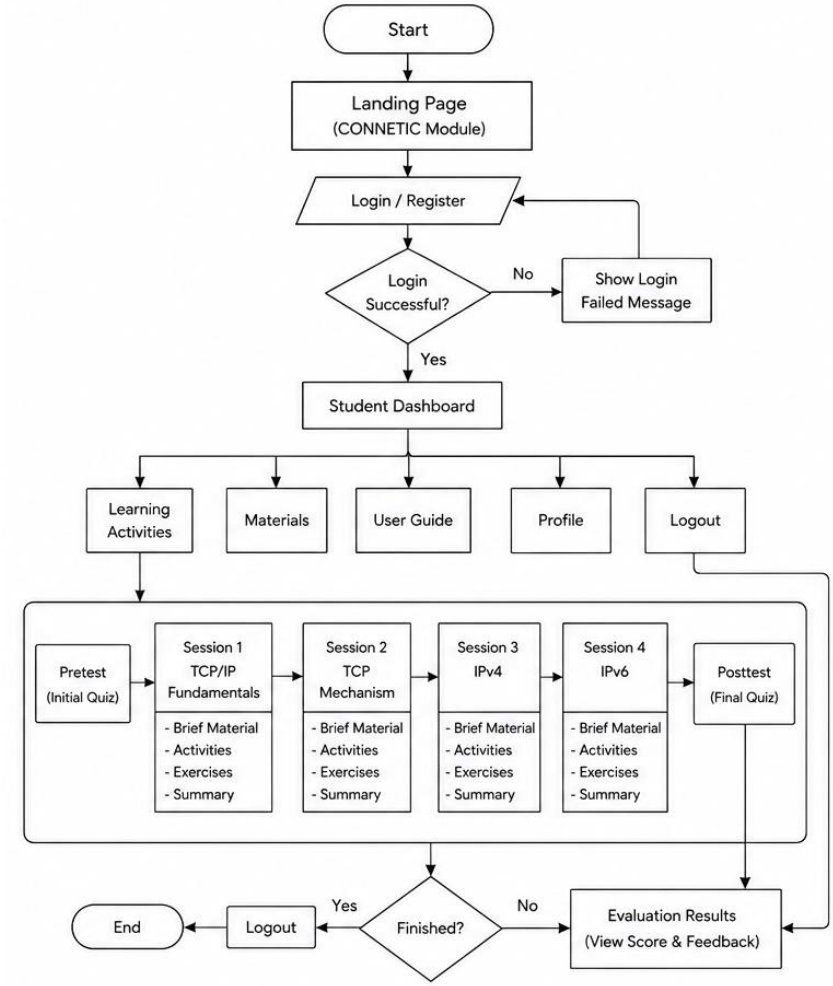
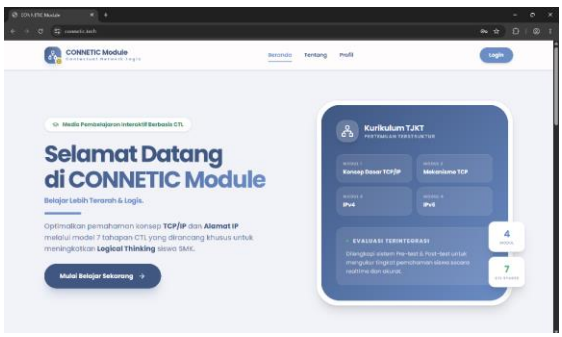


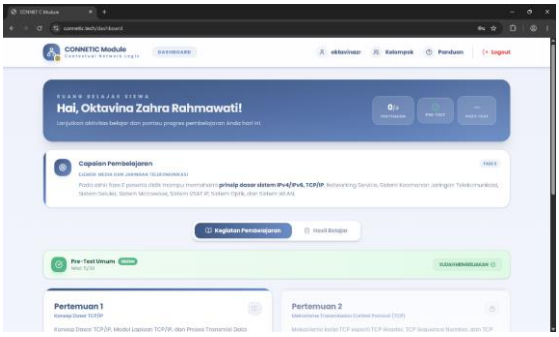
Figure 2. CONNETIC Module Usage Flow

Product Development Results (Develop Stage)

