

Research Article

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Integrating The Tudang Sipulung Culture into The Flipped Classroom Strategy for Conceptual Understanding and Problem Solving in Science Subjects

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Abstract

Background/purpose. Education in the 21st century requires the cultivation of students' competencies in critical thinking, creativity, communication, and collaboration. Despite Indonesia's rich cultural heritage, the country faces challenges in adapting to modern changes, with ancestral traditions still significantly influencing daily life, even in the midst of technological advancements. This study aims to integrate the cultural values of Tudang Sipulung into the Flipped Classroom approach to improve conceptual understanding and problem-solving skills in science subjects at the Madrasah Aliyah level.

Materials/methods. This study falls under the category of research and development, which aims to design and develop a valid, practical, and effective Tudang Sipulung-based Flipped Classroom learning model for science lessons at Madrasah Aliyah Negeri. To ensure a systematic and structured development process, this study uses the ADDIE development model.

Results. The validation results show the model's high validity, practicality, and effectiveness. Testing with the experimental group revealed significant improvements in conceptual understanding and problem-solving skills compared to the conventional Flipped Classroom. Additionally, integrating local culture enhanced social interaction and motivation. Challenges, such as limited time for deliberation and adapting to new methods, were resolved through teacher training and curriculum adjustments.

Conclusion. Conclusion. This study concludes that the integration of Tudang Sipulung cultural values into the Flipped Classroom strategy is valid, practical, and effectively improves students' understanding and problem-solving skills in science. Structured stages rooted in local values facilitate contextual, collaborative, and meaningful learning. Students demonstrated improved post-test scores and moderate N-gain (0.6), indicating strong pedagogical value.

1. Introduction

21st-century education demands a learning paradigm that focuses on developing students' complete competencies, including critical thinking, creativity, communication, and collaboration (Milara & Orduña, 2024). Technological advances support independent, active, and collaborative learning, in accordance with the theory of constructivism (Degeng & Degeng, 2018). In this process, learners become the main agents who develop critical skills, creativity, collaboration, communication, and digital literacy to deal with complex world dynamics (Chusna et al., 2024; Janyam, 2023). Adaptability, analytical thinking, and collaboration are essential in dealing with a complex and dynamic world (Papagiannis & Pallaris, 2024). Scientific research learning improves the cognitive and conceptual competencies of Madrasah Aliyah students, emphasizing the importance of practical skills in science education (Manrique-Toro et al., 2024). Effective science learning not only improves understanding but also fosters scientific attitudes and curiosity needed in life and future work.

Various studies have shown that student science learning outcomes in many countries, including Indonesia, are still less than optimal (OECD, 2023). One of the main obstacles is the imbalance between mastery of theory and application skills, where students tend to memorize concepts without being able to apply them in a real context (Rzyankina et al., 2024). Learning methods that do not encourage active and contextual engagement, as well as the lack of attention to social and cultural aspects, also influence students' low understanding and critical thinking skills (Chew et al., 2020). Ignoring the local cultural context also risks reducing the motivation and meaning of learning (Romrome & Ena, 2022). Therefore, the integration of local cultural values in learning is crucial to shape the character and identity of the nation, while increasing academic effectiveness (Herlina et al., 2024). The learning model developed must be able to activate student involvement, strengthen problem-solving skills, and support holistic social and character values (Irsyadiah et al., 2024).

To improve science learning outcomes, various innovative learning methods have been developed, one of which is the popular Flipped Classroom model (Praherdhiono et al., 2019). This model encourages student collaboration through in-class discussions and group work (Andres & Contelles, 2022). However, despite the promise of increased engagement, the implementation of the Flipped Classroom has not been fully effective in improving the overall learning outcomes. This is due to society's inability to fully adapt to the changing times, where, although technology has been actively utilized, traditional habits inherited from ancestors still strongly influence the lifestyle of Indonesians.

The low ability of students to apply science concepts collaboratively and weak social engagement are real symptoms that arise due to individualistic learning approaches and minimal integration of local cultural values (Ristiana, 2017). Indonesia, with its diverse cultural wealth (Kuswandi, 2023), is contained in Pancasila, namely the values of unity and cooperation (Nurgiansah, 2022), recognising cultural, religious, ethnic, and racial diversity, and upholding tolerance between religions and ethnic groups (Patras et al., 2025). Including the Tudang Sipulung tradition from the Bugis-Makassar tribe, which contains the values of deliberation, mutual cooperation, and respect, has the potential to strengthen collaborative learning. According to social constructivism theory (Vygotsky & Cole, 1978), social interaction is an important element in the learning process, which is in line with the Tudang Sipulung principle that encourages dialogue and active participation among individuals. In addition, active participation in group discussions enables deeper learning. Furthermore, based on interviews with several teachers and students in the Sidenreng Rappang region of Indonesia, the biggest challenge in implementing the Flipped Classroom is the difficulty in accessing technology properly, as well as the ability and habits of teachers and students in the area with their local wisdom still deeply ingrained, which causes difficulties in following video-based learning because not all students have technological devices such as gadgets. Therefore, integration of local wisdom, such as the Tudang Sipulung culture, which emphasises cooperation and mutual respect, is needed.

The integration of these cultural values in the Flipped Classroom model has rarely been systematically researched (Borasheva, 2023). Modernization and globalization also threaten the preservation of these cultural values, even though these values are important as a source of character and social competence of students (Ardiansyah et al., 2021). This study aims to develop an innovative learning model that incorporates the Tudang Sipulung culture in a flipped classroom strategy to improve cognitive learning outcomes while strengthening students' affective and social aspects in a contextual and meaningful way, as well as preserving the local culture. This study also fills the void of empirical studies related to the integration of local culture in modern learning, making a significant contribution to national education (Ayunda et al., 2024) and has become a growing educational need that combines academic excellence with spiritual and moral development found in culture or religion (Ferdinan et al., 2025).

This research focuses on the development and evaluation of integrating Tudang Sipulung cultural values into the flipped classroom strategy in science subject learning. The main focus includes how the values of deliberation, mutual cooperation and mutual respect in the Tudang Sipulung tradition are implemented in flipped classroom learning activities, especially in the process of discussion and problem solving. Another focus is the effect of this cultural integration on improving student learning outcomes, both cognitive aspects and social and character aspects.

