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Google Sites-based statistics learning: Integrating Tri-N ethnopedagogy and cognitive load theory

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ABSTRACT

Background: Google Sites is commonly used as a static repository for learning materials, limiting its potential to foster meaningful cognitive engagement in mathematics education. Moreover, few studies have integrated Ki Hadjar Dewantara's Tri-N philosophy (*Niteni*, *Nirokke*, *Nambahi*) with Cognitive Load Theory (CLT) to design culturally responsive and cognitively structured e-learning, particularly for junior high school statistics.

Purpose: This study aimed to develop and validate a Google Sites-based e-learning platform grounded in Tri-N philosophy and CLT for Grade VIII statistics learning.

Method: This Research and Development (R&D) study employed a modified 3D development model adapted from Thiagarajan's 4D model, consisting of the Define, Design, and Develop stages. Participants included 32 Grade VIII students and one mathematics teacher. Data were gathered through observations, interviews, expert validation questionnaires, and student response questionnaires. Specific instruments were used to measure CLT aspects (e.g., intrinsic, extraneous, and germane cognitive load items) and Tri-N integration (e.g., items assessing *niteni*–observation, *nirokke*–imitation, and *nambahi*–creation activities). Data were analyzed using descriptive qualitative and quantitative techniques.

Findings: The developed e-learning product showed high validity and practicality. Content expert validation yielded a mean score of 4.05 (Valid), and media expert validation reached 4.44 (Highly Valid). Student practicality assessments indicated Practical levels, with overall means of 3.61 (limited trial) and 3.93 (large-scale trial). These findings suggest that integrating Tri-N with CLT provides a culturally responsive and cognitively optimized framework that enhances meaningful digital learning. This approach offers practical implications for designing local wisdom-based e-learning and warrants further research on its effectiveness in broader educational contexts and longer implementation periods.

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INTRODUCTION

Education in the 21st century requires learning environments that are not only supported by technology but also designed to promote meaningful cognitive engagement (Özdoğru, 2022). One of the most influential frameworks for understanding how instructional design affects learning is Cognitive Load Theory (CLT), introduced by (Sweller, 1988) and further developed in subsequent studies (Sweller et al., 2019). CLT emphasizes that learning effectiveness depends on how information is presented and processed within students limited working memory. The theory distinguishes three types of cognitive load: intrinsic load, which stems from the complexity of the content; extraneous load, which results from ineffective instructional design; and germane load, which supports schema construction and deeper understanding. These concepts provide important guidance for designing digital learning environments, particularly in subjects such as mathematics that involve complex and interconnected concepts.

In Indonesia, the increasing adoption of educational technology has encouraged the use of e-learning platforms to support more flexible and accessible learning (Liu & Yu, 2023). Among these platforms, Google Sites has gained attention because it allows teachers to organize and share learning resources through an easy-to-use web environment (Halim & Halim, 2024; Ristanti et al., 2025). Several technical characteristics of Google Sites make it suitable for reducing students' cognitive load: its structured page hierarchy enables content chunking and progressive disclosure; its capacity to embed multimedia elements (e.g., videos, images, interactive widgets) supports dual coding and visual explanations; and its integrated quiz features allow for low-stakes formative assessment with immediate feedback, which can reduce extraneous load by clarifying misconceptions early. Previous studies have shown that Google Sites can improve student engagement and facilitate learning (Mayangsari et al., 2025), while its integration with structured instructional approaches can enhance problem-solving skills and learning independence (Albar et al., 2025). In mathematics education, Google Sites offers opportunities to integrate videos, interactive activities, gamification elements, and digital resources within a single learning space (Sosa-Díaz et al., 2025). However, its implementation in Indonesian classrooms is often limited to storing and distributing materials, rather than supporting students' mathematical thinking through carefully designed learning experiences.

This issue is particularly evident in statistics learning, where students frequently struggle to connect theoretical concepts with practical applications (Fries et al., 2021). Although the curriculum emphasizes critical thinking and mathematical reasoning, many students lack the conceptual readiness and motivation needed to achieve these goals (Ridwan et al., 2022). Preliminary observations conducted in a junior high school in Yogyakarta revealed similar challenges. Data from classroom observations, teacher interviews, and assessment records showed that the average statistics score of Grade VIII students was only 62.5, with just 34.4% of students achieving the minimum mastery criterion of 75. Classroom observations further indicated that learning remained largely teacher-centered, digital learning tools were rarely utilized effectively, and students often relied on copied answers from online sources without understanding the underlying reasoning.

The results of a needs-analysis questionnaire strengthened these findings. Approximately 78% of students reported difficulties in understanding the procedures involved in data presentation and analysis, while 81% considered mathematics learning uninteresting because instruction was dominated by lectures. None of the students expressed satisfaction with the current learning approach. These findings suggest that the problem extends beyond content difficulty and reflects a mismatch between instructional design and the cognitive demands of learning statistics.

Further observations and interviews identified several related challenges. Teachers had limited familiarity with CLT-based instructional design, structured digital learning materials for junior high school statistics were unavailable, scaffolding to support students in completing multi-step statistical procedures was lacking, and digital learning tools were primarily used for content delivery rather than cognitive engagement. In addition, no locally developed instructional model was found that integrated Indonesian educational values with digital learning design.

To address these challenges, the present study proposes a Google Sites-based e-learning product specifically designed with features aligned to both Tri-N philosophy and CLT principles. The product includes: (1) video-based concept explanations with visual annotations and step-by-step narration to support *Niteni* (observing) and to optimize the processing of intrinsic load through content chunking; (2) worked examples and guided practice modules with fading scaffolding to facilitate *Nirokke* (imitating) and to reduce extraneous load by providing clear solution pathways; (3) contextual problem-solving tasks and project-based activities that encourage *Nambahi* (developing) and foster germane load through schema construction and creative application; (4) interactive quizzes with immediate feedback and progress tracking to support self-regulated learning; and (5) a structured page navigation system that organizes content from simple to complex, enabling students to control their learning pace and manage cognitive demands effectively.

