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Development of Sahabat Aktuaria: Website-Based Actuarial Mathematics Learning Using a Learning Trajectory Approach

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Abstract

The digital transformation of higher education has encouraged the use of technology-based, student-centered learning. However, digital technology remains underutilized in university mathematics education, particularly in actuarial mathematics, which involves complex and hierarchical concepts. This study developed and evaluated Sahabat Aktuaria, a website-based learning medium designed with a learning trajectory approach that integrates mastery-based adaptive progression and Universal Design for Learning principles specific to actuarial mathematics, as a developmental (pilot) implementation. Following the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation), the medium was validated by experts and implemented with ten (N = 10) fourth-semester students of the Actuarial Science Study Program at Universitas Darunnajah who had completed the Actuarial Mathematics I course. Data were collected through expert validation sheets, lecturer and student response questionnaires, and learning outcome tests. The medium achieved an expert validation score of 0.764 (valid category), practicality ratings of 85.50% (lecturers) and 86% (students), and an N-Gain score of 0.57 (medium category). A paired-sample t-test showed a statistically significant increase from the pretest (M = 58.50) to the posttest (M = 82.10). These findings provide preliminary evidence that Sahabat Aktuaria is valid, practical, and potentially useful for improving students' conceptual understanding, and they warrant further evaluation in larger controlled studies.

Keywords: Learning trajectory; Students' conceptual understanding; Website based learning; Actuarial mathematics; Learning media

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INTRODUCTION

The digital transformation of higher education relies on technology as a student-centered learning innovation. This transformation promotes a paradigm shift from procedurally based learning to learning focused on deep conceptual understanding (Pettersson, 2021). Technology assisted instruction fosters a more dynamic, adaptable, and cooperative learning environment, which can boost student engagement (Weigand et al., 2024). Integrating technology in mathematics instruction at the university level makes the learning process more meaningful, as students do not merely receive information passively, but actively engage in constructing knowledge and deepening their conceptual understanding (Sofroniou et al., 2025). However, the implementation of digital technology in university mathematics learning remains general in nature and has not yet been fully adapted to the specific characteristics and requirements of the subject matter. In reality, each branch of mathematics possesses distinct conceptual characteristics, levels of complexity, and learning needs. Therefore, there is a need to develop more focused and contextual technology-based instruction to optimize student understanding,

including in actuarial mathematics courses (Sailer et al., 2024). This situation poses a serious challenge to improving the quality of mathematics education, particularly in actuarial mathematics.

One solution considered relevant for addressing this challenge is the development of a website-based learning medium specifically designed to align with the characteristics of actuarial mathematics content, thereby optimally supporting student understanding (Sanusi & Uhomoibhi, 2025). The website-based Sahabat Aktuaria learning medium offers adaptive learning through mastery-based progression, feedback, and remediation tailored to students' learning needs. Pedagogical principles are integrated with a learning trajectory approach to ensure a more structured learning process. The adaptive learning concept of the Sahabat Aktuaria website aligns with research conducted by Elmabaredy and Elkholy, which indicates that website-based adaptive presentation techniques improved student learning outcomes by 21.5% and resulted in a learning satisfaction rate of 85% among respondents (Elmabaredy et al., 2020). Consistent with research conducted by Evelyn H. Tambunan, website-based interactive learning can increase student engagement by 27.8% and improve HOTS scores with a medium effect size (d = 0.62) (Tambunan et al., 2024). Research conducted by Jamilah indicates that the implementation of learning trajectory improved the pedagogical competence of prospective teachers by an average of 23.4% and raised the quality of lesson planning to the "good" category for 78% of the respondents (Jamilah et al., 2023). Furthermore, an analysis of over 120 articles by Syifaurrahmadania reveals an upward trend in learning trajectory research growing by $\pm 18\%$ annually with a dominant contribution to the understanding of mathematical concepts (Syifaurrahmadania et al., 2025). Learning trajectory theory describes learning as a sequence of increasingly sophisticated levels of thinking, together with the instructional tasks designed to move students through that progression (Clements & Sarama, 2004). However, these two strands of research remain largely separate: website-based studies have established the general benefits of digital media, and learning trajectory studies have established the value of developmental sequencing, but neither has specifically addressed the hierarchical, computation-intensive, and misconception-prone characteristics of actuarial mathematics. The present study addresses this gap by embedding the learning trajectory directly into the website design, so that the sequence of materials reflects predicted student thinking and expected conceptual progression in actuarial mathematics. The pedagogical novelty of this study therefore lies in the explicit integration of three elements specific to actuarial mathematics: (1) a learning trajectory that sequences content according to students' developmental thinking and anticipated misconceptions, (2) a mastery-based progression that unlocks subsequent material only after a concept is mastered, with remediation otherwise, and (3) Universal Design for Learning principles that provide multiple means of representation and engagement. Together these constitute a pedagogically structured medium, rather than a conventional website that merely delivers static materials online.