The main objective of this research is to examine the effectiveness of integrating the Tudang Sipulung culture in a flipped classroom strategy to improve students' science learning outcomes holistically. In detail, the study aims to describe the process of integrating the Tudang Sipulung culture into the flipped classroom strategy in science learning, assess the effect of Tudang Sipulung cultural integration on students' learning outcomes, including concept understanding and problem-solving skills, analyze the effect of the Tudang Sipulung cultural values on students' social interaction and collaboration during the learning process, and identify the obstacles and solutions that arise during the implementation of such cultural integration in a flipped classroom. The research questions guiding this study are as follows:

1. How is the implementation process of the Tudang Sipulung cultural integration in the flipped classroom strategy in science learning?
2. To what extent does the integration of the Tudang Sipulung culture affect students' science learning outcomes, particularly in terms of concept understanding and problem-solving skills?
3. What are the obstacles and solutions encountered in the process of integrating the Tudang Sipulung culture into the flipped classroom strategy?

The hypothesis of this study is that the application of the Tudang Sipulung culture-based Flipped Classroom model improves students' conceptual understanding and problem-solving in science subjects compared to traditional learning models. This article provides empirical insights to support policy development in Learning Technology. Findings indicate that the integration of Tudang Sipulung culture into the Flipped Classroom strategy improves Conceptual Understanding and Problem Solving skills in Science subjects, thereby supporting learning innovation in the context of education.

2. Literature Review

Flipped Classroom is a learning model that reverses the traditional pattern, with learners studying material independently outside the classroom (usually through videos or online materials) and using class time for discussion, collaboration, and application of concepts. This model increases learners' active engagement, allowing them to deepen their understanding of the material through direct interaction and problem-solving (Bergmann & Sams, 2012). Constructivism and active learning theories underlie the flipped classroom, where social interaction and group discussion reinforce conceptual understanding. The flipped classroom as an alternative approach encourages active

student participation and increases the amount of time students spend learning in class (Annajmi & Dedi Kuswandi, 2024).

Tudang Sipulung is a tradition of deliberation in the Bugis-Makassar culture, which emphasises the values of collectivity and decision-making through consensus. In the context of education, the values of Tudang Sipulung can increase social engagement, communication, and teamwork among learners. The integration of Tudang Sipulung in learning strengthens learners' character and enriches the group discussion process, as well as supporting problem-solving skills (Rudi & Ln, 2019).

Conceptual understanding and problem-solving are essential skills in the learning process that influence academic success and everyday life. In the Flipped Classroom model, learners are given the opportunity to deepen their understanding of concepts through independent learning outside the classroom, such as watching instructional videos or reading materials online. Class time is then used for collaborative activities such as discussions, problem solving, and application of concepts learned independently (Bergmann & Sams, 2016; Brame, 2019). This model not only increases learner engagement but also encourages the application of higher-order thinking skills needed to solve more complex problems (Lo & Hew, 2017).

The application of Tudang Sipulung, a tradition of deliberation originating from the Bugis-Makassar culture, in education enriches the learning process by adding a strong social dimension. Tudang Sipulung emphasizes collective decision-making through consensus-based discussion, enabling learners to work together collaboratively to solve problems (Rudi & Ln, 2019). This approach supports the development of social skills, communication, and problem-solving, as well as strengthening a sense of shared responsibility in achieving agreed-upon solutions.

By integrating these two models, Flipped Classroom and Tudang Sipulung, the learning process not only focuses on individual understanding of concepts but also emphasises collaboration in problem-solving, which develops social skills and collective teamwork. The social engagement gained through the deliberative principles of Tudang Sipulung enriches the learning experience by making the problem-solving process more interactive and inclusive (Hasby & Muthmainnah, 2019).

The integration of the Flipped Classroom with the local culture of Tudang Sipulung provides a more holistic and contextual learning approach. The Flipped Classroom, which prioritises independent learning outside the classroom and uses class time for discussion and collaboration, strongly supports the development of self-regulated learning (SRL), in which learners regulate and monitor their own learning (Zimmerman, 2015). By leveraging technology, learners can access learning materials anytime and anywhere, enabling them to independently schedule their study time before engaging in classroom activities (Sathio et al., 2021). This not only facilitates deeper conceptual understanding but also enhances active learner engagement in solving complex problems (Brame, 2019).

Tudang Sipulung, on the other hand, adds social value that enriches learning in a local context. With the principle of deliberation and consensus, Tudang Sipulung encourages learners to share ideas, listen to others' opinions, and work together to find the best solutions (Rudi & Ln, 2019). The application of these principles in learning enables learners to develop social and leadership skills that are useful not only in an academic context but also in everyday life. Tudang Sipulung serves to increase student engagement, which is essential in creating interactive and meaningful learning (Franklin-Guy & Schnorr, 2016).

Implications of Using Flipped Classroom and Tudang Sipulung in Education. The combination of the Flipped Classroom with the Tudang Sipulung culture has great potential to increase learner engagement, both cognitively and socially. The Flipped Classroom allows learners to access material independently, which can then be applied in classroom discussions and collaboration activities, in line

with the principle of Tudang Sipulung, which emphasises consensus in decision-making. This collaborative learning experience strengthens conceptual understanding and problem-solving skills while fostering a more socially and culturally aware character in learners (Hasby & Muthmainnah, 2019).

Thus, the integration of these two models can be a solution for creating more effective, inclusive, and sustainable learning. Learning that not only prioritises mastery of material but also develops social skills, collaboration, and collective problem-solving can equip learners with the abilities needed to face real-world challenges (Zainuddin & Perera, 2017).

3. Methodology

3.1. Research Design

This study falls under the category of research and development (R&D) with a mixed-method approach, aiming to design and develop a valid and practical Flipped Classroom (FC) learning model based on the Tudang Sipulung culture and to test its effectiveness for science subjects at the senior secondary education level, specifically at the State Madrasah Aliyah Sidenreng Rappang. This learning model is designed as an effort to address the challenges of 21st-century education, particularly in improving students' problem-solving abilities and developing social and collaborative character through an approach that integrates local cultural values and the use of digital technology. To ensure a systematic and structured development process, this study employs the ADDIE model. The ADDIE model is a widely used framework in instructional design and has proven effective in various modern educational contexts due to its components: analysis, design, development, implementation, and evaluation. The research data consists of quantitative and qualitative data used in the form of questionnaires that will measure the validity and practicality of the Tudang Sipulung flipped classroom learning strategy and provide a holistic picture of the influence of culture-based flipped classrooms as well as measure the effectiveness of concept understanding and problem-solving in science subjects. A convergent design is used to collect and analyse data from both approaches simultaneously (Adeoye et al., 2024).