Although research on e-learning and mathematics instruction continues to grow, limited attention has been given to integrating local pedagogical philosophies into digital learning environments. Existing studies on Google Sites have generally focused on usability and student perceptions without examining how the platform can be designed to manage students' cognitive load during learning (Jari et al., 2022; Rikani et al., 2021). For instance, Jari et al. (2022) examined student satisfaction with Google Sites-based materials but did not analyze the instructional design features that influence cognitive processing. Similarly, (Rikani et al., 2021) evaluated the practicality of Google Sites for mathematics learning, yet their study lacked a theoretical framework for structuring content to reduce extraneous load or enhance germane load. Furthermore, while some studies have explored the integration of local wisdom in conventional classrooms (e.g., ethnomathematics approaches), none have systematically operationalized Tri-N philosophy into a digital learning environment with explicit cognitive load considerations. These gaps highlight the urgent need for a theoretically grounded and empirically validated e-learning model that bridges cultural pedagogy and cognitive science in the context of Indonesian mathematics education. Likewise, Ki Hadjar Dewantara's Tri-N philosophy consisting of *Niteni* (observing), *Nirokke* (imitating), and *Nambahi* (developing) has rarely been explored as a framework for digital learning, despite its strong foundations in Indonesian educational thought and its potential alignment with CLT principles.

More importantly, the relationship between Tri-N and cognitive load management has not been systematically investigated, despite conceptual affinities that merit closer theoretical scrutiny. According to Cognitive Load Theory, intrinsic cognitive load is associated with the element interactivity of learning materials and the learner's prior knowledge, while instructional design can help manage the processing demands imposed by complex information through strategies such as segmentation and pre-training (Sweller, 1988; Sweller et al., 2011). *Niteni* (careful observation) can be conceptually aligned with this principle by directing students' attention to salient features, relationships, and patterns through carefully organized representations before they engage with more complex problem-solving. In this sense, *Niteni* may support learners in managing the processing demands associated with intrinsic cognitive load by helping them organize relevant information into meaningful units, rather than being assumed to directly reduce intrinsic load. *Nirokke* (guided imitation), in turn, can be conceptually aligned with the function of worked examples in reducing unnecessary problem-solving search and extraneous cognitive processing. Worked-example research in mathematics has consistently demonstrated that structured modelling and guided practice can facilitate schema acquisition, particularly for novice learners and materials characterized by high element interactivity (Chen et al., 2019, 2020; Retnowati et al., 2010, 2017).

Nambahi (creative extension) can subsequently be related to learning-relevant cognitive processing traditionally described in terms of germane cognitive load, particularly through schema construction, elaboration, and transfer. As a stage in which learners modify, combine, and extend previously imitated models (Wijayanto, Z., 2019), *Nambahi* may encourage learners to allocate cognitive resources toward understanding relationships and applying previously acquired knowledge to new or contextualized situations. However, consistent with contemporary developments in Cognitive Load Theory, this relationship should not be interpreted as evidence that *Nambahi* constitutes a distinct source of germane load. Rather, *Nambahi* may support the allocation of limited working-memory resources toward learning-relevant processing after unnecessary instructional demands have been minimized (Sweller et al., 2019). Taken together, these conceptual connections suggest that Tri-N and Cognitive Load Theory may be complementary at the level of pedagogical design and cognitive processing: Tri-N provides a culturally grounded sequence for learning through observation, guided imitation, and creative extension, whereas CLT provides a theoretical account of how instructional arrangements may manage learners' limited working-memory resources. Nevertheless, this proposed alignment remains largely theoretical and has not been empirically validated, particularly in digital and ethnomathematical learning contexts (Sunzuma & Umbara, 2025). Consequently, no study has yet systematically integrated Tri-N principles and cognitive-load-informed instructional design into a Google Sites-based e-learning model for junior high school statistics. This gap points to the need for a validated, theoretically grounded learning framework that connects local educational values with evidence-based principles of digital instructional design.

To address this gap, the present study aims to develop and validate a Google Sites-based e-learning product grounded in Ki Hadjar Dewantara's Tri-N philosophy for Grade VIII statistics learning. Specifically, this study seeks to answer the following research questions: (RQ1): What are students' learning needs with respect to statistics instruction that could inform the design of a Tri-N-based e-learning product? (RQ2): How is the Google Sites-based e-learning product developed, and what characteristics does it exhibit based on the integration of Tri-N principles and Cognitive Load Theory? (RQ3): To what extent is the developed product valid, as judged by expert validation? (RQ4): To what extent is the developed product practical for classroom use, as evaluated by students? These questions guide the study through four corresponding stages: needs analysis, product development, expert validation, and practicality testing among students.

This study contributes both theoretically and practically. Theoretically, it operationalizes Tri-N from a general educational philosophy into a concrete framework for designing culturally grounded and cognitively informed digital learning environments. It also demonstrates how Tri-N can be integrated with Cognitive Load Theory to inform the organization of instructional content, learning activities, and digital representations. Practically, the study provides teachers with a feasible and potentially replicable model for developing e-learning that is culturally relevant, pedagogically meaningful, and responsive to students' cognitive needs. The findings provide empirical evidence regarding students' learning needs and the validity and practicality of a Tri-N- and Cognitive Load Theory-informed Google Sites-based e-learning product for statistics instruction in Indonesian junior high schools.

METHODS

This study is a field research grounded in the real learning conditions of Grade VIII students at a junior high school in Yogyakarta, Indonesia. The research was conducted between the second semester of the 2024/2025 academic year at this school, which was selected purposively based on the preliminary findings of low statistics learning outcomes, limited use of digital learning media, and teacher-centred instruction that characterised the classroom environment of the study. The research participants consisted of 32 Grade VIII students and one mathematics teacher.

This study employed a Research and Development (R&D) approach using a modified 3D model adapted from the 4D model proposed by Thiagarajan (1974) consisting of three stages: Define, Design, and Develop. The Disseminate stage was excluded because the study was limited to developing, validating, and evaluating the practicality of the instructional product rather than examining its effectiveness through large-scale implementation. The study primarily relied on quantitative data for product evaluation, while qualitative data were collected as complementary evidence to enrich the interpretation of quantitative findings, particularly when numerical scores alone could not explain the reasons underlying a particular assessment or inform specific product revisions.