Observations of students in the Actuarial Science program at Darunnajah University reveal that 80% of instruction relies on textbooks, while 20% utilizes digital technology. Consequently, 62% of students have not attained core competencies and only 38% are able to correctly solve actuarial mathematics problems. This points to a lack of conceptual understanding and problem-solving ability. This issue is further highlighted by the large number of students struggling to master actuarial mathematics, a subject characterized by its complexity, hierarchical structure, and practical application. The situation is compounded by the fact that mathematics learning resources in higher education remain generic and have not been specifically designed to support actuarial mathematics instruction (Shoffa et al., 2023). Therefore, there is a need to design learning media that align with the learning trajectory specific to this academic discipline (Akker et al., 2006). Given these conditions, there is a need to develop the website-based Sahabat Aktuaria learning resource using a learning trajectory approach, serving as a student-centered innovation for actuarial mathematics education in

higher education. This research offers a practical solution to enhance the quality of actuarial mathematics instruction through the website-based Sahabat Aktuaria platform.

This study aimed to develop and evaluate Sahabat Aktuaria, a website-based actuarial mathematics learning medium designed using a learning trajectory approach. The development followed the ADDIE model, which consists of the stages of Analysis, Design, Development, Implementation, and Evaluation. The scope of the study was limited to a single cohort of fourth-semester students of the Actuarial Science Study Program at Universitas Darunnajah. The medium was evaluated against three criteria: (1) validity, assessed through expert validation; (2) practicality, assessed through lecturer and student response questionnaires; and (3) preliminary effectiveness, assessed through a one-group pretest-posttest design and N-Gain analysis.

METHOD

The Research and Development (R&D) model used in this study was the ADDIE model, which comprises five essential stages: Analysis, Design, Development, Implementation, and Evaluation (Branch, 2010). The ADDIE model was selected because it is a systematic, iterative instructional design framework that facilitates ongoing assessment for product improvement (Sugiyono, 2017). In line with the formative evaluation principle of Borg and Gall, expert and user feedback was collected at each stage and used to revise the product before implementation (Gall, Borg, & Gall, 2003). The systematic research implementation process is illustrated in the Figure 1.