A mixed-method approach that includes quantitative and qualitative phases to evaluate the integrated Flipped Classroom model of Tudang Sipulung.

Table 1. Differences in Quantitative and Qualitative Data Processing

	Quantitative	Qualitative
Design	Experiment with an experimental group (51 students) using the Tudang Sipulung integrated Flipped Classroom model and a control group (51 students) using the traditional Flipped Classroom model.	Case study with thematic analysis to explore students' and teachers' experiences in implementing the Tudang Sipulung integrated Flipped Classroom.
Participants	102 grade XI students, divided into two groups with equal numbers and academic abilities.	15 students from the experimental group and 3 teachers involved in the implementation of the model.
Instruments	Pre-test and post-test to measure concept understanding and problem-solving skills.	Semi-structured interviews and questionnaires as well as classroom observations.

Coding and thematic analysis techniques using interview techniques were used because this method facilitates data organization, identification of themes and patterns, and increases the objectivity of the analysis by ensuring that the data is analyzed systematically without bias.

3.2. Participants

Data collection in this study used quasi-experimental data collection techniques. According to Creswell (2013), a quasi-experimental design is an experimental design that is conducted without randomisation but involves placing participants into groups. A quasi-experimental design was used because the researchers had to use existing or available groups or classes. This limitation of the researcher is due to several factors, including the fact that the researcher cannot randomise participants who are already structured by the school, and administratively, it is not possible for the researcher to randomise learners from a number of schools to be used as experimental classes, and so on (Setyosari, 2016).

The participants involved in this research, which was conducted in a Madrasah Aliyah in Sidenreng Rappang district, South Sulawesi province, Indonesia, were all grade XI students, totaling 128 students, divided into 5 classes. For the development and testing of the learning model, students were divided into the following groups:

Table 2. Research Subject

No.	Class	Number of students	Group
1	XI A	26	Experiment (Flipped Classroom Tudang Sipulung)
2	XI B	25	
3	XI C	25	Control (Conventional Flipped Classroom)
4	XI D	26	
5	XI E	26	Pilot test

Classes XI A and XI B (51 students) became the experimental group with the Flipped Classroom model based on Tudang Sipulung, while XI C and XI D (51 students) became the control group using the conventional model. Class XI E (26 students) served as a pilot class to test the validity and practicality of the learning tools. The individual trial involved 5 students, the small group trial involved 15 students divided by academic ability, and 6 students were not involved because they were less active. The total number of field trial participants was 102 students. Group selection was carried out purposively by considering the equality of the number of students and the homogeneity of initial academic ability between classes, in order to ensure the validity of comparison of research results.

Table 3. Research Group Treatment

Stage	Flipped Classroom <i>Tudang Sipulung</i>	Flipped Classroom konvensional	Description
Introduction	The lesson begins with an introduction to the topic and small group discussions (sipulung) to provide context for the material.	An introduction to the material is presented through video or audio to prepare students for independent learning.	The LMS-assisted Flipped Classroom Tudang Sipulung emphasises social interaction and the establishment of initial context, while the conventional Flipped Classroom uses independent material without initial interaction.

Stage	Flipped Classroom <i>Tudang Sipulung</i>	Flipped Classroom konvensional	Description
Home	Independent learning activities on the LMS are accompanied by group discussions (sipulung) to understand the material collaboratively.	Independent learning activities are carried out by watching videos or listening to audio individually without interaction.	Flipped Classroom Tudang Sipulung assisted by LMS integrates pre-class collaborative discussions, while conventional Flipped Classroom focuses on individual learning
Class	Class time is used for in-depth group discussions, joint reflection, and collaborative application of concepts accompanied by experts	Class time is used for interactive activities such as discussions, question and answer sessions, and individual or small group application of material	Flipped Classroom Tudang Sipulung assisted by LMS emphasises intensive group reflection and collaboration, while Flipped Classroom is more flexible in the use of class time

3.3. Data Collection Techniques and Instruments

The testing was conducted using a questionnaire instrument consisting of a validity sheet, a product practicality questionnaire, and a set of questions to test effectiveness. Product validity is evaluated by at least three competent validators holding doctoral degrees in instructional design, learning technology, and culture, particularly the Tudang Sipulung tradition of the Bugis Makassar community. Validation is conducted using a closed-ended questionnaire with a 5-point Likert scale to measure the suitability and quality of the product. According to Creswell (2015), questionnaires are an appropriate method for collecting quantitative and qualitative data. In this study, questionnaires were used to measure the validity and practicality of the integrated flipped classroom learning strategy in Tudang Sipulung culture.

In the limited trial (individual and small group), the practicability questionnaire collected data based on teacher and student responses, while the problem-solving test measured the effectiveness of the product in improving students' problem-solving ability (Kawuwung & Mamahit, 2023). The control and experimental groups were given pre-tests before treatment, Cresweel dalam (Asiyah et al., 2025). This effectiveness measurement uses pre-tests to measure students' initial abilities and post-tests to measure their final abilities in science learning. Initial abilities were analysed using independent sample t-tests with the help of SPSS software, with a significance level ($p > 0.05$), which means that there were no significant differences or that the results were relatively the same.