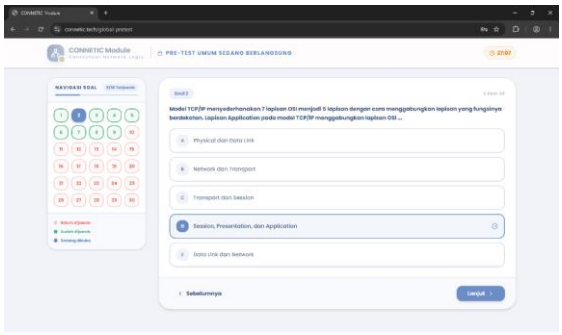
The CONNETIC Module was developed as a robust, high-performance web-based learning platform built on a modern frontend architecture consisting of React and TypeScript, paired with custom CSS to ensure a highly responsive layout seamlessly accessible via both laptops and smartphones. React enables a dynamic, component-based user interface that ensures a smooth and interactive user experience, while TypeScript provides strict type safety, significantly reducing runtime errors and enhancing code maintainability. On the backend, the platform leverages Supabase as its database and infrastructure solution, utilizing a secure PostgreSQL database to handle user authentication, structured data storage, and real-time synchronization. This advanced architecture reliably supports the platform's core functional mechanics, such as the sequential locking mechanism for the Learning Activities menu, CTL-based interactive activities, and pretest-posttest quizzes. Furthermore, Supabase's real-time data capabilities effectively power the integrated score dashboard, delivering immediate and accurate feedback to students directly after completing their activities. The finalized interface of the CONNETIC Module is shown in Figure 3.



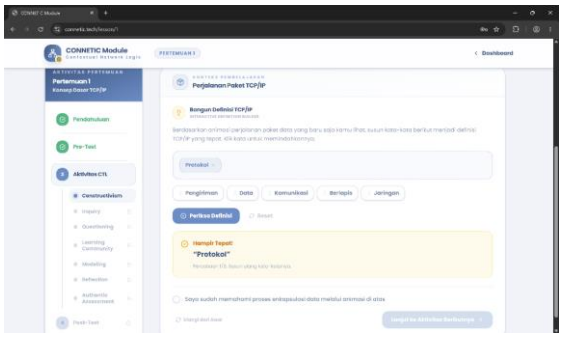
a) Landing Page



b) Student Dashboard Page



c) Pretest Activity Page



d) CTL-Based Learning Activity Page

Figure 3. CONNETIC Module Interface: (a) Landing Page, (b) Student Dashboard Page, (c) Pretest Activity Page, (d) CTL-Based Learning Activity Page

To ensure the pedagogical and technical quality of the platform, the developed media and learning materials were thoroughly validated by an expert lecturer from the Computer Science Education Study Program. This evaluation process utilized the Learning Object Review Instrument (LORI), which encompasses seven core assessment aspects to measure the feasibility and effectiveness of the digital learning objects (Nesbit, 2009). The comprehensive validation results obtained from this expert review are presented in Table 2.

Table 2. Media and Material Expert Validation Results (LORI)

No	LORI Assessment Aspect	Actual Score	Maximum Score	Percentage	Category
1	Content Quality	23	25	92.00%	Very Good
2	Learning Goal Alignment	18	20	90.00%	Very Good
3	Feedback and Adaptation	13	15	86.67%	Very Good
4	Motivation	22	25	88.00%	Very Good
5	Presentation Design	26	30	86.67%	Very Good
6	Interaction Usability	13	15	86.67%	Very Good
7	Accessibility	9	10	90.00%	Very Good
	Overall Total	**124**	**140**	**88.57%**	**Very Feasible**

A total score of 124 out of 140 (88.57%) placed CONNETIC Module in the Very Good/Very Feasible category, with the validator recommending it as feasible for tryout without revision.

The logical thinking test instrument was also validated for content by the same validator. The assessment indicated that the items were substantively sound and required only one round of minor revision to the wording of the stimulus sentences to make them easier for vocational high school students to understand, after which the instrument was declared theoretically valid and approved for field tryout.

The instrument was then empirically tested on Grade XI TKJ students at SMK Negeri 4 Bandung. Of the 90 items tested, 64 items (71.11%) were declared valid and 26 items (28.89%)

invalid. A summary of the validity, reliability, discrimination index, and difficulty index test results is shown in Table 3.

