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Development of Statistical Literacy-Based e-Modules for Pre-service Teachers Learning Statistics

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Abstract: The concepts of statistics could be hard to understand by students without grasping the problem context. Using an easy-to-understand context or context that is close to the students in statistics learning materials could help students' understanding of the statistical concept. This research and development study was conducted to develop an e-module based on statistical literacy for pre-service teachers learning statistics. The topics of e-module developed consisted of topics related to the introduction to statistics and data presentation while using some Islamic contexts and values that are close to the participants. The research was conducted in two stages: the developmental stage and the experimental stage. The developmental stage included problem analysis and literature studies, development of the initial e-module, validation and revision of the e-module. The experimental stage included testing the effectiveness of the e-module for 164 pre-service teachers from 7 study programs of IAIN Lhokseumawe, Aceh. The quantitative data from this experimental phase was analyzed using ANCOVA by controlling prior knowledge in statistics and digital literacy skills to evaluate the influence of the e-module on participants' performance in statistics. The qualitative data of the interview transcripts was analyzed using content analysis. The statistical analysis results showed no significant difference in statistical performance between students using the e-module and students using conventional learning texts. However, from the interviews, we found that, in general, students acknowledged that the e-module used was interesting and that it facilitated their understanding of statistical concepts. However, they encountered obstacles when accessing the e-module due to the weak and unstable internet connection. Suggestions were provided for future research direction to ensure the effectiveness of using the developed e-module.

Keywords: e-module, islamic contexts, statistical literacy, statistical cognitions, pre-service teachers.

▪ INTRODUCTION

The integration of digital technologies into educational practices has become a focal point in enhancing teaching across various disciplines. In particular, the development and utilization of e-learning materials have proven pivotal in addressing challenges related to statistical literacy, especially for pre-service teachers. Statistical literacy defined as the ability to interpret, critically evaluate, and communicate statistical information is a core competency that all educators must possess in today's data-driven world (François et al., 2020). It is essential not only for making informed decisions in educational contexts but also as preparation for pre-service teachers to effectively teach data-related subjects in the future (Forgasz et al., 2024). Despite the recognized importance of statistical literacy, evidence suggests that many pre-service teachers enter the profession with inadequate statistical skills, which presents significant challenges when teaching statistics (Jr et al., 2020; Koparan, 2015). This lack of statistical competency highlights the urgent need for innovative educational resources that can support the development of these crucial skills.

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Statistical literacy, a concept that has evolved over the past few decades, is critical for educators to interpret, analyze, and communicate data effectively. Since its inception in the 1990s, statistics educators have refined the definition of statistical literacy, emphasizing its importance not only for understanding statistical concepts but also for making data-informed decisions (François et al., 2020). However, many pre-service teachers still report difficulties with teaching statistics, as their own understanding of these concepts is often insufficient (Koparan, 2015). This gap in statistical proficiency can hinder their ability to teach students effectively, perpetuating the cycle of statistical illiteracy in future generations. As the demand for statistical literacy grows in all sectors of society, it becomes increasingly important to develop effective educational resources and teaching methodologies that can bridge this gap for pre-service teachers.

Recent advancements in educational technology have led to the creation of innovative e-resources designed to enhance statistical training. These e-learning materials, which include interactive modules, simulations, and multimedia content, aim to address the complexities of teaching and learning statistics. By providing engaging, contextual, and interactive learning experiences, e-module have proven effective in enhancing student motivation and improving learning outcomes (Bilgin et al., 2017; Yulindra et al., 2023). The shift toward digital platforms aligns with broader educational trends that emphasize personalized and accessible learning environments. For pre-service teachers, these tools offer the flexibility to engage with statistical content at their own pace, accommodating the diverse learning needs and schedules of students. Moreover, e-modules help make abstract statistical concepts more tangible by integrating real-world data sets and interactive simulations that provide hands-on learning opportunities (Li, 2022; Lovett & Lee, 2017).

The flexibility of e-learning module is particularly beneficial for pre-service teachers, who often balance their academic training with professional responsibilities. These tools allow for self-paced learning, enabling students to revisit and reinforce difficult concepts at their own convenience. The ability to access digital learning materials anytime and anywhere significantly enhances learning opportunities, especially in the context of teacher preparation programs that often require students to manage time between coursework, internships, and other professional commitments. Additionally, the ability to receive immediate feedback through quizzes and interactive tasks enables students to track their progress and deepen their understanding of statistical concepts (Peng et al., 2019). By catering to individual learning profiles, e-modules offer a more personalized and engaging educational experience, something that is often lacking in traditional classroom settings.

Building on the growing body of research into the role of digital learning materials in education, several studies have highlighted the positive impact of e-learning modules on student engagement and academic performance. E-learning modules, which often incorporate interactive elements such as quizzes, multimedia content, and real-time feedback, have been shown to improve students' understanding and retention of complex topics. Mikropoulos and Natsis (2011) suggest that the use of interactive digital resources can significantly enhance students' conceptual understanding, particularly in fields that require problem-solving and critical thinking, such as statistics. According to Lin et al. (2017), integrating interactive and multimedia-enhanced learning tools can transform traditional classroom settings into dynamic learning environments, making the content

more engaging and accessible. These digital tools are especially beneficial for students who struggle with traditional textbook-based methods, as they provide visual and interactive representations of abstract statistical concepts, catering to a variety of learning styles (Mayer, 2014). By offering a more engaging and multimodal learning experience, e-learning modules can increase students' motivation and interest in the subject matter, making statistics more approachable and less intimidating (Bilgin et al., 2017; Lovett & Lee, 2017).