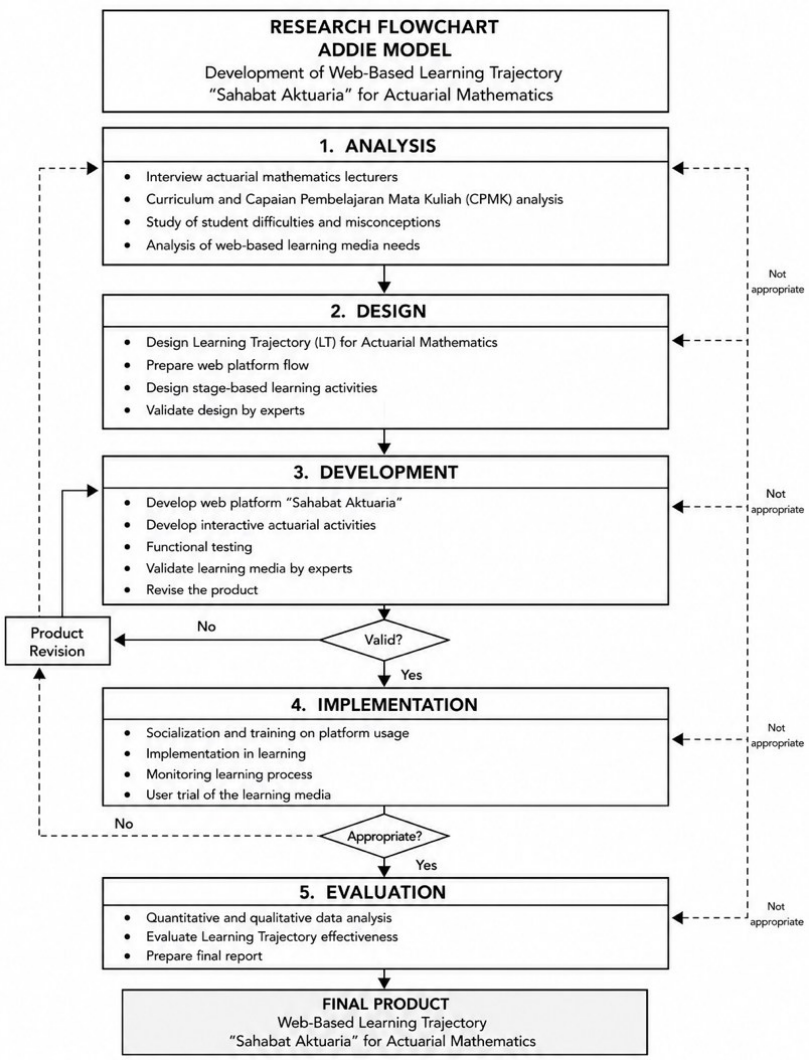


Figure 1. Research Flowchart Based on the ADDIE Model

The ADDIE model, which consists of the stages of Analysis, Design, Development, Implementation, and Evaluation, was used in the development process. The detailed research procedures are illustrated in Figure 1. The procedures included identifying learning needs and students' misconceptions, designing learning trajectories and website platform structures, developing and validating the Sahabat Aktuaria learning medium, implementing the developed media in learning activities, and evaluating its preliminary effectiveness in improving students' conceptual understanding. The medium was designed to facilitate dynamic interaction among students, the learning materials, lecturers, and peers within a specific learning context. These interactions were organized through a structured learning trajectory intended to achieve learning objectives within a specified learning period (Abuhassna et al., 2024). Experts assessed the created learning materials and research tools before they were put into use in order to evaluate media viability, content appropriateness, and material relevance. The learning medium and the research tools were revised and improved based on suggestions and comments from the validators. This study used a One Group Pretest-Posttest Design to assess the preliminary efficacy of the designed learning medium (Ventura et al., 2021). A control or comparison group was unavailable, as there were no parallel classes studying similar material to serve as a comparison group. This design aligns with the research's development objectives, which prioritize evaluating the validity and practicality of the media; consequently, the comparison between pretest and posttest scores provides preliminary evidence of learning improvement. The pretest was administered prior to the implementation of Sahabat Aktuaria, while the posttest was conducted after the learning process concluded. Pretest and posttest results were analyzed to determine whether the students' conceptual knowledge had improved.

Table 1. One Group Pretest-Posttest Design

Pretest	Implementation of "Sahabat Aktuaria"	Posttest
O_1	X	O_2

Legend:
O_1 : Initial ability before implementation
X : Implementation of "Sahabat Aktuaria"
O_2 : Final ability after implementation

To operationalize the learning trajectory that underpins the medium, the instructional content on life insurance and annuities was structured around three progressive stages of increasing difficulty: (1) foundations: insurance economics and the survival function; (2) core concepts: the mortality table, select and ultimate mortality, and life insurance (including term and endowment products); and (3) advanced applications: life annuities and benefit premiums. Within each material, learning follows a fixed sequence of material presentation → learning activity → exercise → feedback → concept mastery before advancing to the next material; if a concept has not yet been mastered, the student is directed to remedial material and repetition before proceeding; this mastery-based progression constitutes the adaptive feature of the medium. This progression embodies scaffolding within students' zone of proximal development and a mastery learning orientation, in which students advance only after demonstrating mastery of prerequisite concepts (Bloom, 1968). Each stage specifies the target concept, the predicted student thinking or misconception, the corresponding learning activity, and the expected conceptual progression, as summarized in Table 2.

Table 2. Hypothetical Learning Trajectory for Actuarial Mathematics I

Stage	Target Concept	Predicted Student Thinking / Misconception	Learning Activity	Expected Conceptual Progression
Foundations (Dasar)	Insurance economics (functions of insurance, risk,	Treating the survival function S(x) as unconditional rather	Diagnostic quiz and interactive examples on insurance	From deterministic notions of loss to the probabilistic foundation of life

	utility, and premiums) and the survival function	than a conditional (survival to age x) quantity; confusing risk pooling with individual loss	principles, risk, pooling, and survival probabilities (S(x), tpx, tqx), with exercises, feedback, and remedial material if the concept is not mastered	contingencies
Core concepts (Inti)	Mortality table, select and ultimate mortality, and life insurance (whole life, term, and endowment)	Confusing qx with npx; discounting without accounting for survival; mixing select and ultimate rates	Worked examples and guided computation of whole-life, term, and endowment insurance (Ax, A1x:n), with progressive unlocking, exercises, and feedback	From reading a life table to computing the expected present value of insurance benefits
Advanced (Lanjut)	Life annuities (1 and 2) and benefit premiums (1 and 2), integrating survival probability, mortality, present value, insurance, and annuities	Confusing annuity-due with annuity-immediate; failing to link insurance and annuity values; misapplying the equivalence principle	Problem solving on life annuities (ax, ax:n) and benefit premiums (Px), including insurance–annuity identities, with exercises and feedback	From valuing benefits to pricing contracts through the equivalence principle

This study was conducted during the 2025/2026 academic year in the Actuarial Science Study Program at Universitas Darunnajah, Jakarta. The participants were the fourth semester students enrolled in the Actuarial Mathematics I course, during which Sahabat Aktuaria was implemented. Purposive sampling was used to define the eligibility criteria: students who had completed the Actuarial Mathematics I course and had participated in the learning activities using Sahabat Aktuaria (Prior et al., 2020). All fourth-semester students who met these criteria the entire eligible cohort were included, so the sample of N = 10 represents a census of the eligible population rather than a randomly drawn subset. This complete-cohort approach is appropriate for a developmental (pilot) study whose aim is to obtain a detailed evaluation of the medium's validity, practicality, and preliminary effectiveness rather than to generalize to a broader population (Tessmer, 1993) it is also consistent with formative and developmental evaluation guidance, in which testing with $5-10$ participants is considered sufficient to identify usability and feasibility issues (Thabane et al., 2010). Because the study used a single cohort and a one-group design, the results are interpreted as preliminary evidence rather than as conclusive proof of effectiveness. All participants provided informed consent, and participation was voluntary; responses were collected anonymously and treated confidentially. The test instrument consisted of five essay questions on Actuarial Mathematics I materials used to measure students' conceptual understanding, covering the survival function, life tables, life insurance, life annuities, and benefit premiums. The instrument was initially drafted with ten items and trialled on 24 students who had completed the course. Item validity was assessed using the Pearson product-moment item-total correlation, with an item considered valid when ($r > 0.404$ (r table, $\alpha = 0.05$, N = 24). Five items were valid ($r = 0.876 - 0.919$) and were