Table 3. Summary of Validity, Reliability, Discrimination Index, and Difficulty Index Test Results

Parameter	Result	Category
Validity	64 of 90 items valid (71.11%)	Valid
Reliability (KR-20)	r_{11} = .93	Very High
Discrimination Index	60.00% of items in good–fair category	Good
Difficulty Index	97.78% of items in easy–moderate category	Feasible

The items were developed to cover cognitive domains C2 through C5, consistent with the cognitive levels established during the Design stage. Of the 64 valid items, 60 items proportionally representing the three logical thinking indicators (consistency of thinking, arguing ability, and drawing conclusions) were selected for use at the implementation stage, divided into 30 equivalent pretest items and 30 posttest items. A reliability coefficient of .93 (very high category) indicated that the instrument was consistent and suitable for use as a measurement tool at the implementation stage.

Implementation Results (Implement Stage)

The implementation stage was carried out at SMK Negeri 4 Bandung in the DDTJKT subject with 36 Grade X TJKT 2 students as subjects, following the One-Group Pretest-Posttest design, in which one group of subjects is given a pretest (O_1) before treatment, followed by treatment (X) involving the use of CONNETIC Module, and a posttest (O_2) after treatment, to determine the effect of the treatment by comparing results before and after (Sugiyono, 2022), with the following pattern:

$$O_1 \; X \; O_2$$

The implementation took place over four meetings, each consisting of 3 class periods (3×45 minutes), beginning with a 30-item pretest to measure students' initial logical thinking ability, followed by the use of CONNETIC Module across the four TCP/IP meetings in sequence—each meeting proceeding through the Brief Material, Activities, Exercises, and Summary phases—and concluding with a 30-item posttest equivalent to the pretest.

During implementation, students displayed enthusiasm and active engagement in following the module's sequential locking flow, as shown in Figure 4. The platform was successfully and responsively accessed on both laptops and smartphones, demonstrating that CONNETIC Module could accommodate students' device limitations in the classroom without diminishing learning interactivity. The pretest and posttest score data collected from the 36 students were subsequently analyzed at the Evaluate stage.

Figure 4. Learning Activity Using CONNETIC Module in Class X TJKT 2 of SMK Negeri 4 Bandung

Evaluation Results (Evaluate Stage)

The pretest and posttest data from the 36 students were first tested for the normality assumption using Shapiro-Wilk ($\alpha = .05$) before hypothesis testing was conducted. The test results are shown in Table 4.

Table 4. Shapiro-Wilk Normality Test Results

Test Type	Mean	b	W count	W table	Conclusion
Pretest	45.11	109.616	.948	.935	Normal
Posttest	87.44	65.461	.878	.935	Not Normal

The posttest data were not normally distributed (W count = .878 < W table = .935); therefore, hypothesis testing used the nonparametric Wilcoxon Signed-Rank Test rather than the Paired Sample t-Test (Sugiyono, 2022).

The Wilcoxon Signed-Rank Test results used to determine the difference in students' logical thinking before and after using CONNETIC Module are shown in Table 5.

Table 5. Wilcoxon Signed-Rank Test Results

Statistical Indicator	Result
n (data pairs)	36
Z count	-5.224
Asymp. Sig. (2-tailed)	1.75×10^{-7} ($p < .001$)
Effect Size (r)	.87 (large)
Decision	H0 rejected, H1 accepted

All 36 students showed a score increase with no decreases whatsoever (negative ranks = 0), with a significance level far below .05 and a large effect size (r = .87), leading to the conclusion that there was a significant and substantial difference in students' logical thinking before and after using CONNETIC Module.

The improvement in logical thinking ability was calculated using N-Gain (Hake, 1999), both overall and per indicator, as presented in Table 6.

Table 6. N-Gain Results of Students' Logical Thinking Ability

Aspect	Pretest Mean	Posttest Mean	N-Gain	Category
Consistency of Thinking	5.63	10.16	.67	Moderate
Arguing Ability	4.56	8.56	.66	Moderate
Drawing Conclusions	3.81	7.44	.86	High
Overall Mean	**45.11**	**87.44**	**.77**	**High**

The highest improvement occurred in the Drawing Conclusions indicator (High category), while Consistency of Thinking and Arguing Ability remained in the Moderate category.