Moreover, e-learning modules have proven effective in promoting self-regulated learning, an essential skill for pre-service teachers as they transition from students to educators. The flexibility and self-paced nature of e-learning allow students to engage with material at their own speed, revisit challenging topics, and approach learning in a more individualized manner. This adaptability is especially significant for pre-service teachers, who often juggle multiple commitments, including classroom observations, internships, and coursework. Studies show that e-learning modules can help reduce anxiety and boost self-confidence in students, particularly when they feel in control of their learning process (Peng et al., 2019). Furthermore, e-modules allow for the integration of assessment tools that provide real-time feedback, which can help students identify their strengths and areas for improvement, ultimately enhancing their academic performance.

In conclusion, the development and use of e-learning modules play a crucial role in enhancing the statistical literacy skills of pre-service teachers. These tools align with modern educational trends that emphasize personalized, flexible learning environments and ensure that future educators are equipped with the skills necessary to teach statistics effectively. As the demand for statistical literacy grows, pre-service teachers must be adequately prepared to foster these skills in their future students. The integration of multimedia content, interactive simulations, and real-time feedback into e-modules provides an engaging, accessible, and effective way for pre-service teachers to improve their own statistical literacy. By investing in these innovative digital resources, we can ensure that future educators are better equipped to navigate the data-driven challenges of tomorrow’s classrooms, contributing to the development of a more statistically literate society. This study, therefore, aims to develop a statistical literacy-based e-module tailored for pre-service teachers, enhancing their ability to understand statistics in a dynamic, data-driven world.

▪ METHOD

This research and development (R&D) study referred to the model developed by Borg and Gall (1983). The system developed in this study was an e-module using the *Kotobee Author* application. The 10 stages in the model were integrated into two phases: (1) the development of learning material and (2) the experimental phase.

The first phase of the study focused on analyzing the problem of insufficient statistical literacy skills among pre-service teachers, followed by a literature review to identify best practices for developing e-learning modules. Based on this analysis, the initial version of the Statistical Literacy-Based e-Module was developed, incorporating multimedia elements, interactive simulations, and quizzes to facilitate learning. The module aimed to present key statistical concepts in an engaging and accessible manner. After the initial development, the e-module underwent a validation process by experts in

both statistics and instructional design, who provided feedback on content accuracy, usability, and instructional effectiveness. Revisions were made based on the feedback, ensuring that the module met educational standards and addressed the specific needs of the target audience. The procedures applied in this phase covered the first 9 phases in Borg and Gal (1983)'s model.

In the second phase, the finalized e-module was implemented in the Introductory to Statistics course for pre-service teachers at IAIN Lhokseumawe. Students were given access to the module, and its use was integrated into their coursework. The experimental phase aimed to assess the module's effectiveness in improving students' understanding. The impact was measured through pre- and post-assessments, which indicated significant improvements in students' understanding of key statistical concepts. Qualitative feedback was also collected to gauge students' experiences and satisfaction with the e-module, offering valuable insights into its strengths and areas for improvement. Based on the results, final adjustments were made to optimize the module for future use. This phase was analogous to the last phase in the Borg and Gal (1983)'s: dissemination and implementation.

Participants

The population for this study consisted of all pre-service teachers at the Institut Agama Islam Negeri (IAIN) Lhokseumawe, which included approximately 2,000 students. The sample participants were purposively selected from those enrolled in the Introductory to Statistics course. A total of 164 pre-service teachers from six teacher training programs were included in the study: Tadris Matematika (Mathematics Education), Tadris Bahasa Inggris (English Language Education), Pendidikan Bahasa Arab (Arabic Language Education), Pendidikan Guru Madrasah Ibtidaiyah (Islamic Elementary School Teacher Education), Pendidikan Islam Anak Usia Dini (Early Childhood Islamic Education), and Tadris Bahasa Indonesia (Indonesian Language Education). At the time of the study, all participants were in their third semester.

Table 1. Study participants

No	Study Program	Number of Classes	Number of Students		Total
			Male	Female	
1	Mathematics Education	2	4	21	25
2	English Language Education	2	6	28	34
3	Arabic Language Education	2	5	36	41
4	Islamic Elementary School Teacher	2	6	23	29
5	Education	1	1	15	16
6	Islamic Education of Early Childhood Indonesian Language Education	1	0	19	19
Total		**10**	**22**	**142**	**164**

As shown in Table 1, the female participants outnumbered the male participants, reflecting the overall gender distribution in the teacher training programs at IAIN Lhokseumawe, where female students are more prevalent than male students. The number of participants in each class varied, ranging from 16 to 41 students.

In accordance with research ethics guidelines, before the study commenced, all students were informed that the course would be part of a research project. They were assured that their participation was voluntary and that their decision to participate or not would have no impact on their course evaluation or academic standing.

Instruments

Three instruments were used in this study: an attitude and digital literacy questionnaire, a basic knowledge of statistics instrument, and a statistical cognition competency test. The attitude and digital literacy questionnaire and the basic knowledge of statistics instrument were administered as pre-tests before the teaching experiment, while the statistical cognition competency test was used as a post-test to assess participants' performance in statistics.

The Attitude and Digital Literacy Questionnaire

The attitude and digital literacy questionnaire was used to measure the students' attitudes and digital literacy, which served as the covariate in this study. The questionnaire, adapted from Ng (2012), consisted of 17 items: 7 items assessing attitudes toward the use of ICT media in learning, 6 items measuring the technical dimension of digital literacy, 2 items evaluating the cognitive dimension, and 2 items addressing the social-emotional dimension (see Table 2). Each statement in the questionnaire was rated on a 5-point Likert scale, with a score of 5 indicating strong agreement and a score of 1 indicating strong disagreement.