Each stage generated data with a distinct function. In the Define stage, classroom observations and semi-structured teacher interviews (qualitative) were conducted alongside a student needs questionnaire (quantitative) to identify students' learning needs, characteristics, and existing problems in statistics instruction, corresponding to the first research question. In the Design stage, the findings from the Define stage were translated into a product blueprint. No empirical data were collected at this stage because its purpose was to translate the identified needs and instructional requirements into the instructional design, content structure, learning activities, and technical specifications of the e-learning product prior to development.

In the Develop stage, two types of evaluation data were collected. First, expert validation data consisted of Likert-scale ratings of the product's content, media, and instructional design quality (quantitative), supplemented by experts' written comments and revision suggestions (qualitative). These data were used to determine the validity of the developed product and to guide subsequent revisions. Second, student practicality data consisted of responses to a Likert-scale questionnaire (quantitative), supplemented by students' open-ended comments (qualitative). These data were used to determine the practicality of the product from the learners' perspective. Thus, quantitative data provided the primary basis for determining students' learning needs, product validity, and product practicality, whereas qualitative data provided contextual explanations and informed product refinement.

Data were collected in junior high school settings in Yogyakarta and involved Grade VIII students and teachers during the needs analysis, as well as designated subject-matter, instructional-design, and media experts during the validation stage. This procedure established a clear correspondence between the research questions, development stages, data sources, instruments, and intended outputs: needs analysis informed the development requirements, the Design and Develop stages produced the instructional product, expert evaluation established its validity, and student assessment established its practicality.

The Define stage was conducted first to identify the learning needs that the product was designed to address. During this stage, the researcher interviewed the mathematics teacher, observed classroom learning, and distributed a needs assessment questionnaire to 32 students. These activities provided the data needed to identify instructional needs, understand students' characteristics, and analyse the Grade VIII statistics curriculum under *Kurikulum Merdeka*.

The Design stage focused on developing the initial design of the e-learning product. The researcher designed the site structure, page layout, colour scheme, and navigation of the Google Sites platform, using Canva for visual elements and Google Forms for interactive assessments. The design was based on the three stages of the Tri-N philosophy: *Niteni* (observing and understanding), *Nirokke* (imitating and practising), and *Nambahi* (modifying and extending knowledge). Each stage was linked to specific learning objectives, student activities, and Google Sites features, resulting in a conceptual design that integrated the Tri-N framework with the principles of Cognitive Load Theory.

The Develop stage produced the actual e-learning product and subjected it to a structured validation and trial process. Data for this stage were collected through two main instruments: expert validation questionnaires and student response questionnaires. Validation was carried out by two categories of validators: a content expert and a media expert, both drawn from lecturers in the Mathematics Education programme at Universitas Sarjanawiyata Tamansiswa and experienced junior high school mathematics teacher. The validation instruments were adapted from (Mailani et al., 2024) and modified to fit the characteristics of the Tri-N-based Google Sites e-learning product. After expert validation and product revision, the product was tested in two stages: a limited trial with five students and a field trial with all 32 students in the class. Data in this stage were collected through questionnaires as the primary research instrument. Two questionnaires were employed: a validation questionnaire completed by expert validators to assess the product's validity and a practicality questionnaire completed by students to evaluate the product's practicality.

Data analysis was conducted using both qualitative and quantitative descriptive techniques. Qualitative analysis was used to analyse the comments and suggestions from the validators and the mathematics teacher, which were used to revise and improve the product. Quantitative analysis was used to analyse the scores from the validation and student response questionnaires. The mean score for each assessment aspect was calculated and then converted into qualitative categories using the criteria of Nuritha & Tsurayya (2021) for validity and Putri (2019) for practicality. The mean score for each aspect was computed using the formula:

$$\bar{x} = \Sigma x / n$$

where $\bar{x}$ denotes the mean score per aspect,

Σx denotes the total score,

and n denotes the number of assessment items.

The mean scores obtained from the data analysis were converted into qualitative assessment categories. The criteria for product validity are presented in Table 1.

Table 1.

Criteria for Product Validity Classification

Mean Score Range	**Validity Category**
$\bar{x} > \bar{x}_i + 1.8\, SB_i$	Highly Valid (HV)
$\bar{x}_i + 0.6\, SB_i < \bar{x} \leq \bar{x}_i + 1.8\, SB_i$	Valid (V)
$\bar{x}_i - 0.6\, SB_i < \bar{x} \leq \bar{x}_i + 0.6\, SB_i$	Moderately Valid (MV)
$\bar{x}_i - 1.8\, SB_i < \bar{x} \leq \bar{x}_i - 0.6\, SB_i$	Less Valid (LV)
$\bar{x} \leq \bar{x}_i - 1.8\, SB_i$	Invalid (IV)

The practicality of the developed e-learning product was evaluated using the criteria presented in Table 2.

Table 2.

Criteria for Product Practicality Classification

Mean Score Range	**Practicality Category**
$\bar{x} > 4.20$	Highly Practical (HP)
$3.40 < \bar{x} \leq 4.20$	Practical (P)
$2.60 < \bar{x} \leq 3.40$	Moderately Practical (MP)
$1.80 < \bar{x} \leq 2.60$	Less Practical (LP)
$\bar{x} \leq 1.80$	Not Practical (NP)

A product was considered valid if it met the "Valid" category and practical if it met the "Practical" category. Practicality was also supported when the implementation of learning activities reached at least 75%.

RESULT AND DISCUSSION

Results

This section presents the findings organised according to the four research questions guiding this study, moving sequentially from students' learning needs, through product development and its characteristics, to the product's validity and practicality.

