

Improving the Quality of Colloidal System Learning through Lesson Study with Inquiry-Based Experimental Methods

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ABSTRACT

Purpose of the study: The purpose of this study is to determine the lesson study learning process using the guided inquiry-based experimental method on the main material of colloidal systems at Madrasah Aliyah Darut Taqwa.

Methodology: This study employed a descriptive qualitative method with a lesson study approach (plan–do–see cycle). Instruments included observation sheets (Likert scale 1–5), interview guides, and documentation checklists. Data were collected through observation, semi-structured interviews, and document review. Data analysis used the Miles and Huberman model. Data processing utilized Microsoft Excel.

Main Findings: The results of this study indicate that lesson study activities involve three stages: planning (Plan), implementation (Do), and reflection (See). Prior to this activity, initial observations were conducted to compare the pre-lesson and post-lesson study sessions. As a result, teachers' ability to manage learning improved. For example, the ability to guide problem formulation increased from 41.25% to 53.75%. Improvements also occurred in the ability to conduct experiments, analyze and present results, and communicate. Based on these data, lesson study activities can improve the quality of learning.

Novelty/Originality of this study: This study introduces an integrated implementation of lesson study with guided inquiry-based experimental methods specifically applied to colloidal system learning. It advances existing knowledge by emphasizing collaborative teacher development alongside student-centered inquiry processes. The study provides new insights into how iterative lesson study cycles enhance instructional quality, teacher competence, and active student engagement in chemistry learning contexts.

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1. INTRODUCTION

Chemistry instruction at the secondary school level plays a strategic role in developing students' understanding of scientific concepts and developing their thinking skills [1], [2]. Colloidal systems are often considered difficult by students due to their abstract nature and the need to understand microscopic concepts [3], [4]. The lecture-based learning process tends to leave students passive and less actively engaged [5], [6]. This

results in poor conceptual understanding and diminished scientific skills. Therefore, learning innovations are needed to improve the overall quality of student learning processes and outcomes.

Colloidal systems, as part of chemistry, have complex characteristics and require a contextual learning approach [7], [8]. Concepts such as the Tyndall effect, Brownian motion, and coagulation are difficult to grasp if presented solely theoretically. Direct student involvement through experimental activities is one solution to overcome these difficulties [9], [10]. Through experiments, students can observe real-world phenomena, making the concepts learned more meaningful. Therefore, the experimental method has significant potential to improve the quality of chemistry instruction [11], [12].

The inquiry approach is a learning strategy that emphasizes students' independent concept discovery [13], [14]. In inquiry-based learning, students are encouraged to ask questions, formulate hypotheses, conduct experiments, and draw conclusions [15], [16]. This approach not only improves conceptual understanding but also develops critical and scientific thinking skills. Guided inquiry is an appropriate alternative because it provides sufficient direction for students without reducing opportunities for independent thinking [15], [17]. Therefore, integrating experimental methods and inquiry approaches can create more effective learning.

Beyond selecting learning methods, improving the quality of learning can also be achieved through collaboration between teachers [18], [19]. Lesson study is a model for teacher professional development that is carried out collaboratively and continuously [20], [21]. In lesson study, teachers jointly plan, implement, and reflect on learning to improve its quality [22], [23]. This activity allows teachers to share experiences and systematically improve teaching practices. Therefore, lesson study is a relevant approach for improving the quality of classroom learning.

The application of lesson study combined with inquiry-based experimental methods provides opportunities for creating more innovative learning [24], [25]. Through the planning stage (plan), teachers can design experimental activities that are appropriate to the characteristics of the colloidal system material [26], [27]. In the implementation stage (do), learning is carried out by actively involving students in the inquiry process [28], [29]. Furthermore, in the reflection stage (see), teachers and their team evaluate the ongoing learning process. This integration is expected to improve the quality of learning, both in terms of the process and student learning outcomes.

However, various previous studies have shown that the application of experimental or inquiry methods is often not optimized through collaborative approaches such as lesson study [25], [30]. Most research still focuses on the use of a single learning method without integrating it with teacher professional development models [31], [32]. Furthermore, studies on the application of lesson study to colloidal systems are still limited. This situation indicates a research gap that requires further examination. Therefore, research that integrates lesson study with inquiry-based experimental methods in chemistry learning is needed.