Table 2. Dimensions of attitude and digital literacy questionnaire (Ng, 2012)

No	Dimension	Description	Number of items	Sample of items
1	Attitude Statement	attitude towards the use of ICT media in learning	7	*I am more motivated to learn with ICT*
2	Digital literacy: technical dimension	possessing the technical and operational skills to use ICT for learning and in everyday activities	6	*I can learn new technologies easily*
3	Digital literacy: cognitive dimension	the ability to think critically in the search, evaluate and create cycle of handling digital information	2	*I am familiar with issues related to web-based activities e.g. cyber safety, search issues, plagiarism*
4	Digital literacy: social-emotional dimension	being able to use the Internet responsibly for communicating, socializing and learning	2	*ICT enables me to collaborate better with my peers on project work and other learning activities*

The Basic Knowledge of Statistics Instrument

The basic statistical knowledge of the participants was assessed using a test instrument consisting of 14 questions. This instrument, developed and previously

validated by Idris (2017), evaluates three components of statistical cognition: basic statistical knowledge, statistical reasoning, and statistical thinking. The topics covered in the instrument include concepts related to data, variables, and data presentation. The 14 questions were categorized into these three components of statistical cognition (see Table 3), with some questions addressing more than one component.

Table 3. Structure of test items for the prior knowledge in statistics

Statistical Cognitions	Category	Item
Basic Knowledge	Reading information in a graph	S1
	Understanding the idea for constructing graph	S2*. S3. S8. S10*
	Describing statistical concept from the type of data	S4.
	Describing type of data from the given phenomenon	S6. S7. S9*. S13*. S14*. S15(B)
	Doing simple calculation based on information from a graph	S11. S12*
Reasoning	Analyzing the given phenomena by selecting appropriate graph	S2*. S10*
	Predicting the phenomenon from the given graph	S12*. S13(A). S14(A)
Thinking	Thinking to select suitable graph for the given question	S2*. S5. S10*
	Thinking what variable needed to answer the given question	S9. S15(A)

Note: (*) the items can be assigned to more than one component of statistical cognitions

The Statistical Cognition Competency Test

The statistical cognition competency test consisted of 7 questions focused on qualitative data presentation, including bar graphs, pie charts, and line graphs. The indicators, sub-indicators, and the number of items for each are presented in Table 4.

Tabel 4. Indicators and category of the statistical cognition competency test

Statistical cognitions	Category	Items
Basic Knowledge	Know how or procedure to present data using tables	S1 (a)
	Know how or procedure to present data using graphs	S1 (b)
	Being able to read information displayed in graphs	S2 (b)*
Reasoning	Knowing the appropriate type of data presentation to display a particular data	S2 (a)*. S3 (b)*
	Being able to interpret data and provide comments based on knowledge of the context of the data	S2 (b)*
	Knowing the appropriate type of data presentation to display a particular data	S3 (a)*
Thinking	Knowing the implications of the disadvantages and advantages of a type of graph in displaying data	S2 (a)*. S3 (a)*
	Able to criticize data based on knowledge of the context of the data	S2 (c)
	Able to criticize and evaluate data	S3 (b)*

Note: (*) the items can be assigned to more than one component of statistical cognitions

The statistical cognition competency test underwent a validation process before being administered to the participants. The validation included content validity and construct validity, involving input from three experts, specifically lecturers in the Statistics Course. In addition, three pre-service teacher completed the validated test and were interviewed to assess their understanding of the questions and identify any difficulties they encountered.

Expert validation was conducted using a question validation sheet, aimed at ensuring that the questions effectively measure statistical cognitions in accordance with the established indicators and sub-indicators. The validation process employed a 5-point rating scale for two criteria: (1) the alignment of the questions with the indicators and sub-indicators and (2) the appropriateness of the score criteria. The rating scale ranged from 1 (very inappropriate) to 5 (very appropriate). In addition to rating the alignment, validators were encouraged to provide comments or suggestions regarding the indicators/sub-indicators and the score criteria.

The validation process results indicated that the suitability of the test items with the indicators/sub-indicators received an average score of 4.6 from the three validators for five questions, with the highest average score being 5 for two questions. These results suggest that all the questions were consistent with the established indicators. Regarding the appropriateness of the score criteria, the lowest average score was 4.3 (for two questions), while the highest average score was 5 (for three questions). Based on these validation scores, it was concluded that the questions met the established criteria for statistical literacy.

Data Analyses

The quantitative data in this study involved scores on attitudes and digital literacy and scores on statistical cognitions. The data distributions were described using descriptive statistics, including displaying data in graphs, appropriate statistics measurements and boxplots. The effect of the e-module was analyzed using inferential statistics involving tests of mean difference and analysis of covariate (ANCOVA) to analyze impact of using the e-module on students' statistical cognitions by controlling their attitudes and digital literacy.

▪ RESULT AND DISSCUSSION

Development of e-Module

The development process of the e-module began with a literature review focusing on essential components of statistical literacy and relevant Islamic contexts. In collaboration with statistics course lecturers, the study targeted categorical data displays, such as tables, bar charts, pie charts, and line charts for time series data.