Table 4. Concept Understanding and Problem-Solving Instrument Lattice

No.	Learning Objectives	Student Achievement Indicator	Cognitive Level
1	Understand the concept of wave types and phase difference	Describe the types of waves and distinguish the phase difference of waves on the example of phenomena	2 (Understanding)

No.	Learning Objectives	Student Achievement Indicator	Cognitive Level
2	Apply the sound propagation speed formula in the context of a problem	Calculate the speed of the propagation of sound in a given medium based on the given data	3 (Applying)
3	Analyze the phenomenon of the Doppler Effect in everyday life	Explain the change in sound frequency due to the Doppler Effect and solve related problems	4 (Analyzing)
4	Create a simple solution related to the principle of the interference or diffraction of light	Design a simple solution or device that uses the concept of the interference/diffraction of light	6 (Creating)

3.4. Data Analysis Technique

This research uses descriptive quantitative and qualitative data approaches. Quantitative data was obtained through the distribution of questionnaires focused on assessing product feasibility, as well as giving essay questions to measure students' problem-solving skills. Meanwhile, qualitative data was collected from input and suggestions given by experts, teachers, and students. All data obtained from the validators and respondents were then analyzed using descriptive percentage techniques with the following formula:

$$P = \frac{\sum X}{\sum X_i} \times 100\%$$

Description:

P : Percentage

X : The value of the respondent's answer in all items

X_i : Ideal score value in one item

100 : Constant

Source: (Ferdiansyah et al., 2021)

The results of the analysis for each instrument can be interpreted as follows:

Table 5. Product Feasibility Criteria

Achievement Level	Achievement qualification
81% - 100%	very valid, very practical, very effective, suitable for use without improvement
61% - 80%	moderately valid, moderately practical, moderately effective, worth using but needs a little improvement
41% - 60%	less valid, less practical, less effective, needs major improvement, not suitable for use
21% - 40%	not valid, not practical, not effective, should not be used
<20%	highly invalid, highly impractical, highly ineffective, not allowed at all

Source: (Akbar, 2017)

To determine the effectiveness of FC Tudang Sipulung products on problem solving skills, the researchers conducted a test analysis of learning outcomes analyzed using t-test (independent and paired). To strengthen the results of the assessment of the effectiveness of this study, this study was also analyzed using N-gain.

$$N - gain = \frac{posttest - pretest}{Max - pretest}$$

Description:

Post-test = Scores obtained from participants after the intervention or learning.

Pre-test = Scores obtained from participants before intervention or learning.

Max = The maximum score possible in the test.

The N-gain value is used to assess the effectiveness of an intervention in increasing students' knowledge or skills (Utami et al., 2025) . Based on the N-gain value, the interpretation is as follows:

Table 6. Interpretation of the N-gain

Category	Value Range	Description
High Gain	$0.7 \leq N\text{-gain} \leq 1.0$	The improvement was large, indicating that the intervention was highly effective.
Medium Gain	$0.3 \leq N\text{-gain} < 0.7$	Moderate improvement, indicating the moderate effectiveness of the intervention.
Low Gain	$0.0 \leq N\text{-gain} < 0.3$	Small increase, less effective intervention, or no significant effect.
No Gain	$N\text{-gain} = 0$	No improvement, indicating no change between the pre-test and post-test.

Hake in (Isnaini et al., 2022; Nurrijal et al., 2023)

4. Results

4.1. Analysis

In developing the FC Tudang Sipulung learning model, the researchers conducted a structured and comprehensive analysis. This analysis process aims to ensure that the model developed is not only effective in achieving learning objectives but also in accordance with the local cultural context and student needs. The following is the analysis that needs to be done by researchers in order to develop this learning model:

Table 7. Analysis That Needs to be Done in the Development of the Flipped Classroom Tudang Sipulung Learning Model

Aspect Analysis	Purpose of the Analysis
Learning Objective Analysis	Ensure learning objectives are clear, measurable, and support collective decision-making
Learning Needs Analysis	Identify student needs for more interactive and practical learning approaches

Aspect Analysis	Purpose of the Analysis
Analysis of Learner Characteristics	Adapting learning models to students' learning styles, technology readiness, and culture
Learning Resources and Media Analysis	Choosing learning media that is easily accessible and supports the local cultural values of Tudang Sipulung

Source: (Dick et al., 2015)

This table contains the analysis needed to ensure the suitability of the Flipped Classroom learning model with educational objectives and the local cultural context, particularly the value of collaboration and deliberation in Tudang Sipulung culture. With such thorough analysis, the Tudang Sipulung-based Flipped Classroom model can be effectively developed to improve students' problem-solving skills in science learning.

4.2. Design

This stage is the process of integrating the local wisdom of the tudang sipulung culture into the flipped classroom learning model. The activities in this process are focused on developing the syntax of FC Tudang Sipulung learning. The learning design framework for the Tudang Sipulung Flipped Classroom strategy is shown below:

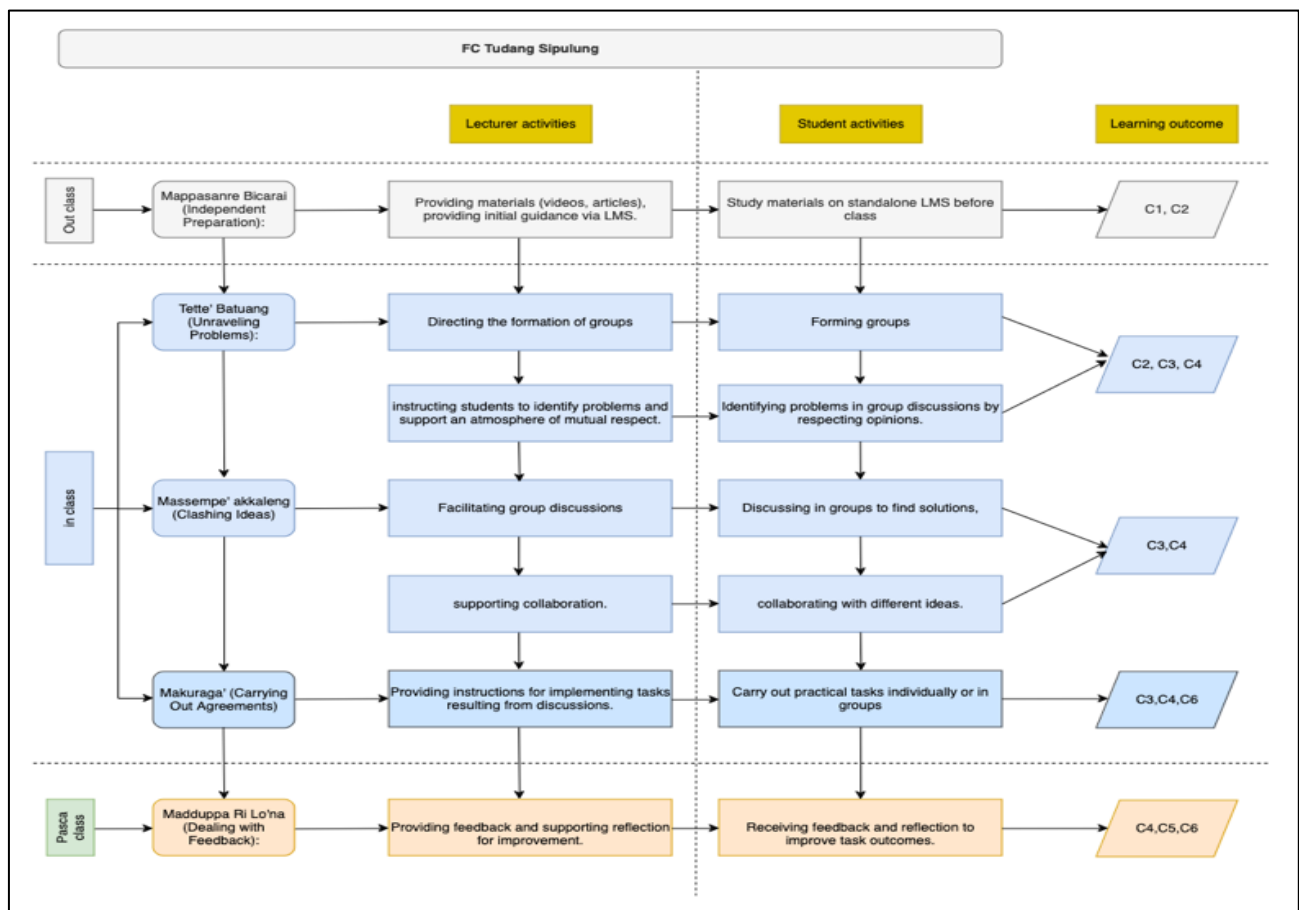


Figure 1. FC Tudang Sipulung Learning Strategy Framework

The figura above can be briefly explained as follows:

- a. Independent *Mappasanre Bicarai* (Preparation Stage). Teachers provide learning materials through videos and articles on the LMS, which students study independently with the motivation of social honor (*Siri'*) as preparation before the lecture.
- b. *Tette' Batuang* (Unraveling the Problem) Stage. The teacher facilitates the discussion to identify the problem by creating an atmosphere of mutual respect and inclusive communication, while students actively raise the problem collectively.
- c. *Massepe' Akaleng* (Brainstorming) Stage. The teacher supports group discussions to find solutions with the principle of collaboration (*Abbulosibattang*), so that students can exchange ideas constructively to reach consensus.
- d. *Makuraga'* Stage (Implementing the Agreement). The teacher gives instructions on the implementation of the task resulting from the discussion, and students perform the task individually or in groups with shared responsibility.
- e. *Madduppa Ri Lo'na* (Facing Feedback) Stage. Teachers provide constructive feedback for reflection, and students receive and use the feedback to improve the quality of learning outcomes.

4.3. Development

The product produced in this development is the syntax of the Flipped classroom learning method in the context of the local wisdom of the tudang sipulung culture for science subjects (Waves, Sound, and Light). Stage 1 Mappasanre Bicarai: The teacher uploads material on the LMS to be studied independently by students. Each learning week is equipped with learning resources and activities that provide 120 minutes for independent learning and 120 minutes for structured tasks collaboratively in accordance with the syntax of FC Tudang Sipulung.

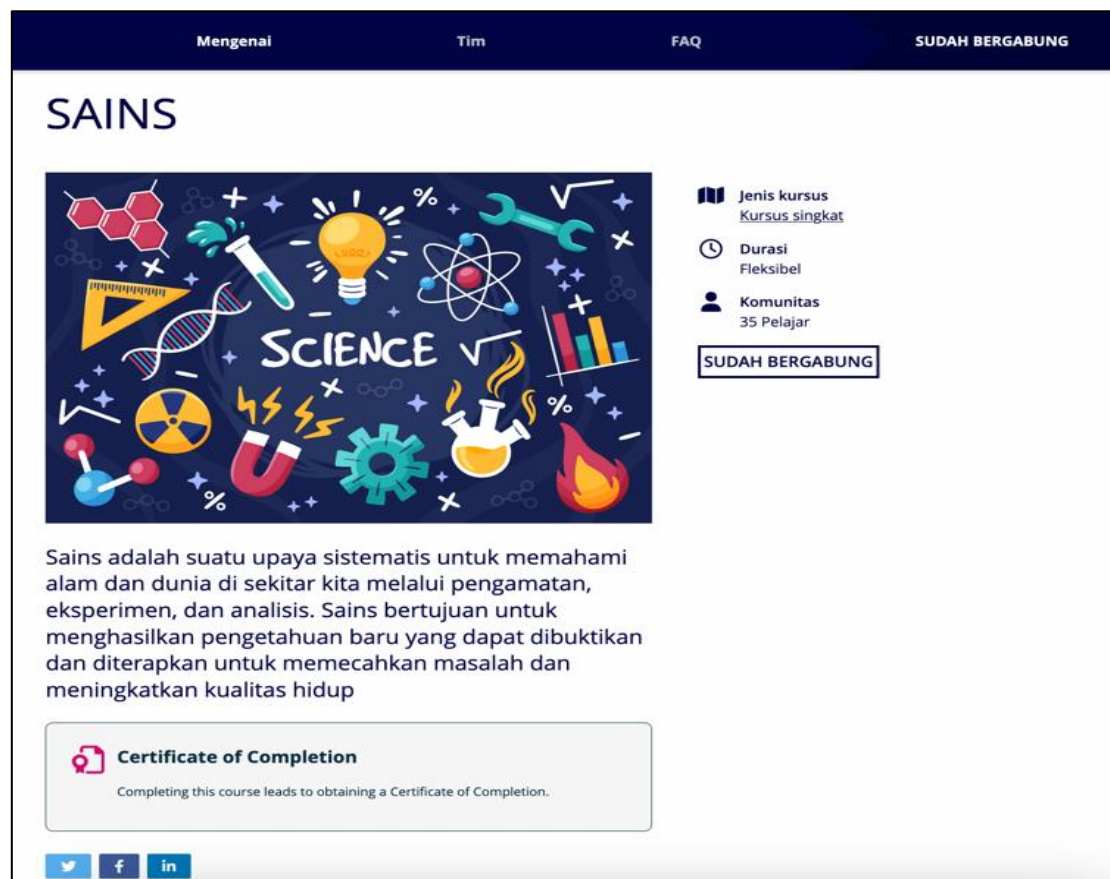


Figure 2. Integration of the FC Tudang Sipulung Model on the LMS for Science Subjects

The experts then validated the products that had been developed by reviewing the criteria for the product indicators produced. The assessment results are presented in Table 8 below.