Based on this analysis, the novelty of this research lies in the integration of lesson study with guided inquiry-based experimental methods on colloidal systems. This research not only emphasizes learning outcomes but also the collaborative and reflective learning process. The urgency of this research is based on the need to improve the quality of chemistry learning to make it more active, meaningful, and student-centered. With this learning innovation, it is hoped that students will more easily understand the concept of colloidal systems and develop scientific skills. Therefore, the main objective of this study is to determine the learning process of lesson study using guided inquiry-based experimental methods on the subject of colloidal systems.

2. RESEARCH METHOD

2.1. Type of Research

Research is a scientific process undertaken to obtain valid data for specific purposes and benefits. This study employed a descriptive qualitative approach, a research procedure that produces data in the form of written and oral descriptions, sourced from subjects and observed behavior [33]. This approach was chosen because it provides an in-depth picture of learning phenomena occurring in the classroom. Through this method, researchers sought to comprehensively describe and analyze the learning process. Thus, the resulting knowledge is built on understanding and findings related to the application of the lesson study learning model with guided inquiry-based experimental methods to the topic of colloidal systems.

The research was conducted in two stages, adjusted to the time allocation and scope of the material studied. Each stage encompassed the three main stages of lesson study: planning (plan), implementation and observation (do), and reflection (see) [34], [35]. During the planning stage, the researcher and team developed the learning materials to be used. The implementation and observation stage involved implementing the learning in the classroom and observing the learning process. Furthermore, the reflection stage was conducted to evaluate and improve the learning based on the observations obtained.

2.2. Data Collection Techniques

Data collection techniques are a crucial stage in research because the primary goal is to obtain accurate and relevant data [36]. Without a proper understanding of data collection techniques, researchers will encounter difficulties in obtaining data that meets established standards. Therefore, selecting the right technique is essential to ensure relevant and accountable data. In this study, the data collection techniques used included documentation, interviews, and observation, which complement each other. These three techniques were used to obtain comprehensive data regarding the implementation of learning.

Documentation techniques were conducted by reviewing various documents related to the research, such as notes, transcripts, books, archives, and other official documents. In this study, documentation was used to obtain information regarding the conditions of teachers and educational staff, school facilities and infrastructure, and the condition of students during the learning process. Furthermore, documentation was used to collect data in the form of lists of 11th-grade students and documents related to the planning, implementation, and evaluation of lesson study activities. Data obtained through documentation served as supporting data that strengthened the research findings. Thus, documentation techniques helped provide a more complete picture of the research situation.

Interviews were conducted through a direct question-and-answer process between the researcher and respondents to obtain in-depth information. In this study, interviews were used to determine teachers' and students' responses to the implementation of lesson study using the guided inquiry-based experimental method. Furthermore, the interviews also aimed to identify various obstacles and supporting factors that influence learning success. The information obtained from the interviews is expected to provide a deeper understanding of the ongoing learning process. The results of these interviews are then used as analytical material for learning improvements.

Observation techniques were conducted by systematically directly observing the learning process in the classroom. Observations in this study focused on the implementation of lesson study using the guided inquiry-based experimental method, encompassing the planning, implementation, and reflection stages. The observation instrument used was an observation sheet with a rating scale ranging from 1 to 5. This scale indicates the assessment categories from very poor to very good, according to the level of implementation of the observed inquiry activities. The results of these observations were then analyzed to determine the quality of the teacher's learning and to provide a basis for learning improvements. The assessment criteria used in this study are shown in the following table:

Table 1. Assessment Criteria

Score	Qualitative	Description
5	Very Good	Many inquiry activities were conducted and were very much in line with the indicators.
4	Good	Most inquiry activities were conducted and were in line with the indicators.
3	Fairly Good	Few inquiry activities were conducted and were less in line with the indicators.
2	Poor	Very few inquiry activities were conducted and were not in line with the indicators.
1	Very Poor	No inquiry activities were conducted.

2.3. Data Analysis Techniques

Data analysis is a systematic process of organizing, grouping, and examining the relationships between collected data to produce meaningful conclusions. In this study, data analysis refers to the model proposed by Miles and Huberman, which includes three main stages: data reduction, data presentation, and conclusion drawing [37], [38]. Data reduction is carried out by summarizing, selecting, and focusing data on those that are important and relevant to the research objectives. At this stage, researchers also eliminate unnecessary data and organize data from observations, interviews, and documentation to facilitate analysis. Thus, the data reduction process helps researchers simplify data without eliminating important information.