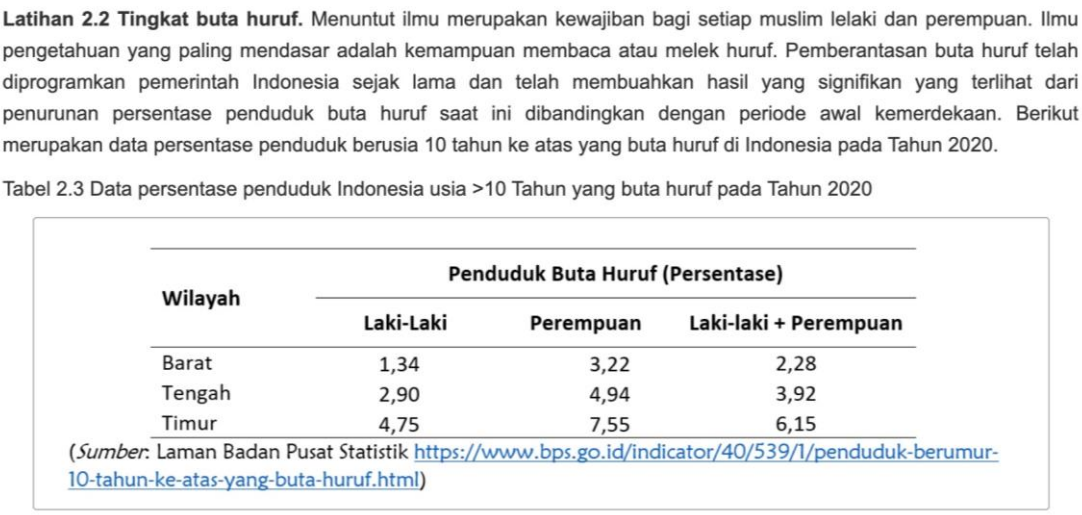
The literature review synthesized two critical aspects essential for the design of the e-module: content and presentation. The content aspect of the e-module focused on the content of the concept/topic of the statistical material discussed, which consisted of two components: statistical literacy and familiar context. The presentation aspect was related to how the concepts are arranged in the e-module to facilitate students learning the concepts. The presentation aspect included 3 components: interactivity, proper language, and layout. Table 5 shows the aspects and their indicators.

Table 5. Aspect, component, and indicators for developing e-module

Aspect	Component	Indicators
Content	Statistical Literacy	1. Statistical cognitions 2. Real data 3. Technology
	Contexts	1. Meaningful 2. Islamic values
Presentation	Interactivity	1. Simulation and animation 2. Constructive representation 3. Exercises with direct feedback
	Graph and Text	1. Sequence 2. Information in the graph
	Language	1. Efficient words and sentences 2. Appropriate to student's background level 3. Good and Proper
	Layout	1. Proper font size 2. Proper coloring of texts and graphs 3. Proper layout

Content Aspect

The content aspect of the e-module was designed based on recommendations from statistics education literature. The statistical content emphasizes two main components: statistical literacy and familiar contexts. The statistical literacy component includes statistical cognitions (Yang & Idris, 2021),, the use of real data (Carter et al., 2017; Engel, 2017), and technology (Çakıroğlu & Güler, 2021; Suhermi & Widjajanti, 2020). The problem contexts were selected to reflect issues familiar to pre-service teachers in Islamic universities. These contexts included not only religious topics such as zakat and salat, but also broader issues aligned with Islamic values, such as education and waste management. An example of a problem context related to education is shown in Figure 1.



Latihan 2.2 Tingkat buta huruf. Menuntut ilmu merupakan kewajiban bagi setiap muslim lelaki dan perempuan. Ilmu pengetahuan yang paling mendasar adalah kemampuan membaca atau melek huruf. Pemberantasan buta huruf telah diprogramkan pemerintah Indonesia sejak lama dan telah membuahkan hasil yang signifikan yang terlihat dari penurunan persentase penduduk buta huruf saat ini dibandingkan dengan periode awal kemerdekaan. Berikut merupakan data persentase penduduk berusia 10 tahun ke atas yang buta huruf di Indonesia pada Tahun 2020.

Tabel 2.3 Data persentase penduduk Indonesia usia >10 Tahun yang buta huruf pada Tahun 2020

Wilayah	Penduduk Buta Huruf (Persentase)		
	Laki-Laki	Perempuan	Laki-laki + Perempuan
Barat	1,34	3,22	2,28
Tengah	2,90	4,94	3,92
Timur	4,75	7,55	6,15

(*Sumber*: Laman Badan Pusat Statistik https://www.bps.go.id/indicator/40/539/1/penduduk-berumur-10-tahun-ke-atas-yang-buta-huruf.html)

Figure 1. An example of real data and problem context used in the e-module

The statistical cognitions in the e-module were addressed by presenting basic statistical knowledge, statistical reasoning, and statistical thinking in appropriate proportions. For instance, the module included a section titled "Ayo Berdiskusi" (Let's Discuss) to encourage students to share their opinions on the topics presented (see Figure 2). This approach follows Gal's (2019) recommendation that teaching statistical literacy should engage students with the societal meaning or implications of the statistics and data they encounter, prompting them to reflect on and discuss these implications. To incorporate real data, we provided links to original data sources, which students could access directly (see Figure 1).