retained as the final instrument, while the remaining five items were excluded. Instrument reliability was assessed using Cronbach's Alpha: the ten-item trial instrument yielded 0.720, and the final five-item instrument yielded 0.96, indicating very high internal consistency (Taber, 2018). Each item was scored using a rubric with a score range of $0-4$points. Scoring was performed by a single scorer using the $0-4$ rubric to ensure consistent application of the scoring criteria. The results of the validity and reliability analysis are summarized in Table 3.

Table 3. Test Instrument Validity, Difficulty, and Reliability Analysis

Item	Item Total Correlation (r)	Difficulty Index (P)	Decision
1	0.902	0.760	Valid
2	0.261	0.708	Not valid
3	0.876	0.719	Valid
4	-0.108	0.698	Not valid
5	0.913	0.760	Valid
6	-0.249	0.510	Not valid
7	-0.212	0.688	Not valid
8	0.919	0.760	Valid
9	0.919	0.760	Valid
10	0.050	0.510	Not valid

Note: r table = 0.404 (α = 0.05, N = 24). The five valid items (1, 3, 5, 8, 9) formed the final test instrument. Cronbach's Alpha = 0.720 for the ten-item trial and 0.96 for the final five-item instrument.

Students' pretest and posttest results were used to collect quantitative data. Descriptive and inferential statistics were used to examine the gathered data. For the pretest and posttest data, descriptive analysis involved calculating the mean, minimum score, maximum score, and standard deviation. The Shapiro–Wilk normality test, which is frequently used in educational research because of its sensitivity in determining data normality, was performed to look at the distribution characteristics of the data prior to additional analysis (Mishra et al., 2019). Following the implementation of Sahabat Aktuaria, a paired-sample t-test was used to evaluate the research hypotheses and ascertain whether there was a statistically significant difference between students' pretest and posttest scores. In a pretest-posttest paradigm, the paired-sample t-test is frequently used to compare two related measurements obtained from the same individuals (Kusuma Dewi & Subekti, 2024). The following hypotheses were developed and tested in this study:

$$H_0: \mu_{post} = \mu_{pre}$$
$$H_a: \mu_{post} \neq \mu_{pre}$$

Legend:
H_0 : Pretest and posttest scores do not differ significantly
H_a : Pretest and posttest scores do differ significantly
Paired-sample t-test formula:

$$t = \frac{\bar{d}}{S_d/\sqrt{n}}$$

Following the implementation of Sahabat Aktuaria, the efficacy of the created learning medium was assessed using normalized gain (N-Gain) analysis to gauge increases in students' conceptual understanding. In educational intervention research, N-Gain analysis has been routinely used to assess learning changes based on pretest and posttest scores (Coletta & Steinert, 2020). The following formula was used to determine the N-Gain score:

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

Meanwhile, the commonly used N-Gain categories are derived from the research of Richard R. Hake (Hake, 1998)and are classified into three categories:

Table 4. N-Gain Categories

H-Gain Value Range	Categories
$g \geq 0.70$	High
$0.30 \leq g < 0.70$	Medium
$g < 0.30$	Low

RESULTS AND DISCUSSION

Analysis

The needs analysis phase was conducted to identify issues in learning actuarial mathematics and to determine the specifications for the learning media to be developed using a learning trajectory approach. This analysis involved interviewing lecturers, examining the curriculum and course learning outcomes (CPMK), studying student difficulties and misconceptions, and analyzing requirements for the website-based Sahabat Aktuaria learning media to ensure alignment among learning objectives, student characteristics, and the media being developed (Branch, 2010). The identified issues serve as the basis for developing the website-based Sahabat Aktuaria learning media using a learning trajectory approach. (1) Regarding the mastery of core competencies, it was found that 62% of students had not met the proficiency targets for actuarial mathematics core competencies, based on course evaluations and examination results. These findings indicate that students continue to struggle with understanding concepts ranging from fundamental to advanced in a systematic manner. (2) Regarding problem-solving ability, only 38% of students were able to solve actuarial mathematics problems correctly and systematically. These results indicate a low level of reasoning ability and a lack of proficiency in applying actuarial mathematics concepts to problem solving. (3) Regarding the use of instructional technology, it was found that 80% of instruction still relies on textbooks, while digital media is generic in nature and does not specifically support the teaching of actuarial mathematics. Based on the needs analysis, a website-based learning medium named Sahabat Aktuaria was developed as an adaptive learning tool designed to meet students' needs; it employs a learning trajectory approach to support a systematic learning path and enhance the understanding of actuarial mathematics concepts.