Table 8. FC Tudang Sipulung Learning Design Validation Results

No.	Aspects assessed	Validator Score			Amount	Score Max
		1	2	3		
1	Relevance and Linkage to the Learning Objectives	4	4	5	15	15
2	Clarity and Ease of Implementation	4	5	4	12	15
3	Student Engagement in Learning	4	4	5	14	15
4	Cultural Integration of the Tudang Sipulung	5	4	5	14	15
5	Effectiveness in improving problem-solving skills	4	4	4	13	15
6	Use of media and learning resources	5	4	4	12	15
7	Suitability with learner characteristics	5	5	5	14	15
8	Overall and appropriateness of the learning context	5	5	5	15	15
Overall average		36	35	37	109	120

Based on the summary of information in Table 8, overall the experts gave an assessment of 109 out of a maximum score of 120, so that after being analyzed with descriptive percentage techniques

$$\frac{109}{120} \times 100\% = 90,83 \%$$

which indicates that the product is very valid, practical, effective, and feasible to use without the need for improvement (see Table 5). This demonstrates conformity with the learning system design theory, thereby validating the learning design developed and declaring it ready for testing at the practicality stage.

a. Implementation

This stage includes testing the practicality of the product, which is carried out by individual and small group trials, which are then tested by teachers and students.

Individual Trial

The individual trial stage is the initial stage of the implementation part of the ADDIE development model. Individual trials were conducted on 5 people whose data were analyzed using the SPSS application, namely normality testing using the Shapiro-Wilk test and obtained a significance value > 0.05. This proves that the data are normal. Furthermore, *Paired Sample Statistic* and *Paired Sample Test* testing, the results of these tests are as follows:

Table 9. Individual Trial Data of the FC Tudang Sipulung Learning Strategy

	Test Subject	<i>Paired Sample Statistic Results</i>	<i>Paired Sample Test Results</i>	Decision
1	Individual trial	The post-test value of the science problem-solving ability variable was higher than the pre-test value.	The FC Tudang Sipulung learning design can improve problem solving skills because there is a significant difference between the pretest and post-test scores in individual trials.	The FC Tudang Sipulung learning design can be used to teach individual learners

Small Group Trial

The small group trial was conducted on 15 students from the trial class (XI e). Based on the Shapiro-Wilk test results, the significance values for the pre-test (0.553) and post-test (0.991) are greater than 0.05, indicating that the data is normally distributed. Furthermore, *Paired Sample Statistic* and *Paired Sample Test* testing, the results of these tests are as follows:

Table 10. Small Group Product Trial Results

	Test Subject	<i>Paired Sample Statistic Results</i>	<i>Paired Sample Test Results</i>	Decision
1	Small group trial	The post-test value of the science problem-solving ability variable was higher than the pre-test value.	The FC Tudang Sipulung learning strategy can improve problem-solving skills because there is a significant difference between the pretest and posttest scores in the small group trials.	The FC Tudang Sipulung learning design can be used to teach learners in small groups.

After the individual and small group tests were carried out and feasible results were obtained, a practicality test was held. The questionnaire used contains responses from science subject teachers and students. The results of the practicality test evaluated by the teacher can be seen in this table.

Table 11. Practicality Test Results of the FC Tudang Sipulung Model by MA Teachers

No.	Aspects assessed	Score	Category
1	The steps of this model are clearly structured.	92	Very practical
2	This model increases student engagement.	92	Very practical
3	This model encourages teacher-student interaction.	90	Very practical
4	This model is suitable for a variety of learning styles.	82	Practical
5	This model is easily adaptable to classroom conditions.	82	Practical
6	This model suits the needs of the students.	90	Very practical
7	This model supports creative and innovative methods.	90	Very practical
8	The resources for this model are easily accessible.	85	Very practical

No.	Aspects assessed	Score	Category
9	This model enhances students' critical thinking skills.	94	Very practical
10	I would recommend this model to other teachers.	90	Very practical
Average		88,7	Very practical

Based on the conclusion of the information presented in Table 11, overall the teachers gave an assessment of 88.7%, which means the product is considered very feasible in its practicality aspect. Table 5 shows that a score of 81% - 100 means that the product, in this case the integrated flipped classroom learning strategy, falls into the very practical category. After conducting the first field test by teachers, the learning design model will be tested on 20 students. The purpose of this trial was to determine the extent to which the model's practicality is applicable to students in learning activities. Table 11 describes the practicality test results of the FC Tudang Sipulung strategy.

Table 12. Practicality Test Results of the FC Tudang Sipulung Model by MA Students

No.	Assessed Aspect	Average score	Category
1	The steps of the learning model are easy to understand.	89	Very practical
2	This model makes me more active in learning.	85	Very practical
3	This model encourages communication with the teacher.	90	Very practical
4	This model suits my learning style.	85	Very practical
5	This model is flexible for my classroom conditions.	86	Very practical
6	This model suits my learning needs.	85	Very practical
7	This model encourages creative learning methods.	85	Very practical
8	Media and learning resources are easily accessible.	92	Very practical
9	This model helps me think critically.	81	Very practical
10	I would like to see this learning model applied more widely.	91	Very practical
Average		86,9	Very Practical

Based on the data presented in Table 12, overall, students gave an assessment of 86.9%, indicating that this product is very practical (see Table 5). Where if the achievement score is 81% - 100, it means that the product, in this case the integrated flipped classroom learning strategy, falls into the highly practical category.

b. Evaluation

After the validity and practicality tests were conducted and deemed feasible, the next step was to conduct an evaluation. This stage involved assessing the effectiveness of the developed learning model, namely FC Tudang Sipulung, with the aim of improving HOTS, particularly in problem-solving skills.

The subjects involved in this large group/field test were 102 people consisting of 2 groups, namely the experimental group and the control group. Because the number of subjects was 102, we used the results of the Kolmogorov-Smirnov. The results of the SPSS analysis show Sig. > 0.05, indicating that the data are normally distributed, In the homogeneity test, the Sig. The pre-test and post-test values are > 0.05, which means that all variances between groups are homogeneous.

The pretest data was tested using an independent sample t-test to determine whether there was a difference in the initial abilities of students in science lessons.