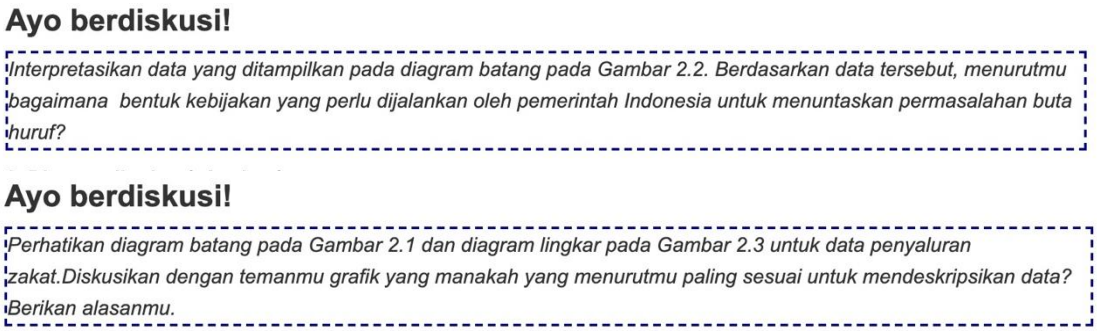


Figure 2. Two examples of texts that emphasize statistical literacy in the e-module

Presentation Aspect

The presentation of materials in the developed e-module included components focused on interactivity and the positioning of graphs and texts. Previous studies have shown that placing images before related textual explanations helps readers better

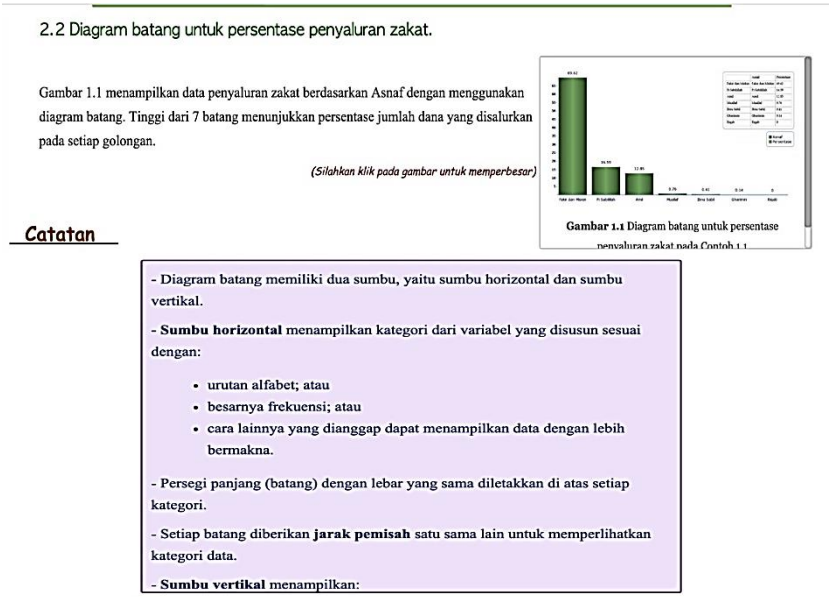


Figure 3. An example of the arrangement of graph and texts in the e-modul

understand the material (Jian & Wu, 2015; Yang & Idris, 2021). Consequently, in the second topic of the e-module, which involves graphical images, the graphs are placed before the corresponding explanatory text (see Figure 3). This arrangement was designed to enhance students' ability to interpret and engage with the visual data before diving into more detailed textual explanations.

Validation of the Developed E-Module

The validity of the learning material was assessed through both content validity and construct validity, involving two experts in statistics education and one expert in learning media and technology. The validators were asked to evaluate whether the indicators for each aspect (see Table 2) were effectively represented in the e-module. The statistics education experts reviewed the content aspects of the e-module, which consisted of 13 items, while the learning media and technology expert evaluated the presentation aspects, which consisted of 7 items. Additionally, the validators were asked to provide feedback for each aspect.

The results of the first-round validation showed that the material content aspect received an average validation score of 78.57% from Validator 1 and 85.71% from Validator 2, both of which fall within the "good" category. The presentation aspect scored 90.15%, indicating that it was highly effective. Based on the feedback, revisions were made to the e-module, including the addition of a “home” button in the display, as suggested by Validator 3, to allow users to easily return to the main menu without navigating back and forth through the material.

In the second round of validation, particularly for the content aspect, Validator 1 provided a score of 90.91%, and Validator 2 gave a score of 96.36%. These results suggest that the material arrangement was considered very effective, confirming the overall high quality of the content and presentation aspects of the e-module.

Implementation of the Developed E-Module

The e-module was implemented in a quasi-experimental design to evaluate its impact on students' statistical literacy skills, controlling for digital literacy and prior statistical knowledge. A total of 164 participants were divided into experimental (98 students) and control (66 students) groups. Pre-tests included measures of digital literacy and prior knowledge in statistics. After implementing three class sessions using either the e-module or conventional materials, post-tests assessed students' statistical cognitions competency.

Description of Participants’ Attitudes and Digital Literacy Skills

The results of attitudes and digital literacy skills are presented in Table 6. The mean score of 3.66 (SD = 0.76) indicates that participants generally had medium digital literacy. The social-emotional dimension of digital literacy received the highest score (mean = 3.92, SD = 1.01), suggesting that participants were more adept at using digital tools for communication and collaboration. However, they exhibited relatively weaker skills in the technical aspects of digital literacy (mean = 3.42, SD = 0.84). This finding aligns with previous research showing that students often feel more comfortable with the social aspects of technology than with its technical components (Ng, 2012).

Table 6. Description of attitude and digital literacy scores

	Minimum	Maximum	Mean	Standard Deviation
Total Score	1.94	5.00	3.66	0.76
Score for each dimension:				
a. Attitude items	1.00	5.00	3.63	0.87
b. Technique	1.17	5.00	3.42	0.84
c. Cognitive	1.00	5.00	3.66	0.97
d. Social-Emotional	1.00	5.00	3.92	1.01

While students' digital literacy skills were generally at a medium level, the higher scores in social-emotional dimensions suggest that students were more adept at using technology for communication and collaboration rather than for technical tasks. This highlights the importance of considering students' digital literacy profiles when designing e-learning materials. As students' technical skills were relatively weaker, this may have contributed to challenges in engaging with the e-module effectively, particularly in areas requiring more complex interaction with the technology.