Design

The product design phase involves developing the user interface to create digital learning media that centers on students' learning needs while remaining structured according to the principles of the learning trajectory approach. A user-oriented digital learning interface design plays a crucial role in enhancing student engagement and learning effectiveness (Nikou & Economides, 2023). The following are three key features aimed at facilitating a systematic learning process:

1. *Monitoring Dashboard Design (Lecture Dashboard).*

The lecture dashboard is designed with informative data visualizations based on a card-based layout, facilitating quick and efficient monitoring of learning progress (De Vreugd L et al., 2024). The system also supports drill-down analysis, ranging from class performance to individual student achievements.

2. *Learning Path Interface Design.*

This page presents the students' step-by-step learning journey based on the learning trajectory approach (foundations, core concepts, and advanced applications), using color coding to indicate the sequence of materials. To ensure learning quality, guided interaction is implemented through a module locking system, requiring students to complete the material sequentially and thoroughly. This progressive unlocking reflects the developmental progression of the learning trajectory: students cannot advance to a later concept until they have demonstrated mastery of the preceding one.

3. Content Delivery Layout.

The material layout features a minimalist design to maintain focus and reduce cognitive load (Sari et al., 2025). Complex content is presented using a "chunking" approach within the navigation and is supported by multimodal features that allow students to choose between Text Mode and Slide Mode based on their learning preferences.

Development

The development phase of this study focuses on the production and testing of the designed learning media prototype. The development process begins with creating a prototype of instructional materials by applying the learning trajectory approach as a pedagogical framework to structure the actuarial mathematics learning sequence within functional software, utilizing the Universal Design for Learning (UDL) framework (CAST, 2018). To clarify the theoretical architecture, the three frameworks serve distinct roles: the ADDIE model serves as the overall development procedure, the learning trajectory provides the pedagogical sequencing of content, and UDL provides principles for accessibility and multiple forms of representation, engagement, and action/expression. The Sahabat Aktuaria learning media implements the three UDL principles as follows:

1. Multiple Means of Action and Expression.

The monitoring dashboard provides real-time, data-driven feedback to students and lecturers, while facilitating diverse expressions of understanding and the development of effective learning strategies in accordance with UDL guidelines.

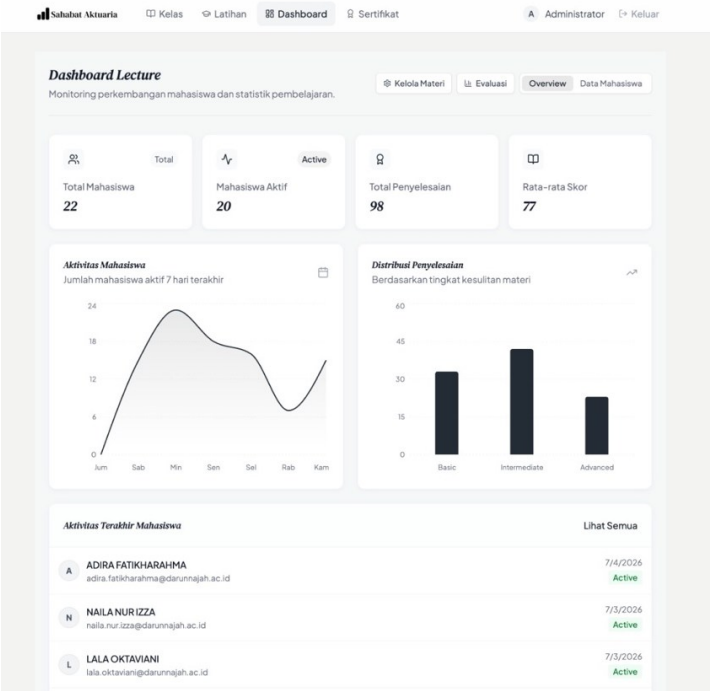


Figure 2. Monitoring Dashboard Design

2. Multiple Means of Engagement.

The learning path implements gradual scaffolding through progressive unlocking to motivate students and foster self-regulation in alignment with UDL guidelines by providing clear progress visualization (Matcha et al., 2020).

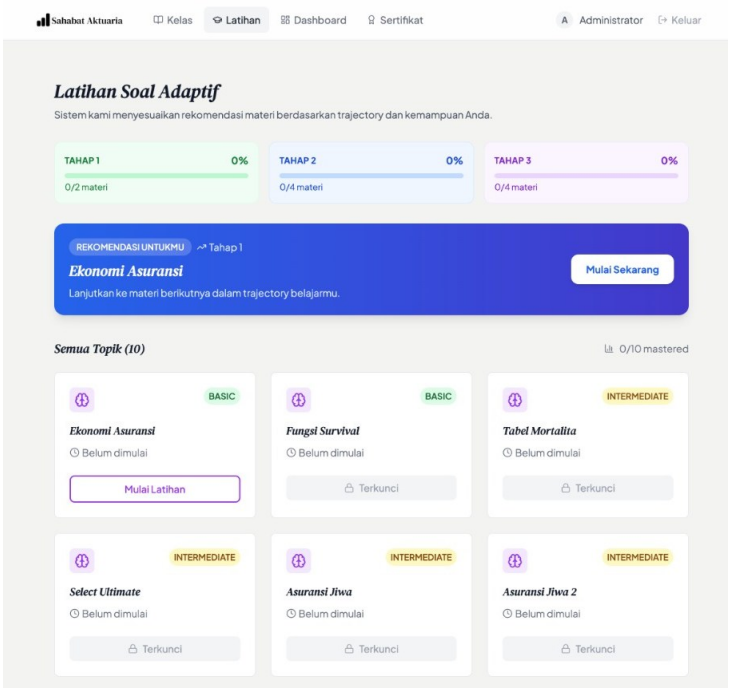


Figure 3. Learning Path Interface

3. Multiple Means of Representation.

The multimodal feature offers Text Mode (narrative) and Slide Mode (visual graphic) to accommodate differences in how students comprehend information, in alignment with UDL guidelines principles and individual learning preferences (Zakariyah et al., 2024).