Students' responses to the usability of CONNETIC Module were measured through a usability testing questionnaire based on five dimensions (Nielsen, 1993): Learnability, Efficiency, Memorability, Errors, and Satisfaction. The recapitulation results are shown in Table 7.

Table 7. Usability Testing Questionnaire Results

Aspect	Actual Score	Ideal Score	Percentage	Category
Learnability	450	540	83.33%	Very Good
Efficiency	433	540	80.19%	Very Good
Memorability	455	540	84.26%	Very Good
Errors	432	540	80.00%	Very Good
Satisfaction	456	540	84.44%	Very Good
Total	**2,226**	**2,700**	**82.44%**	**Very Good**

A cumulative score of 2,226 out of 2,700 (82.44%) placed CONNETIC Module in the Very Good category, with all five usability aspects falling within the Very Good category, the highest being Satisfaction (84.44%) and Memorability (84.26%).

Discussion

The results of the Wilcoxon Signed-Rank Test ($Z = -5.224$, $p < .001$) together with an overall N-Gain of .77 (High category) demonstrate that CONNETIC Module effectively improved the logical thinking of Grade X TJKT 2 students on TCP/IP material, consistent with the findings of Santyadiputra et al. (2024) and Bunga et al. (2025) that simulation-based interactive media can enhance mastery of abstract computer network concepts. This effectiveness further underscores the role of the CTL approach integrated into every meeting of the module (Brief Material, Activities, Exercises, Summary), as previously demonstrated by TriLaksono et al. (2025) and Umah et al. (2019) that CTL effectively improves both students' cognitive learning outcomes and logical thinking ability.

The greatest improvement occurred in the Drawing Conclusions indicator (N-Gain .86, High category), while Consistency of Thinking and Arguing Ability remained in the Moderate category. This pattern suggests that the Exercises and Summary phases of CONNETIC Module—which require students to solve subnetting problems and reflect on discussion outcomes—were more effective at training students to draw logical conclusions than at training them to construct arguments or sequence solution steps coherently. This finding is consistent with the challenge raised by Adeliani et al. (2025) that CTL-based interactive media must be designed more carefully to genuinely foster coherent thinking rather than merely being interactive in appearance, suggesting this aspect warrants attention in the further development of CONNETIC Module.

The usability testing results, reaching 82.44% (Very Good category), further reinforce the effectiveness of CONNETIC Module from a user-acceptance perspective. The highest scores, on the Satisfaction (84.44%) and Memorability (84.26%) aspects, indicate that the Edu-Tech Style interface design and the sequential locking mechanism implemented succeeded in creating a memorable and satisfying learning experience for students, consistent with Nielsen's (1993) usability principle that ease of recalling system functions (memorability) contributes to long-term user acceptance. Meanwhile, the relatively lower Efficiency score (80.19%) compared to the other aspects points to room for improvement in inter-feature navigation speed, consistent with the internet connectivity issues reported by students during the implementation stage. Overall, the combination of a significant improvement in logical thinking and highly positive user acceptance indicates that integrating CTL into an Interactive Learning Module is not only cognitively effective but also positively received in terms of user experience, thereby reinforcing the position of CONNETIC Module as a learning medium worth applying to TCP/IP material at the vocational high school level.

CONCLUSION

Based on the research results, CONNETIC Module was successfully developed through the ADDIE procedure as a Contextual Teaching and Learning (CTL)-based interactive learning medium on TCP/IP material, and was declared very feasible for use based on media and material expert validation (88.57%). The application of CONNETIC Module was shown to significantly improve the logical thinking ability of Grade X TJKT 2 students (Wilcoxon Signed-Rank Test, $Z = -5.224$, $p < .001$), with an overall N-Gain of .77 (High category), although the improvement in the Consistency of Thinking and Arguing Ability indicators remained in the Moderate category compared to the High category achieved by Drawing Conclusions. Students also gave positive responses regarding the usability of the module (usability testing 82.44%, Very Good category).

This study has a limitation in that it employed a One-Group Pretest-Posttest design without a control group, meaning the improvement in students' ability cannot be fully attributed to CONNETIC Module without considering other factors such as the testing effect from repeated exposure to the items. Future research is recommended to use an experimental design with a

control group, to strengthen activities that specifically train consistency of thinking and arguing ability, and to extend the trial to other classes or schools to test the generalizability of the findings.

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