Description of Participants' Basic Knowledge of Statistic

Basic statistical knowledge was measured through a test consisting of 14 questions on data and data presentation. The mean score was 50.09 (SD = 14.28), indicating moderate prior knowledge. The distribution of scores was nearly normal, with students struggling most on questions related to identifying independent and dependent variables, suggesting gaps in prior education. 189 participants took this test. However, not all of these students participated in the learning material experiment stage. The average basic knowledge of statistics test score was around 50, with a standard deviation of 14.28, indicating moderate prior knowledge. The distribution of scores was nearly normal, as shown by the histogram and boxplot in Figure 4.

The moderate prior knowledge of statistics among participants suggests that foundational understanding may be a limiting factor for fully benefiting from the e-module. Students' struggles with basic concepts such as independent and dependent variables underscore the need for scaffolding in statistical education. The lack of significant improvement in statistical literacy could be partially attributed to these gaps in prior knowledge, reinforcing the importance of ensuring that students have a solid foundation before engaging with more complex materials.

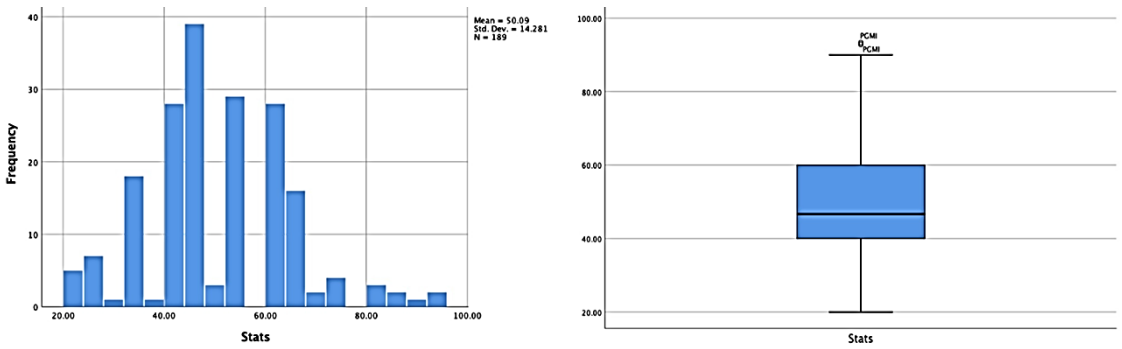
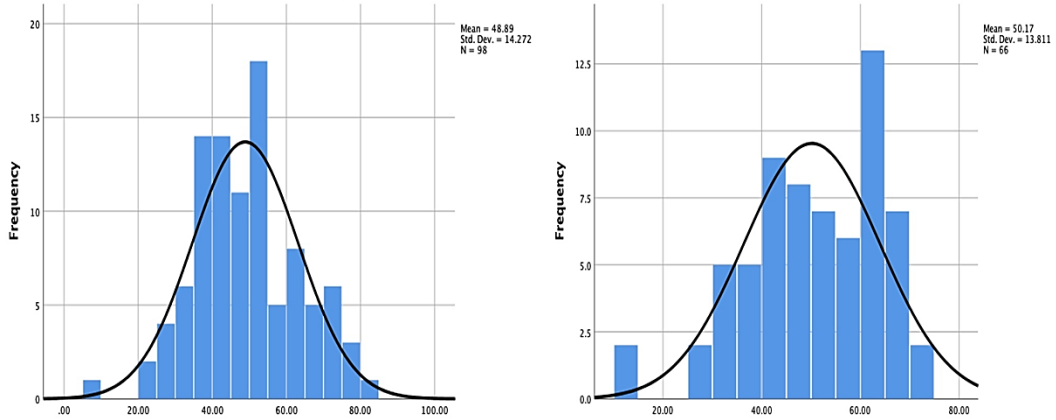


Figure 4. Histogram and boxplot of basic knowledge of statistics scores

Further analysis revealed that the questions most students answered incorrectly involved the identification of independent and dependent variables within a given problem context. This is likely because many participants had not encountered these concepts in high school, indicating the need to reinforce basic statistical concepts before engaging with more complex topics.

Effect of E-Module on Statistical Cognitions Competency

After attending lectures on data presentation, students' statistical cognitions competency was measured using a test consisting of seven descriptive questions. The scores obtained were converted into percentages for further analysis. The distribution of statistical cognition test scores for both the experimental and control groups is displayed in the histogram in Figure 5.



(a) (b)

Figure 5. Distribution of statistical cognition scores of (a) experimental and (b) control groups

The distribution of statistical cognitions scores in the experimental group appeared to be more concentrated in the middle of the curve. In contrast, the distribution in the control group was more spread out. The experimental group's value range was larger than the control group, and both groups had minimum values that seemed separate from the rest of the data, which may be considered outliers (as confirmed by the boxplot in Figure 6). Furthermore, the Shapiro-Wilk normality test revealed that the scores for the experimental group were normally distributed ($T = 0.985$; $p = 0.328$), while the scores for the control group were not ($T = 0.949$; $p = 0.009$). The statistical cognition test score descriptions for the experimental and control groups are shown in Table 7.