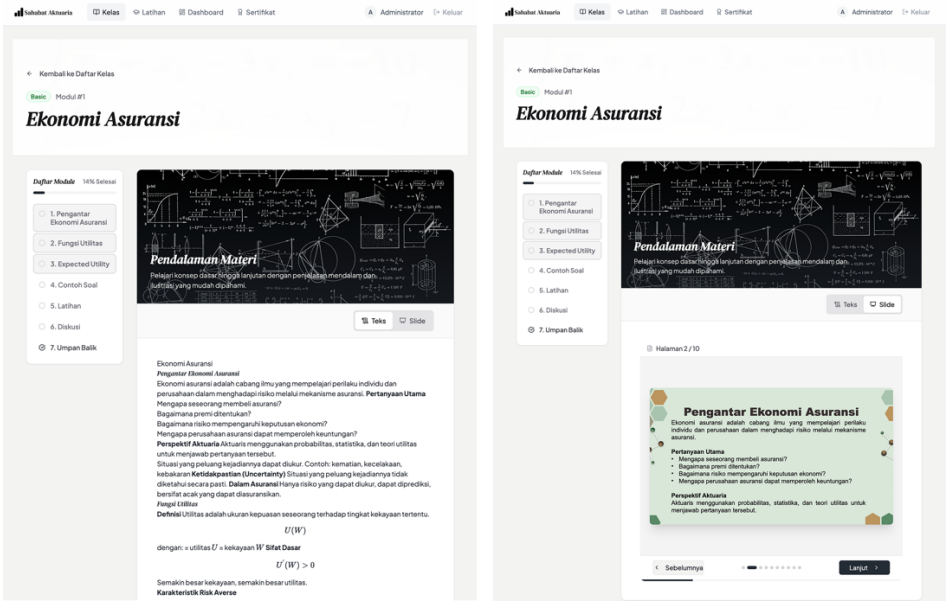


Figure 4. Content Delivery Layout

The developed Sahabat Aktuaria learning media was validated by two experts: one material expert and one media expert. The material expert (an actuarial expert from Universitas Pertamina) evaluated the actuarial mathematics content and learning trajectory approach, while the media expert (a full-stack developer from Universitas Pamulang) assessed the instructional media design, usability, and functionality. The validators rated each aspect on a 5 point scale (1 = very poor to 5 = very good), and the ratings were converted into Aiken's, where s is the difference between the validator's rating and the lowest rating, n is the number of validators, and c is the number of rating categories (Aiken, 1985). Because the number of validators is

limited to two, the Aiken's V results are interpreted descriptively as a measure of expert agreement rather than as a statistically validated coefficient. The validation results are presented in Table 5.

Table 5. Content Validity Analysis Using Aiken's V

No	Assessment Aspect	Aiken's V	Category
1	Suitability of actuarial mathematics content with learning outcomes	0.875	Valid
2	Suitability of learning sequence with Learning Trajectory approach	1.000	Valid
3	Implementation of UDL principles	0.917	Valid
4	Instructional media interface design	0.750	Valid
5	Usability and navigation of the learning media	0.667	Valid
6	Interactivity and functionality of learning features	0.375	Requires revision
Overall Average		0.764	Valid

Based on Table 5, the actuarial mathematics learning medium is deemed valid and suitable for use, with an overall average Aiken's V index score of 0.764. Following established interpretation standards for Aiken's V, an average score exceeding the 0.60 threshold indicates that the product possesses a high level of content validity (Sukadari, 2019). The material aspects received high scores (0.875−1.000), whereas the interactivity and functionality of the learning features received a comparatively low score (0.375), reflecting the technical issues identified by the media expert. Because the number of validators is limited to two, these Aiken's V values are interpreted descriptively rather than as statistically validated coefficients.

Implementation

The implementation phase of this study involves the application of the Sahabat Aktuaria learning medium, which has already been developed and validated. This phase utilizes the website-based Sahabat Aktuaria medium within actuarial mathematics instruction, enabling lecturers and students as users to utilize the tool effectively (Alqahtani & Rajkhan, 2020). The implementation process included a practicality test based on lecturer and student feedback. Practicality was assessed using a brief rating form completed by the lecturer and the ten students during the implementation. The form comprised two aspects for the lecturer (ease of operating the medium and efficiency of the learning-path implementation) and two aspects for the students (learning interest and motivation, and ease of interaction and navigation). Responses were converted into percentages and classified as highly practical. Because the form was a brief, informal rating instrument, it was not subjected to a formal validity and reliability analysis.Table 6 presents the overall operational practicality results based on the lecturer's evaluation of the developed learning media.