Students' Learning Needs in Statistics Instruction (RQ1)

To answer the first research question (students' learning needs with respect to statistics instruction) data were collected through classroom observations, teacher interviews, and a needs-assessment questionnaire during the Define stage. The Define stage was conducted to identify the learning needs that formed the basis for product development. Data were collected through classroom observations, semi-structured interviews with the mathematics teacher, and a needs-assessment questionnaire completed by 32 Grade VIII students. The findings showed that statistics learning relied mainly on lectures, textbooks, and static PowerPoint presentations. Students were generally passive during lessons, and learning activities provided limited opportunities for active engagement with the material. These findings were supported by the teacher's interview. As the teacher explained, *"Selama pembelajaran, sebagian besar siswa hanya mendengarkan penjelasan guru dan jarang terlibat aktif dalam diskusi"*. (*"During the lesson, most students only listened to the teacher's explanation and rarely participated actively in discussions").* The teacher also stated, *"Media yang digunakan masih sebatas buku paket dan PowerPoint, sehingga siswa cepat merasa bosan, terutama pada materi statistika."* (*"The learning media are still limited to textbooks and PowerPoint presentations, so students quickly lose interest, especially when learning statistics."*)

The quantitative data also showed that students had difficulty learning statistics. The average score on the daily statistics assessment was 62.5, and only 11 of the 32 students (34.4%) achieved the minimum mastery criterion of 75. The needs-assessment questionnaire indicated that 78% of students had difficulty understanding the procedures for presenting and analysing data, while 81% found mathematics lessons less interesting because they were mainly teacher-centred. These findings indicate the need for a more interactive learning approach that better supports students' understanding and engagement.

The student analysis showed that most students had access to electronic devices and the internet, but they mainly used them for entertainment rather than learning. They were also unfamiliar with using e-learning for independent study and still relied heavily on teacher explanations, especially in statistics, which they considered difficult to learn.

The task analysis showed that the Grade VIII statistics curriculum under *Kurikulum Merdeka* requires students to formulate questions, collect and present data, analyse measures of central tendency and dispersion, and solve contextual problems. The concept analysis identified a sequence of topics, beginning with data types and data presentation, followed by mean, median, mode, range, quartiles, and interquartile range. These findings indicate that the statistics content is relatively complex and requires well-structured instructional support for junior high school students.

Taken together, these findings indicate that students needed a more interactive, well-structured, and cognitively manageable learning approach. This need directly informed the design of the Tri-N–CLT e-learning product presented in the following section.

Development and Characteristics of the Tri-N–CLT E-Learning Product (RQ2)

Building on the needs identified above, the second research question concerns how the e-learning product was developed and what characteristics it exhibits as a result of integrating Tri-N principles with Cognitive Load Theory. The Design stage translated the Define-stage findings into a concrete instructional product. Google Sites was chosen as the delivery platform due to its accessibility, multimedia integration capacity, and suitability for structuring sequenced learning without requiring advanced technical skills (Halim & Halim, 2024; Sosa-Díaz et al., 2025). Supporting tools included Canva for visual design and Google Forms for interactive assessment.

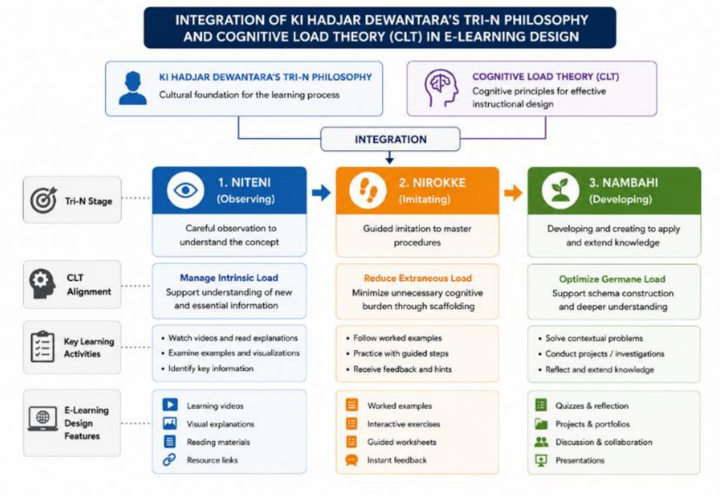
The primary design challenge was operationalizing Ki Hadjar Dewantara's Tri-N philosophy: *Niteni* (observe), *Nirokke* (imitate), and *Nambahi* (develop), into sequenced learning activities, while aligning each stage with specific cognitive load management principles from CLT. The site structure, page layout, navigation, visual elements, and learning activities were designed using the integration of Ki Hadjar Dewantara's Tri-N philosophy and Cognitive Load Theory (CLT), as illustrated in Figure 1.

Figure 1 shows how the three stages of the Tri-N philosophy (*Niteni, Nirokke*, and *Nambahi*) were integrated with the three components of Cognitive Load Theory (intrinsic load, extraneous load, and germane load) to guide the design of learning activities and Google Sites features. Rather than functioning as separate frameworks, Tri-N provided the pedagogical sequence of learning, while CLT informed the design of instructional materials to reduce unnecessary cognitive burden and support meaningful learning.

In the *Niteni* phase, learning activities were designed to help students understand the fundamental concepts of statistics before performing calculations, so as to manage the intrinsic load arising from the complexity of the content. The materials were presented gradually using instructional videos, contextual illustrations, annotated diagrams, and explanatory text. The statistics topics were organised sequentially, beginning with data types and methods of data presentation, followed by measures of central tendency (mean, median, and mode), and then measures of dispersion (range, quartiles, and interquartile range). For example, students first observed authentic data presented in tables, bar charts, and pie charts before learning how to interpret the data and calculate statistical measures.

Figure 1.

Conceptual Model of Tri-N and CLT Integration in the E-Learning Design



The *Nirokke* phase was designed to reduce extraneous load by providing worked examples and guided practice, so that students first learned from step-by-step examples before solving similar problems independently. Google Sites provided worked examples that demonstrated each calculation step in detail. For instance, students learned how to calculate the mean from grouped and ungrouped data through step-by-step examples accompanied by explanations of each procedure, and similar guidance was provided for determining the median, mode, quartiles, and range. After studying the examples, students completed interactive practice exercises and guided worksheets and received immediate feedback before proceeding to more challenging tasks.