The results generally show no significant difference in scores between the two groups. Although the average score of students in the experimental group was slightly lower than that of students in the control group, the experimental group achieved a higher maximum score, close to 11 points higher than the control group. The experimental group also showed a wider range of scores, as indicated by the difference between the minimum and maximum values. The boxplot in Figure 6 compares the statistical values for statistical literacy between the two groups. The median values for both groups were almost identical, suggesting no significant difference despite the higher maximum score

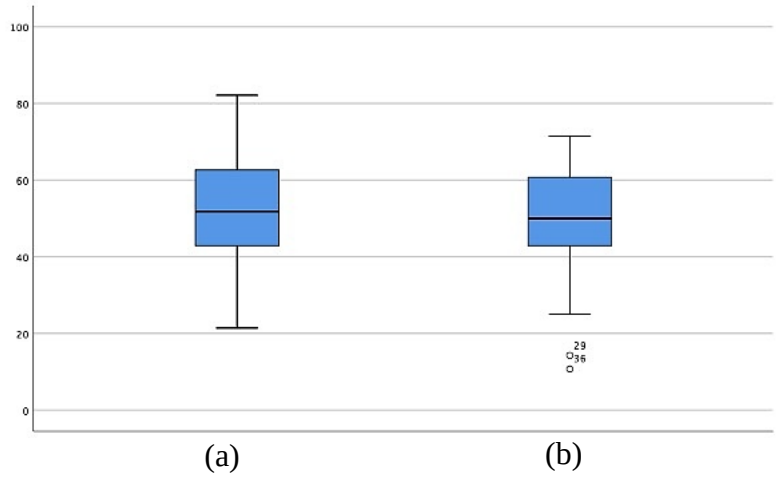


Figure 6. Boxplots of statistical cognition scores of (a) experimental and (b) control groups

Table 7. Statistics description of Statistical cognition scores of experimental and control groups

Group	Minimum	Maximum	Mean	Standard Deviation
Experimental	7.14	82.14	48.89	14.27
Control	10.71	71.43	50.17	13.81

in the experimental group. Additionally, two outliers in the control group, both with scores below 20, were identified.

To test the influence of e-module on students' statistical cognitions competency, a t-test for two independent samples was used. Before conducting the t-test, it was essential to verify that the experimental and control groups in this study came from the same population. To ensure this, a Levene's test for homogeneity of variance was performed to confirm that the assumption of equal variances was not violated. The results of the analysis yielded a significance value ($p = 0.923$), indicating that the variances between the two groups were equal and that they could be considered as coming from the same population.

Subsequently, a t-test was conducted to determine whether the online learning materials had any significant effect on students' statistical literacy skills. The results of the t-test showed no significant difference in literacy scores between the two groups, with $t(162) = -0.57$ and $p = 0.569$. Based on these results, it can be concluded that the online learning materials did not significantly impact the students' statistical literacy skills compared to the conventional materials.

Further analysis was then carried out to explore the influence of online learning materials on students' literacy skills, taking into account additional variables, such as initial statistical ability and students' attitudes and digital literacy.

The Influence of Online Learning Materials on Statistical Cognitions Controlled by Basic Knowledge of Statistics and Attitudes and Digital Literacy

As discussed in the previous section, no significant influence of the developed online learning materials on students' statistical literacy skills was found. Two covariates were included in the follow-up analysis to account for potential effects from variables outside the learning materials: basic knowledge of statistics and attitudes and digital literacy. This analysis was conducted using Analysis of Covariance (ANCOVA), with statistical cognitions as the dependent variable, the type of learning material (Experimental Group vs. Control Group) as the independent variable, and the aforementioned covariates.

Before performing the ANCOVA, several assumptions needed to be tested: (1) the linear relationship between the covariates and the dependent variable, and (2) the homogeneity of regression slopes between the experimental and control groups. These prerequisite tests were conducted prior to running the ANCOVA.

The linear relationship between the covariates and the dependent variable was tested using Spearman's correlation analysis, as both the statistical literacy scores and the covariates were not normally distributed. The results indicated a significant linear correlation between initial statistical ability and statistical literacy scores ($r = 0.291$; $p < 0.01$) and between attitudes and digital literacy and statistical literacy scores ($r = 0.213$; $p < 0.01$). These results confirmed that the linear relationship assumption was met.

The next assumption, homogeneity of the regression slopes, was tested using Levene's test for the interaction between the independent and covariate variables. The analysis revealed no significant interaction between statistical literacy ability and initial statistical ability ($F = 0.998$, $p = 0.463$), nor between initial statistical ability and attitudes and digital literacy ($F = 0.595$, $p = 0.888$). Therefore, it can be concluded that the assumption of homogeneity of regression slopes was satisfied, and ANCOVA could be conducted. The results of the ANCOVA are presented in Table 8.

Table 8. Analysis covariance for statistical literacy scores

Source	df	Sum of Square	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	3	3163.794	1054.598	5.807	0.001	0.098
Intercept	1	2594.249	2594.249	14.285	0.000	0.082
Group	1	45.026	45.026	0.248	0.619	0.002
Covariate:						
- Basic knowledge of statistics	1	2167.389	2167.389	11,935	0.001	0.069
- Attitude and digital literacy	1	702.555	702.555	3,869	0.051	0.024

From the results presented in Table 8, after controlling for the effect of basic knowledge of statistics and attitudes and digital literacy, no significant difference in statistical cognitions was found between the experimental and control groups ($F = 0.248$, $p = 0.619$). However, basic knowledge of statistics as a covariate significantly supported students' statistical cognitions ($F = 11.935$; $p = 0.001$), while attitudes and digital literacy did not significantly impact statistical cognitions ($F = 3.869$; $p = 0.051$). The model explained 9.8% of the variance in statistical cognition scores.