Tabel 13. Pre-Test Table

<i>Pre test</i>		<i>Levene's Test</i>		<i>t-test for Equality of Means</i>				
		<i>F</i>	<i>Sig.</i>	<i>t</i>	<i>df</i>	<i>Sig. (2-tailed)</i>	<i>95% Confidence Interval of the Difference</i>	
							<i>Lower</i>	<i>Upper</i>
<i>Sains</i>	Equal variances assumed	.529	.469	1.629	73	.108	-.85087	846.396
	Equal variances not assumed			1.632	72.131	.107	-.84323	845.631

The Independent Samples Test table shows the results of the t-test for learning outcomes in concept understanding and problem solving between the experimental and control groups, with a pretest score of 0.108 ($p > 0.05$), indicating that there is no significant difference in the pretest scores between the experimental and control groups.

Table 14. Paired Sample T-Test (Within Group)

		<i>Mean</i>	<i>Std. Deviation</i>	<i>Lower</i>	<i>Upper</i>	<i>t</i>	<i>df</i>	<i>Sig. (2-tailed)</i>
Pair 1	Experimental Pretest- Experimental Posttest	-31.824	1.658	-32.290	-31.357	-137.090	50	.0000
Pair 2	Control Pretest- Control Posttest	-7.196	1.510	-7.621	-6.771	-34.028	50	.0000

Paired Sample T-Test (In Group) was conducted, yielding the output of pair 1 and a significant (Sig) value. (2-tailed) With a p-value of $0.00 < 0.05$, it can be concluded that there is a statistically significant difference in the average value of student learning outcomes between the pretest and posttest. Therefore, it can be concluded that there is a significant effect of FC Tudang Sipulung on science learning outcomes, both before (pretest) and after (posttest) implementation. This suggests that the FC Tudang Sipulung learning model has an effect on improving students' problem-solving skills in science subjects.

After knowing the results of the paired sample T-test (within groups), the researchers then conducted an independent sample T-test (between groups) and obtained the following results:

Table 15. Independent Sample T-Test (Between Groups)

	Class	N	Mean	Std. Deviation	Std. Error Mean
Posttest results	Experiment	51	82.88	4.877	0,474305556
	Control	51	57.08.00	4.251	0,413194444

The data in the statistical table between the groups also confirms that the average score of the experimental group of 82.88 is higher than that of the control group, which only reached 57.08. The increase that occurred in the experimental group was significantly greater than that in the control group. These results indicate that the application of FC Tudang Sipulung learning strategy is proven to be more effective in improving science problem-solving learning outcomes than the conventional flipped classroom method.

a. Ngain Test

To determine how much the level of improvement in learning outcomes occurred, the N-gain value was calculated using the following formula:

$$\frac{82,88 - 57,08}{100 - 57,08} = \frac{25,8}{42,92} = 0,6$$

The N-gain value of 0.6 indicates an increase in participants' learning outcomes by 60% of the maximum potential improvement that could be achieved after the treatment. According to Hake's commonly used N-gain interpretation criteria in table 6, this value is included in the medium gain category ($0.3 \leq \text{N-gain} < 0.7$). This means that the Tudang Sipulung flipped classroom learning treatment in science lessons shows that the learning outcomes of problem-solving skills have increased moderately and shows sufficient intervention effectiveness. Overall, these results show that the applied learning methods could able to make a positive contribution in significantly improving students' science learning outcomes. The difference can be seen in the following figure:

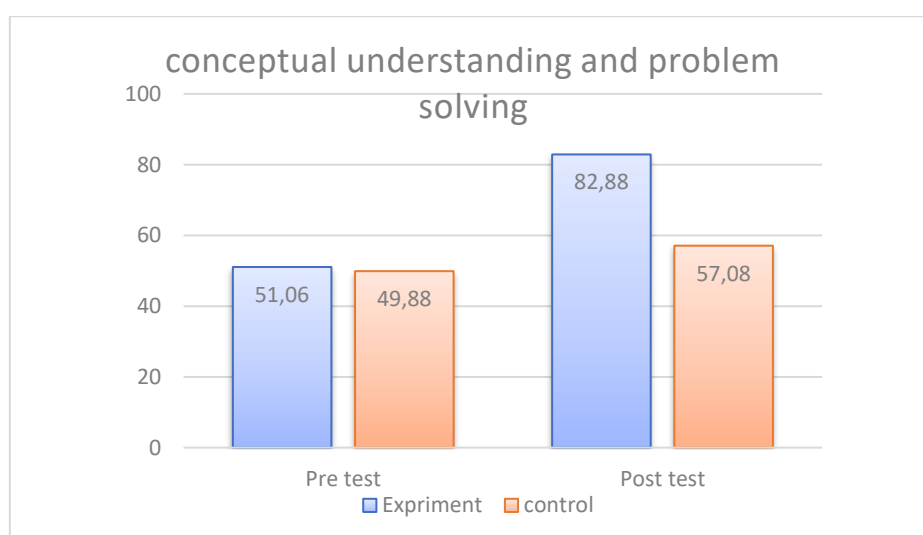


Figure 3. Diagram of the Improvement of Students' Science Learning Outcomes in the Experimental and Control Classes

Based on the N-gain calculation, the value for the experimental group using the Tudang Sipulung-based Flipped Classroom is 0.6. Based on Table 4. Interpretation of the N-gain score, 0.6 falls into the medium gain category (N-gain between 0.3 and 0.7). This value indicates a moderate improvement in students' conceptual understanding and problem-solving skills after the intervention was implemented.

Interpretation of Effect Size with N-gain: An N-gain value of 0.6 indicates that the Tudang Sipulung-based Flipped Classroom model intervention has a moderate effect on improving student learning outcomes. Although the N-gain value does not explain the magnitude of the difference between the two groups, this value indicates that 60% of the potential improvement that could be achieved by students was realised after the implementation of this learning model. Therefore, this intervention can be considered effective, although there is still room for improvement.

With an N-gain of 0.6, it can be concluded that the Tudang Sipulung-based Flipped Classroom model has a moderate effect on improving students' problem-solving skills and conceptual understanding in science learning. This N-gain value indicates that the intervention is quite effective in providing practical impact on student learning outcomes.