The *Nambahi* phase was designed to optimise germane load by engaging students in contextual tasks, independent assessments through Google Forms, and reflective activities. Once students had acquired conceptual understanding and procedural skills, they were asked to solve contextual statistical problems independently, analysing data from real-life situations. Students then interpreted the results, selected appropriate statistical measures, justified their answers, and reflected on their problem-solving processes. Google Forms was used to deliver quizzes and formative assessments, while discussion pages and project activities encouraged students to compare solutions, explain their reasoning, and construct new knowledge collaboratively.

The design of Google Sites also reflected the characteristics identified during the needs analysis. Since students were already familiar with smartphones, the platform was designed with simple navigation, responsive page layouts, clear menus, and multimedia resources that could be accessed both inside and outside the classroom. Learning materials, instructional videos, interactive exercises, quizzes, and supporting resources were organised according to the Tri-N learning sequence so that students could study independently at their own pace while still receiving sufficient instructional guidance.

The implementation of these design principles in the Google Sites platform is illustrated in Figure 2, which presents the homepage and its main interface. Each component was designed to facilitate navigation, provide structured access to learning resources, and support the progressive learning sequence based on the Tri-N philosophy while keeping visual and interface complexity to a minimum.

Figure 2.

Design Homepage of the Tri-N Statistics Google Sites E-Learning Platform

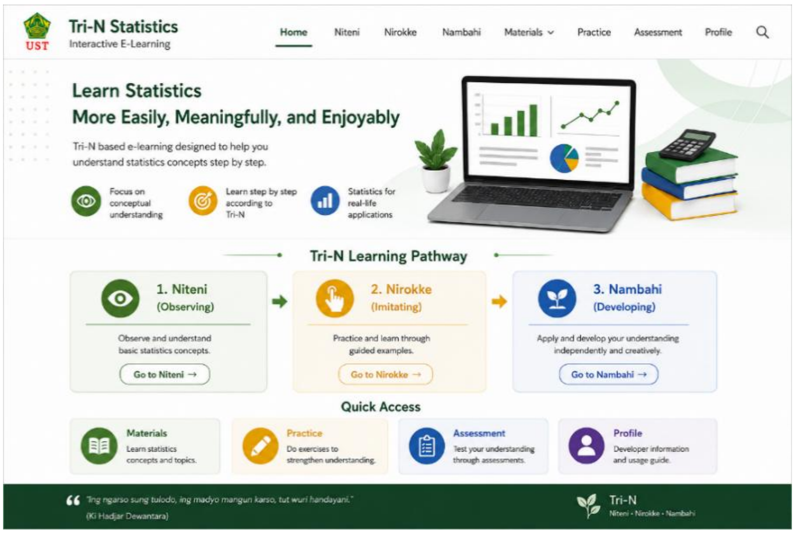


Figure 2 presents the homepage of the Google Sites-based e-learning product developed for Grade VIII statistics. The homepage was designed as the main interface to help students access learning resources easily while providing a clear overview of the learning process. Following the needs analysis, the interface emphasises simplicity, consistency, and ease of navigation so that students can focus on learning rather than searching for information. At the top of the page, the navigation bar provides direct access to the Home, *Niteni, Nirokke, Nambahi*, Materials, Practice, Assessment, and Profile pages. This structure allows students to move easily between learning sections and revisit previously studied materials whenever needed, with clear and consistent menus that keep navigation simple.

The homepage banner introduces the purpose of the e-learning platform through a short description and visual illustrations related to statistics. Key learning goals are summarised using three icons that highlight conceptual understanding, step-by-step learning, and real-life applications, providing students with an overview of what they will learn before beginning the lesson. The centre of the homepage features the Tri-N Learning Pathway, which visually presents the sequence of learning through *Niteni, Nirokke*, and *Nambahi*. Rather than displaying all learning materials simultaneously, the homepage guides students through the learning process in a progressive order, encouraging them to complete one stage before moving to the next.

Below the learning pathway, the Quick Access section provides shortcuts to Materials, Practice, Assessment, and Profile. The Materials page contains instructional videos, reading materials, visual explanations, and supporting resources covering data presentation, measures of central tendency, and measures of dispersion. The Practice page provides guided exercises and worked examples, while the Assessment page links students to Google Forms quizzes. The Profile page contains user information and instructions for using the platform.

The visual design uses a consistent colour scheme, meaningful icons, sufficient white space, and a clean page layout to improve readability and direct students' attention to important information. Decorative elements were kept to a minimum, and the responsive interface allows students to access the platform using smartphones or computers, reflecting the needs-analysis finding that most students regularly use mobile devices. These design characteristics constitute the concrete product whose quality is evaluated in the next two sections. The Develop stage subjected the designed product to expert validation and student field trials, addressing two central evaluative questions: whether the product is valid according to content and media experts, and whether it is practical as experienced by student users.

Validity of the Developed Product (RQ3)

The third research question asks to what extent the developed product is valid, as judged by expert validation. Expert validation was conducted by a content expert and a media expert using structured questionnaires adapted from Mailani et al. (2024). The content expert assessed content appropriateness, material presentation, and language quality, while the media expert evaluated visual display quality, interactivity and media suitability, media completeness, and technical and graphic quality. Results are presented in Tables 1 and 2.

Table 1.

Results of Content Expert Validation

Aspect	**Mean Score (1–5)**	**Category**
Content Appropriateness	3.86	Valid
Material Presentation	4.00	Valid
Language Quality	4.30	Highly Valid
Overall Mean	4.05	Valid

The content validation yielded an overall mean of 4.05, which falls within the Valid category. Language quality received the highest score (4.30, Highly Valid), while content appropriateness (3.86) and material presentation (4.00) were both rated Valid. The validator noted that further refinement in concept sequencing would strengthen the material.

Table 2.

Results of Media Expert Validation

Aspect	Mean Score (1–5)	Category
Visual Display Quality	4.30	Highly Valid
Interactivity and Media Suitability	4.60	Highly Valid
Media Completeness	4.50	Highly Valid
Technical and Graphic Quality	4.37	Highly Valid
Overall Mean	4.44	Highly Valid

Media validation achieved an overall mean of 4.44 (Highly Valid) across all aspects. Interactivity and media suitability scored highest (4.60), followed by media completeness (4.50), technical and graphic quality (4.37), and visual display quality (4.30), all of which fell within the Highly Valid category.