The ANCOVA results underscored the significant influence of basic knowledge of statistics on the attainment of statistical cognitions. This highlights the necessity of scaffolding digital materials through preliminary knowledge assessments to identify students needing additional foundational support prior to engaging with advanced content. Considering the limited impact of attitudes and digital literacy on statistical cognitions, subsequent research may investigate the potential effectiveness of customized e-module adaptations informed by individual learner profiles.

Students' Perceptions of the E-Module

Several students from the experimental group were interviewed regarding the effectiveness of the e-module. The interviews were conducted outside of the classroom after the learning sessions had been completed. A total of 12 students participated in the interviews. The interview questions focused on two main topics related to their experience with the effectiveness of the e-module. The questions were as follows:

Q1. What obstacles did you face in understanding the learning materials on the shared link?
   a. Obstacles related to access to materials
   b. Obstacles related to the content of the material
   c. Other

Q2. Do you agree that material like this should be provided for you to study independently, without the need for a detailed explanation from the lecturer? Why?

Based on the interview results, several obstacles were identified that students faced while using the online learning materials. As mentioned earlier, the e-module in this study was developed using the Kotobee Author application. After the materials were completed, they were converted into HTML format and posted on a website that students could access without needing to download the application. One significant disadvantage of this application is that when opened outside the app (e.g., through a website), it requires a strong internet connection to function smoothly. This was a primary obstacle encountered by many students. Of the 12 students interviewed, only one reported no issues with accessing the materials, while the remaining 11 students mentioned that they experienced slow loading times when accessing the material. This obstacle occurred both when opening the material links and when reading the content, as illustrated by the following two student responses:

"the link was difficult to open and the text was difficult to zoom and scroll…"
"the link is easy to open, it's just a bit problematic to read the content of the link."

This obstacle was further compounded by the fact that students primarily used mobile phone networks for internet access. At IAIN Lhokseumawe, students typically rely on their mobile phones for online learning.

Moreover, there were three distinct types of responses from the interviewed students. Students who achieved high statistical literacy scores reported that they did not encounter difficulties in understanding the content of the materials, and they found the material relatively easy to comprehend. In contrast, several other students indicated that

certain sections of the material were challenging and required additional clarification from the lecturer.

"For the material, some of it can be understood by themselves and some of it must be explained by the lecturer so that they can understand it as a whole properly and correctly."

Meanwhile, students whose statistical literacy score category is relatively low admitted that they could not understand the online learning materials provided, as stated by one of the students as follows.

"The material is difficult to understand without an explanation from a lecturer."

Furthermore, for the Q2 question, most students interviewed did not agree if online learning materials were given without explanation from lecturers; only one student stated that they agreed. The reason they disagree in general is because they think that everyone's learning ability must be different. They feel that their understanding will be better when there is a more detailed explanation from the lecturer or at least they are given the opportunity to ask questions when there is a part of the material that they cannot understand.

"... However, if a little explanation from the lecturer is added, it may be even better, for example, to clarify what is not understood, it will be asked to the lecturer."

"... Because I think there is material that must be explained in detail by the lecturer because I think there is material that is difficult to understand so I need help to be able to understand."

Based on the interview results, it was found that students were not fully prepared to learn statistical material independently using the online e-module developed for this study. This may be attributed to students' readiness for self-directed learning. Although the e-module was designed to promote autonomous study, interview responses indicated that students preferred a blended approach integrating digital materials with instructor support. This finding suggests that students benefit more from structured, guided learning, particularly those with lower basic knowledge of statistics. Strategies such as the flipped classroom model and interactive reading guides can enhance student engagement and comprehension by allowing them to first interact with the e-module content using their foundational knowledge, thereby reducing confusion (Adams et al., 2015; Cilli-Turner, 2015; Hwang & Lai, 2017).

Multiple factors likely contributed to these outcomes. A significant barrier was internet connectivity, as unstable connections hindered seamless access to the e-module, particularly in remote regions. This issue is common in online learning environments in Indonesia, highlighting the urgent need for improved infrastructure to support effective e-learning experiences. Educational institutions must prioritize the provision of reliable internet access to address digital disparities and ensure equitable learning opportunities for all students.

▪ CONCLUSION

This study developed and assessed an e-module designed to enhance statistical cognitions among pre-service teachers by integrating Islamic contexts and interactive

features. While students using the e-module reported positive engagement and found the materials interesting, quantitative analysis showed no significant difference in statistical cognition scores between the e-module and conventional learning groups. These findings suggest that, although digital materials can enrich the learning experience, their effectiveness may be limited without sufficient internet infrastructure and additional instructional support.

The study highlights two critical factors for successful digital learning: reliable internet access and guided instruction. Students in remote areas experienced connectivity issues that hindered the seamless use of e-modules, pointing to the importance of infrastructure improvements. Additionally, interview feedback revealed a preference for blended learning approaches, combining digital resources with instructor-led guidance. This indicates that the e-modules may be most effective when integrated within structured learning environments that allow real-time feedback and clarification.

In conclusion, while the e-module did not significantly outperform traditional methods in statistical literacy outcomes, it showed promise in enhancing engagement and facilitating learning. Future research should explore hybrid models and adaptive digital materials tailored to individual learner needs to maximize the potential of digital learning in statistics education. Institutions should also consider investments in internet infrastructure and blended learning models to effectively support digital literacy development for pre-service teachers.

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