Table 6. Practicality Assessment Results from the Lecturer's Perspective

No	Assessment Aspect	Practicality Percentage (%)	Category
1	Ease of operating the Sahabat Aktuaria learning media	82.00	Highly Practical
2	Efficiency of learning path implementation in learning activities	89.00	Highly Practical
Overall Average		85.50	Highly Practical

Table 6 shows that the Sahabat Aktuaria learning media is highly practical from the lecturer's perspective (85.50%). The lecturer indicated that the developed medium simplified the management of learning activities and supported the structured learning process through the learning trajectory approach. A practicality testing process and feedback collection were also conducted with students. Table 7 presents the overall operational practicality results based on the student evaluation of the developed learning media.

Table 7. Practicality Assessment Results from the Student's Perspective

No	Assessment Aspect	Practicality Percentage (%)	Category
1	Learning interest and motivation in actuarial mathematics learning	83.60	Highly Practical
2	Ease of interaction and navigation within Sahabat Aktuaria features	88.40	Highly Practical
Overall Average		86.00	Highly Practical

The outcomes shown in Table 7 reveal that, with an average score of 86.00%, students considered the Sahabat Aktuaria learning medium highly practical. Overall, these results show that the conveniently available and flexible elements of the produced learning medium efficiently assist the student learning process.

Evaluation

The evaluation phase of this study focuses on testing the preliminary effectiveness of the Sahabat Aktuaria website-based learning medium applied to actuarial mathematics instruction. This phase was conducted to refine the developed product (Wulandari et al., 2025). The collected data were analyzed using descriptive statistics and effectiveness analysis. Descriptive statistics were employed to provide an overview of students' learning performance before and after the implementation of the learning medium.

Table 8. Descriptive Statistics of Students' Scores

	N	Range	Min.	Max.	Mean	Std. Deviation
Pretest	10	20	50.00	70.00	58.5000	5.50252
Posttest	10	20	79.00	89.00	82.1000	3.14289
Valid N	10					

The average posttest score (82.10) was higher than the average pretest score (58.50), indicating an improvement in student learning outcomes after using the Sahabat Aktuaria learning medium. Prior to hypothesis testing, the Shapiro-Wilk normality test was conducted to ensure that the difference scores between the pretest and posttest were normally distributed.

Table 9. Shapiro-Wilk Normality Test Results

Variable	Statistic	df	Sig.
Difference (Posttest-Pretest)	.952	10	.688

The assumption of normality is required to determine the appropriate statistical test. Regarding the normality of the data, Table 9 shows a significance value of 0.688 ($p > 0.05$), indicating that the score differences satisfy the normality assumption. Subsequently, hypothesis testing was conducted to assess whether there was a statistically significant difference between students' pretest and posttest scores. Since the normality assumption was met, a paired-sample t-test was used. The results of the paired-sample t-test are presented below.

Table 10. Paired-Sample t-test Results

Paired Difference	Mean Difference	Std. Deviation	t	df	Sig. (2-tailed)
Posttest-Pretest	23.60	3.75	19.90	9	< .001

Table 10 shows a significance value of $p < 0.001$; therefore, H_0 is rejected and H_a is accepted. This indicates a statistically significant difference between the pretest and posttest scores. The paired-samples Cohen's d was 6.29, indicating a very large effect, and the 95% confidence interval for the mean difference of 23.60 points was [20.92, 26.28]. Because this study used a one-group design without a control group, these results are interpreted as a significant pre-post increase following the implementation of Sahabat Aktuaria rather than as causal evidence that the medium improved learning outcomes. Furthermore, the preliminary efficacy of the instructional media was analyzed using the normalized gain (N-Gain) score.

The N-Gain was calculated for each student individually and then averaged. The N-Gain results are presented below.

Table 11. N-Gain Results

Mean Pretest	Mean Posttest	N-Gain	Category
58.50	82.10	0.57	Medium

The N-Gain analysis yielded a score of 0.57, indicating a medium level of improvement in students' conceptual understanding. The N-Gain was calculated individually for each student and then averaged. This finding suggests a moderate normalized improvement following the implementation of Sahabat Aktuaria; however, it does not by itself establish that the medium caused the improvement.

Discussion

This Discussion is organized around four scientific claims: (1) the development contribution of Sahabat Aktuaria in operationalizing actuarial-specific learning needs; (2) its validity and design quality; (3) its practicality; and (4) its preliminary learning outcomes. The main findings were as follows: expert validation yielded an overall Aiken's V of 0.764 (valid category); practicality was rated highly by both the lecturer (85.50%) and students (86%); and the pretest-posttest comparison showed a statistically significant increase ($p < 0.001$) with a moderate normalized gain (N-Gain = 0.57).