5. Discussion

This study successfully developed and tested a Flipped Classroom (FC) learning model integrated with the local cultural values of Tudang Sipulung and demonstrated its effectiveness in significantly improving students' problem-solving skills in science subjects at the Madrasah Aliyah level. Findings from individual, small group and field trials confirmed that the model is not only valid and practical, but also able to meaningfully improve learning outcomes. This finding is consistent with recent studies that reveal that the flipped classroom model is very effective in improving students' collaborative problem-solving (CPS) skills in science learning, especially when utilizing technology optimally and promoting active social interaction (R. Rahayu et al., 2024). The integration of the cultural values of Tudang Sipulung, which emphasizes deliberation, consensus, and collaboration directly strengthens the collaborative learning process, so that students not only build knowledge individually, but also socially and contextually (Santosa et al., 2023). This is relevant to the results of a meta-analysis that showed a significant positive effect of a flipped classroom on improving students' problem-solving skills in science education (Bai et al., 2022).

The uniqueness of this study lies in the incorporation of Tudang Sipulung local cultural values that enrich the affective and social aspects of learning, which have often received less attention in conventional flipped classroom implementations. (Jamaluddin et al., 2021) found that the integration of local cultural values into the flipped classroom can significantly improve student character, in addition to improving academic results. The application of cultural values such as gotong royong, mutual respect, and consensus creates an inclusive and conducive learning atmosphere, which motivates students to actively participate and take responsibility (Zakirova, 2024). Agree with Wulansari et al. (2023), who reported increased student motivation and learning satisfaction through the integration of technology and local culture-based collaborative approaches.

This strategy supports Vygotsky's social constructivism theory, which emphasizes the role of cultural context and social interaction in learning (Santosa et al., 2023). With the cultural integration of Tudang Sipulung, students build knowledge together through real cultural experiences in group discussions and deliberations, so learning becomes more meaningful and in-depth. Teachers' and students' recognition of the practicality of this model shows that the learning steps are easy to follow, flexible, and encourage active engagement (Arslan & Erdem, 2024).

However, constraints such as a lack of initial understanding of Tudang Sipulung's cultural values, limited deliberation time, and resistance to changes in methods demand special attention in implementation. Therefore, teacher training and ongoing mentoring are required for effective cultural integration, as well as curriculum adjustments to support culture-based collaborative activities (Syamsuddin & Mujahid, 2023). (Alias et al., 2020) emphasized the importance of professional teacher training to implement a flipped classroom that is oriented toward developing critical thinking skills and collaboration. Further research is recommended to develop intensive training modules, interactive digital learning media that contain local cultural values, and evaluate

the long-term impact on students' character and social skills (Jamaluddin et al., 2021). This is in line with (Han & Rokenes, 2020), who emphasize the need for structured teacher training and further studies on the long-term pedagogical impact as well as the development of contextual learning media.

In addition, the integration of the flipped classroom with problem-based learning (PBL) method shows great potential in improving critical thinking and collaboration skills, as expressed (M. N. Rahayu et al., 2025) in the combination of FC and PBL to maximize students' critical thinking and problem-solving skills. Theoretically, the results of this study strengthen the argument that the local cultural context is a crucial element in active learning that emphasizes collaboration and social interaction. Cross-cultural studies also reveal that cultural values influence students' responses to the flipped classroom model, and the development of learning models in multicultural countries such as Indonesia should accommodate local values to make learning more relevant, meaningful and effective (Lawter & Garnjost, 2021). This study not only showed significant improvement in students' cognitive aspects, but also strengthened the character and social values essential for 21st-century education. Further research should focus on optimizing teacher training, developing learning media, and evaluating the long-term impact to ensure the sustainability and effectiveness of learning models that integrate local culture.

6. Conclusion

This study concludes that the learning strategy of integrating Tudang Sipulung cultural values into the Flipped Classroom (FC) strategy is valid and practical and significantly improves students' concept understanding and problem-solving skills in science learning. The structured implementation-through stages such as *Mappasanre Bicarai*, *Tette' Batuang*, *Massempé' Akaleng*, *Makuraga'*, and *Madduppa Ri Lo'na* - was able to contextualize science learning in local cultural practices that emphasize collective dialog, mutual respect, and shared responsibility. The cultural component of Tudang Sipulung plays an important role in students' social development through discussion, while its impact on cognition is more evident in the improvement of problem-solving skills, where cultural interaction strengthens students' understanding of the material. Students in the experimental group showed higher post-test scores and moderate N-gain values (N-gain = 0.6), indicating that this learning model has a strong pedagogical value. The study also proved that Tudang Sipulung creates a socially constructive learning atmosphere, strengthens cooperation in solving problems and encourages active participation. While the conventional FC model increases student autonomy and engagement, the integration of local cultural values enriches the learning experience holistically in terms of cognitive, affective and social aspects. Despite implementation challenges such as limited time for deliberation, teachers' and students' lack of initial understanding, and resistance to new methods, the solutions implemented - such as teacher training and curriculum adjustments - proved effective.

This study shows that Tudang Sipulung FC has an effect on both cognitive and social aspects. However, the cultural impact of Tudang Sipulung on problem solving (cognitive) has not been completely separated from other influences. Regarding the cultural influence on problem solving, Tudang Sipulung cultural values encourage more collaborative and deliberative group discussions, which enrich conceptual understanding and problem solving. In discussions, students are encouraged to collaborate and seek solutions together, which influences the improvement of their cognitive abilities. Furthermore, regarding the separation of cultural influences, although cultural impacts are evident, the influence of technology and active learning strategies also plays a role in student engagement in problem-solving. Therefore, a more separate analysis between cultural influences and other factors is needed to assess the contribution of culture more accurately.

Declarations

Author Contributions. All authors have read and approved the final version of this article. Handy Ferdiansyah: Writing - designed the research, collected and analysed data, and drafted the manuscript. I Nyoman Sudana Degeng: provided theoretical guidance and supervised the research process. Dedi Kuswandi: contributed to the development of the learning model and data interpretation. Henry Praherdhiono: critically reviewed and edited the manuscript for important intellectual content.

Conflict of Interest. The authors declare that there are no conflicts of interest in this publication.

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Ethical Approval. Prior to conducting the research, approval was obtained from the principal of Madrasah Aliyah Negeri Sidenreng Rappang with number 572/MA.21.18.0001/TL.00/08/2024 to ensure that this research complies with ethical standards and respects the privacy and confidentiality of all participants.

Data Availability Statement. Data are available upon request from the corresponding author.

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