Practicality of the Developed Product (RQ4)

The fourth research question concerns the extent to which the developed product is practical for classroom use, as evaluated by students. Following expert validation and product revision, the e-learning product was trialled in two rounds: a limited trial with five students and a large-scale trial with all 32 students. Student responses were collected using a questionnaire assessing visual display quality, material presentation, and perceived benefit. Results are presented in Table 3.

Table 3.

Results of Product Practicality Trials

Aspect	Limited Trial (n=5)	Large-Scale Trial (n=32)
Visual Display Quality	3.36 (67%)	4.00 (80%)
Material Presentation	4.08 (82%)	3.90 (78%)
Perceived Benefit	3.38 (67%)	3.90 (78%)
Overall Mean Score	3.61	3.93
Category	Practical	Practical

Both trials yielded Practical overall ratings, with mean scores of 3.61 for the limited trial and 3.93 for the large-scale trial. The most notable change was in visual display quality, which rose from 3.36 (67%) in the limited trial to 4.00 (80%) in the large-scale trial. Perceived benefit also increased, from 3.38 (67%) to 3.90 (78%). Material presentation scored 4.08 (82%) in the limited trial and 3.90 (78%) in the large-scale trial.

Discussion

The discussion is organised around the four research questions that guided this study, so that the interpretation of the findings corresponds directly to the study's aims: students' learning needs (Question 1), the development and characteristics of the product (Question 2), its validity (Question 3), and its practicality (Question 4). Taken together, the findings do more than confirm that the product functions adequately; they suggest that embedding a culturally rooted pedagogical logic into digital instructional design shapes how students and experts perceive its quality, not merely whether it works.

Interpreting Students' Learning Needs (RQ1)

Regarding the first research question, the needs analysis revealed that statistics instruction was dominated by lectures, textbooks, and static presentations, that students were largely passive, and that low mastery coincided with limited interactive and well-structured support. Interpreted through Cognitive Load Theory, these conditions describe a learning environment in which the intrinsic complexity of statistical content was compounded by extraneous load arising from teacher-centred delivery, leaving little room for the germane processing needed to build understanding. This interpretation clarifies why the identified needs pointed not simply to "more technology," but to instruction that is cognitively manageable and actively engaging. The needs analysis therefore did more than describe a problem; it specified the design requirements that the Tri-N–CLT product was subsequently built to meet, establishing a direct line from Question 1 to the development reported under Question 2.

This reading is consistent with prior evidence that statistics is a persistently difficult domain: Fries et al. (2021) attribute much of this difficulty to students' struggle to connect procedures with underlying concepts, and Ridwan et al. (2022) report that limited conceptual readiness and motivation constrain reasoning in mathematics. What the present needs analysis adds is a critical shift in how the problem is located. Rather than treating low mastery primarily as a student deficit, Cognitive Load Theory reframes it as a mismatch between instructional design and learners' limited working-memory resources: when intrinsically complex content is delivered through undifferentiated lectures, the extraneous load imposed by the delivery format competes for the very resources that conceptual understanding requires (Sweller, 2020). Interpreted this way, the needs analysis does not merely confirm that statistics is hard; it specifies that the difficulty is, in part, a designable problem, which is precisely what justifies a cognitively structured rather than a content-delivery approach.

Development and Characteristics of the Tri-N–CLT Product (RQ2)

The second research question concerns how the product was developed and what characteristics it exhibits as a result of integrating Tri-N with Cognitive Load Theory. The most consequential characteristic is that the product is not a repository of materials but an instructional sequence in which each Tri-N stage is deliberately aligned with a cognitive-load function, as interpreted below.

The characteristics of each Tri-N stage can be interpreted in relation to established instructional-design principles. The multimodal presentation used in the *Niteni* stage is consistent with Mayer's (2019) multimedia learning principle, according to which learning is more effective when verbal and visual information are presented together, thereby supporting the management of intrinsic load. The worked examples and guided practice that characterise the *Nirokke* stage reflect the worked-example effect, whereby studying solved examples reduces the extraneous effort of independent solution search during the early stages of learning (Atkinson et al., 2000; Renkl, 2017). The gradual withdrawal of support in the *Nambahi* stage, as students move toward independent and contextual problem-solving, is consistent with Vygotsky's (1978) notion of scaffolding. Interpreted together, these correspondences indicate that the product's design characteristics are not arbitrary but are grounded in recognised principles of instructional design aligned with Cognitive Load Theory.

At the same time, the Tri-N–CLT correspondence should be interpreted with appropriate caution rather than as a one-to-one equivalence. Contemporary formulations of Cognitive Load Theory no longer treat germane load as a separate, additive source of load; instead, germane processing refers to the allocation of working-memory resources to learning-relevant activity once extraneous demands have been minimised (Sweller et al., 2019). Read critically, this means that the *Nambahi* stage does not "generate" germane load so much as create conditions under which students can direct their remaining cognitive resources toward schema construction and transfer. Framing the alignment in this way avoids overclaiming a mechanistic mapping and locates the study's theoretical contribution more defensibly: Tri-N supplies a culturally grounded pedagogical sequence, while CLT explains why that sequence is cognitively reasonable. This is a stronger claim than the surface compatibility noted by Huda et al. (2025), because it identifies the specific instructional mechanism through which the two frameworks cohere.

Beyond the validity and practicality findings, this study raises a broader and arguably more significant question: what does it mean to ground digital learning design in an indigenous pedagogical philosophy, and what value does this grounding add? The answer, emerging from both the design process and the validation outcomes, is that Tri-N provides something that generic instructional models often do not offer: a culturally resonant logic that connects the structure of learning to the lived values and educational heritage of the learners themselves.