Regarding the development contribution, Sahabat Aktuaria operationalizes actuarial specific learning needs by embedding a learning trajectory into the website structure. Unlike generic digital mathematics media, the content is organized into sequential stages foundations, core concepts, and advanced applications that are progressively unlocked; when a concept has not been mastered, the system directs the student to remedial material before advancing, a mastery-based adaptive mechanism that distinguishes Sahabat Aktuaria from a conventional static website. This design reflects the hierarchical nature of actuarial mathematics, in which each concept builds on previously mastered ideas, and it aligns with learning trajectory research showing that instruction sequenced according to students' developmental thinking improves conceptual understanding. This structure reflects the constructivist view that conceptual understanding is built incrementally through carefully sequenced tasks within the learner's zone of proximal development (Vygotsky, 1978) and the mastery-based unlocking aligns with mastery-learning principles (Bloom, 1968). The novelty of the medium therefore lies in this pedagogical sequencing rather than in the website technology itself.

Regarding validity and design quality, expert validation yielded an overall average Aiken's V of 0.764, placing the medium in the valid category. The highest scores were achieved for the suitability of the learning sequence with the learning trajectory approach (1.000), the implementation of UDL principles (0.917), and the suitability of actuarial content with learning outcomes (0.875), indicating strong pedagogical alignment. By contrast, the interface design (0.750) and usability and navigation (0.667) received moderate scores, and the interactivity and functionality of the learning features received the lowest score (0.375). This pattern suggests that, while the pedagogical substance of the medium is well aligned, the technical functionality and interactivity require further refinement, consistent with the media expert's feedback on programming and functional issues. This is consistent with prior research indicating that user-interface design and usability are critical factors influencing the effectiveness of digital learning systems and that a well designed interface enhances ease of use and supports the learning process (Hasani, Sensuse, Kautsarina, & Suryono, 2020).

Regarding practicality, lecturer responses averaged 85.50% and student responses 86.00%, both classified as highly practical. The lecturer reported that the medium simplified the management of learning activities and supported a structured learning process through the learning trajectory approach, while students reported that the medium increased their interest and motivation and was easy to navigate. These results corroborate earlier studies showing that

website-based media can improve student engagement, motivation, and learning opportunities, and they suggest that the progressive unlocking and multimodal features contributed positively to the user experience (Turmuzi & Lu'luilmaknun, 2023).

Regarding preliminary learning outcomes, the average score increased from 58.50 on the pretest to 82.10 on the posttest (mean difference 23.60; 95% CI [20.92, 26.28]), and a paired-sample t-test showed a statistically significant difference ($p < 0.001$) with a large effect size (Cohen's $d = 6.29$). The N-Gain of 0.57 (medium category) indicates a moderate normalized improvement. The improvement may be explained by the structured learning trajectory, which allowed students to build conceptual understanding incrementally, and by the adaptive, mastery-based progression and immediate feedback, which directed students to remedial material when a concept was not yet mastered. However, because the study used a one-group design with a single cohort and no control group, this improvement cannot be attributed causally to the medium and may partly reflect testing effects, maturation, or normal course instruction. A meta analysis of website-based mathematics learning media reported an average effect size of 1.06, which is consistent with the direction of the present finding but should be interpreted cautiously given the single cohort design (Samo et al., 2023). Taken together, these four findings support the feasibility and practical usability of Sahabat Aktuaria, while underscoring the need for larger controlled studies to establish its effectiveness.

CONCLUSION

This study developed and evaluated Sahabat Aktuaria, a website-based actuarial mathematics learning medium designed using a learning trajectory approach within the ADDIE framework. The results indicate that the medium is valid (Aiken's $V = 0.764$) and practical (85.50% lecturer and 86% student responses). An implementation with a single cohort of ten students showed a statistically significant pretest-posttest increase in conceptual understanding ($p < 0.001$) and a moderate normalized N-Gain score of (0.57). Overall, the learning trajectory-based website appears feasible and practically usable, providing preliminary evidence of improved conceptual understanding in a small developmental sample. These findings warrant further evaluation in larger controlled studies before broader effectiveness claims can be made.

RECOMMENDATION

Future research is advised to involve partner institutions through research collaboration to expand the size and characteristics of the sample, so that the findings are more representative and possess greater generalizability. In addition, future studies should: (1) include a comparison or control group to establish causal effectiveness; (2) measure long-term retention of conceptual understanding; (3) validate the test and practicality instruments in larger samples and involve more expert validators; (4) compare the medium with an alternative digital platform; (5) use test items with more varied difficulty to avoid ceiling effects and reduce redundancy; (6) evaluate additional actuarial topics; and (7) investigate how individual student misconceptions change over the course of the learning trajectory.

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AUTHOR CONTRIBUTIONS STATEMENT

Ad

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Ani Nuraini	✓	✓	✓	✓	✓	✓	✓	✓				✓	✓	✓
Lailatul M. W. Mufaridho				✓				✓	✓	✓	✓	✓	✓	
Wahyu Joko Saputro				✓								✓	✓	

CONFLICT OF INTEREST STATEMENT
The authors declare no conflict of interest.

INFORMED CONSENT
We have obtained informed consent from all individuals included in this study.

DATA AVAILABILITY
The data that support the findings of this study are available from the corresponding author, AN, upon reasonable request.

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