Ki Hadjar Dewantara's Tri-N philosophy was not developed as a framework for digital instruction. It emerged from a rich tradition of Javanese educational thought, rooted in the Tamansiswa movement's conviction that education should be humane, contextual, and respectful of the learner's own cultural identity (Kafah et al., 2026). When this philosophy is operationalised within a digital environment, it does not simply provide a three-step instructional sequence, this integration embeds a deliberate pedagogical structure that students perceive as coherent and supportive, even if not explicitly identified. The observation phase invites genuine curiosity. The imitation phase affirms that procedural competence is worth building carefully. The development phase treats students as capable of genuine intellectual growth. These are not merely pedagogical strategies; they are expressions of a worldview about what learners deserve.

This point connects to a growing body of research emphasising the importance of integrating local wisdom and cultural values into technology-based learning design. (Purwoko et al., 2023; Puspita et al., 2022) demonstrated that mathematics learning media grounded in local cultural frameworks produced higher levels of student engagement and motivation compared to culturally neutral alternatives. Prihatin et al. (2024) similarly found that the Tri-N approach, when implemented in an elementary school context, helped create a learning environment that felt closer to students' natural ways of engaging with knowledge. The present study adds to this literature by showing that such integration is not only meaningful at the interpersonal level of the classroom but is also technically viable within a structured digital platform and is recognised as valid and practical by both expert validators and student users.

Theoretical contribution. There is also a significant theoretical contribution embedded in this study's design logic. By explicitly mapping each stage of Tri-N onto a corresponding dimension of CLT: *Niteni* to intrinsic load management, *Nirokke* to extraneous load reduction, and *Nambahi* to germane load optimisation, the study demonstrates that an indigenous Indonesian pedagogical framework and a globally recognised cognitive theory are not merely compatible but structurally aligned. This alignment is not coincidental or forced; it reflects the deep pedagogical wisdom encoded in the Tri-N philosophy, which understood that meaningful learning requires first building understanding, then practising carefully, and finally creating independently. Huda et al. (2025) have similarly noted the compatibility of the Tri-N framework with contemporary cognitive and constructivist learning theories, suggesting that this alignment represents a genuine theoretical contribution rather than a surface-level parallel.

However, a practical challenge emerged concerning the design of the *Nambahi* (develop) stage within the Google Sites environment. While the platform supports basic multimedia integration and linear content sequencing, facilitating open-ended, creative, or project-based activities requires more advanced digital competencies. Teachers must be able to embed external tools (e.g., Google Jamboard for collaborative brainstorming, Padlet for idea sharing, or Google Forms for self-directed projects), design branching navigation paths that allow student choice, and curate resources that support differentiated exploration. Given the varying levels of digital literacy among Indonesian teachers, these demands may pose significant obstacles to the faithful implementation of the Tri-N framework in digital settings. This challenge highlights the need for structured professional development and technical support to accompany the dissemination of Tri-N-based e-learning products, ensuring that the pedagogical intent of the *Nambahi* stage is not compromised by technological limitations.

Validity of the Product and Comparison with Prior Research (RQ3)

The third research question concerns the validity of the developed product as judged by expert validation. Content validation (overall mean 4.05, Valid) and media validation (overall mean 4.44, Highly Valid) indicate that the product met recognised quality standards for both its statistical content and its digital presentation. These outcomes are best interpreted not as isolated scores but as evidence that the underlying design logic is sound: the Tri-N–CLT structuring produced materials that experts judged appropriately sequenced, cognitively calibrated, and technically coherent.

This finding reinforces the work of Rikani et al. (2021) and Buchori et al. (2023), who identified Google Sites as a practical platform for mathematics learning when content is appropriately structured and interactive. Ciung et al. (2022) similarly developed a Google Sites-based media for arithmetic sequence material, further illustrating the platform's growing use for structured mathematics content in the Indonesian context. However, a closer reading reveals an important point of divergence between this body of work and the present study: none of these prior efforts articulated an explicit theoretical rationale for why their structuring choices should reduce cognitive burden or improve learning. The present study extends their findings by demonstrating that Google Sites' practical value is significantly amplified when organised around an explicit and culturally grounded pedagogical framework (Ki Hadjar Dewantara's Tri-N philosophy) integrated with Cognitive Load Theory, rather than used simply as a vehicle for content delivery. The high media-validity ratings are consistent with Wulandari et al. (2025), who reported that Google Sites-based interactive media for junior high school science achieved high validity when they incorporated multimedia and clear navigation.

A critical qualification is nonetheless warranted. The comparisons above, together with the present results, establish that the product is valid in the sense of being judged appropriate, well-structured, and technically sound by content and media experts using instruments adapted from Mailani et al. (2024); they do not, however, establish that it improves learning outcomes. Expert-judged validity is a necessary but not sufficient condition for instructional effectiveness. The divergence identified above, namely that prior Google Sites studies rarely articulated a cognitive rationale, cuts both ways. While it distinguishes the present design, it also means that the causal link between CLT-informed structuring and reduced cognitive load remains, at this stage, a theoretically motivated expectation rather than an empirically measured effect. The validity findings should therefore be read as evidence that the design logic is sound and expert-endorsed, not as direct proof of cognitive or achievement gains.

Practicality of the Product (RQ4)

The fourth research question concerns the practicality of the product as evaluated by students. Both trials yielded Practical ratings, and the improvement from the limited trial (mean 3.61) to the large-scale trial (mean 3.93) indicates that student feedback was genuinely incorporated into product refinement rather than treated as a formality. Interpreted alongside the validation evidence, the practicality findings suggest that the qualities experts recognised in the product were also experienced as meaningful and usable by the learners for whom it was designed.

One further finding deserves attention. The media validation data showed that interactivity and media suitability received the highest score among all assessed aspects, with a mean of 4.60 (Highly Valid). This score indicates that the validator judged the platform's interactive features, (including embedded quizzes, navigational prompts, and response-triggered feedback) as highly appropriate for supporting active student engagement. This finding is corroborated by the student practicality data, which consistently reflected positive perceptions of the material's presentation and sequencing. The visual display quality aspect improved notably from 3.36 (67%) in the limited trial to 4.00 (80%) in the large-scale trial, while material presentation maintained strong scores of 4.08 and 3.90 across both rounds. These converging results suggest that students found the platform not only visually coherent but also cognitively accessible. This interpretation is in line with Sabri et al. (2024), who argued that the educational impact of technology depends not on the technology itself but on the quality of the accompanying pedagogical design.

Read critically, however, the practicality data are not uniformly strong, and the pattern is informative. In the limited trial, visual display quality (3.36) and perceived benefit (3.38) sat near the lower boundary of the Practical category before rising in the large-scale trial, whereas material presentation was rated highly from the outset. This suggests that students more readily recognised the clarity of the content than the interface or the learning value of the platform, and that the latter perceptions depended on the iterative revisions made between rounds. The improvement is therefore better interpreted as evidence of a responsive design process than as an inherent property of the product. This aligns with studies reporting positive student responses to Google Sites-based mathematics media (Mayangsari et al., 2025; Ristanti et al., 2025), but it also tempers them: favourable perceptions emerged only after the interface was refined in response to user feedback, underscoring that accessibility in digital learning is achieved through design iteration rather than assumed from the platform itself.

Read together, the practicality data indicate that the Tri-N rhythm was experienced by students as a coherent and followable learning path: *Niteni* invited observation without immediate performance pressure, *Nirokke* offered guided practice that reduced anxiety about unfamiliar procedures, and *Nambahi* positioned students as capable of extending their own learning. This convergence between what experts judged valid and what students found practical directly answers Question 4 and reinforces the interpretation offered for Questions 2 and 3.

Finally, it is important to delimit what the practicality findings can and cannot support. Practicality here refers to a perceptual and usability construct, that is, what students found clear, navigable, and worthwhile, rather than a measure of learning effectiveness. Consistent with Sweller (2020), a reduction in perceived interface complexity is a plausible indicator of lowered extraneous load, but perceived accessibility does not by itself demonstrate that intrinsic content was better understood or that schema construction occurred. Because the study concluded at the Develop stage, these interpretations remain design-level inferences; establishing whether the Tri-N–CLT product actually reduces measured cognitive load or improves achievement requires the experimental work identified in the conclusion.

Practical Implications and Contribution

The practical implication of this theoretical convergence is significant. It means that educators who wish to develop CLT-informed digital learning materials do not need to look exclusively to Western instructional design models, they can find equivalent, and culturally richer, guidance in the Tri-N tradition. This has particular relevance for Indonesian mathematics teachers, many of whom may find the CLT framework conceptually unfamiliar, but who are deeply familiar with the values and rhythms of learning embedded in the Tamansiswa educational philosophy.

These findings suggest that the key to the product's success lies not in the technology itself, but in the quality of the instructional thinking that shaped how that technology was used. Google Sites is a flexible and accessible platform for mathematics instruction in digital environments, but its effectiveness is not automatic; it depends on whether the platform is organised to serve a coherent pedagogical vision. This study shows that when it is, and when that vision is grounded in both a rigorous cognitive theory and a culturally meaningful educational philosophy, the result is a product that is valid, practical, and genuinely educationally purposeful.

CONCLUSION

This study concludes that the Google Sites-based e-learning platform, grounded in Ki Hadjar Dewantara's Tri-N philosophy and informed by Cognitive Load Theory (CLT), successfully addresses the need for a culturally relevant and cognitively structured digital learning environment for Grade VIII statistics. The sequential implementation of *Niteni*, *Nirokke*, and *Nambahi* was operationalized into a coherent instructional design that optimizes intrinsic load processing through content chunking and multimodal presentation, reduces extraneous load through worked examples and guided practice, and fosters germane load through contextual problem-solving activities. Expert validation confirmed the product's quality, with content experts rating it Valid (overall mean 4.05) and media experts rating it Highly Valid (overall mean 4.44). Student practicality trials yielded Practical ratings in both limited (mean 3.61) and large-scale (mean 3.93) rounds, confirming the product's feasibility for classroom use. These findings demonstrate that integrating indigenous educational values with evidence-based cognitive principles provides a robust foundation for digital learning design.

Theoretically, this study contributes by positioning Tri-N not merely as a philosophical foundation but as an operational instructional framework structurally aligned with CLT in technology-enhanced learning. This integration enriches educational scholarship by demonstrating that local pedagogical wisdom can be transformed into scientifically grounded instructional design principles for digital environments. However, as this study was limited to the Develop stage, it did not measure the product's direct impact on student learning outcomes, achievement scores, or higher-order thinking skills. Therefore, future experimental or quasi-experimental studies are recommended to investigate the effectiveness of the Tri-N–CLT framework in improving measurable learning outcomes across different mathematical topics and educational contexts. Additionally, educators and policymakers are encouraged to promote culturally responsive digital learning resources that integrate local educational philosophies with contemporary instructional design theories to support sustainable and contextually meaningful education in Indonesia.

DECLARATIONS

Author Contribution

Istiqomah, Conceptualization, methodology, supervision, dan writing (review and editing); **Kusumaningrum, B.,** Methodology, validation, formal analysis, dan writing (review and editing); **Pramudianti, T.,** Product development, investigation, data collection, formal analysis, dan writing (original draft); **Widodo, S.A.,** Supervision, validation, dan writing (review and editing); **Agustito, D.,** Software, resources, dan data curation; **Trisniawati,** Investigation, visualization, dan writing (review and editing); **Hakeem Nafiu.,** Data curation, project administration, dan writing (review and editing).

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Conflict of Interest

The authors declare no conflict of interest.

Declaration of AI Use

Generative artificial intelligence (AI) tools were used solely to assist in improving the clarity, grammar, and academic style of the manuscript, as well as to support the refinement of figures and conceptual illustrations. Specifically, ChatGPT (OpenAI) was used to enhance language quality, improve the organization of the manuscript, and assist in editing visual materials under the authors' supervision. All research ideas, study design, data collection, data analysis, interpretation of findings, and final editorial decisions were carried out entirely by the authors. The authors take full responsibility for the accuracy, originality, and integrity of the content presented in this manuscript.

Additional Information

Not applicable.

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