The next stage is data presentation, which is the process of organizing data in a systematic format to facilitate understanding of the research results. The reduced data is then presented in descriptive narrative form for easier analysis and interpretation. This data presentation aims to provide a clear picture of the ongoing learning process and serve as a basis for decision-making. Through structured data presentation, researchers can see patterns, relationships, and trends emerging from the collected data. Thus, data presentation plays a crucial role in supporting a more in-depth analysis process.

The final stage is drawing conclusions or verification, which involves reviewing all the data obtained to ensure consistency between the data and the analysis results. Researchers compare data from various sources, such as field notes, interviews, documentation, and observations, to ensure data validity. Conclusions are based on evidence found during the research process. This process is carried out continuously until valid conclusions are reached that answer the research problem formulation. Thus, the three stages of data analysis are interrelated and inseparable.

Furthermore, in this study, data analysis was also conducted to determine the quality of learning after implementing lesson study using a guided inquiry-based experimental method. Analysis was conducted on observational data by calculating an average score for each aspect observed during the learning activity. The average score was obtained by comparing the total score obtained with the number of indicators assessed. Next, these quantitative scores were converted into qualitative scores based on ideal assessment criteria. These criteria include the categories of "very good," "good," "sufficient," "poor," and "very poor," which are determined based on the ideal average value and the ideal standard deviation.

The ideal mean score (M_i) is calculated from half the sum of the ideal maximum score and the ideal minimum score, while the ideal standard deviation (S_{Bi}) is calculated from one-third of the difference between the ideal maximum and minimum scores. The ideal maximum score is obtained from the number of assessment items multiplied by the highest score, while the ideal minimum score is obtained from the number of items multiplied by the lowest score. In addition, to strengthen the analysis, the percentage of inquiry-based learning implementation is also calculated. This percentage is obtained by comparing the score obtained with the maximum score, then multiplied by one hundred percent. The percentage results are then classified into categories of very good, good, sufficient, less, and very less according to the established assessment criteria. The percentage results of the assessment criteria can be seen in Table 2 below:

Table 2. Ideal Assessment Categories

Average Class Grade	Category
$80\% < X \leq 100\%$	Excellent
$67\% < X \leq 80\%$	Good
$53\% < X \leq 67\%$	Fair
$40\% < X \leq 53\%$	Poor
$X < 40\%$	Very Poor

3. RESULTS AND DISCUSSION

3.1. Implementation of Lesson Study with an inquiry-based experimental method in Observation I

The lesson study activities in this study were implemented through three main stages: planning (plan), implementation (do), and reflection (see). In the first observation stage, the planning process began with an explanation of the lesson study's mechanisms and techniques, the activity's objectives, and the desired targets. Furthermore, the learning scenarios to be implemented in the classroom were discussed. This planning activity aimed to provide the team with a comprehensive understanding of the lesson study concept and to encourage motivation to improve the quality of learning and teacher professionalism [39], [40]. The results of this planning stage were learning tools, including a Lesson Implementation Plan using an inquiry-based experimental method, student activity sheets, and learning assessment instruments.

The next stage was implementation (do), which was the implementation of the previously prepared plan. At this stage, the teacher carried out the lesson according to the designed Lesson Implementation Plan. The learning activity began with an apperception session, consisting of prompting questions that guided students' attention to the material to be learned. This apperception session played a crucial role in building learning readiness and increasing student motivation. This aligns with the characteristics of inquiry-based learning, which requires active student involvement from the beginning of the learning process. Next, in the core learning activities, the teacher implemented a guided inquiry approach. This type of inquiry was chosen to accommodate students who were unfamiliar with inquiry-based learning and therefore still needed teacher guidance. The inquiry learning process involved several stages: formulating questions, developing hypotheses, collecting and analyzing data, and drawing conclusions. The inquiry process was divided into two stages: an initial stage focused on problem formulation and hypothesis development, and a more advanced stage involving experimental activities to test the hypotheses. Through these experimental activities, students obtained data that was then analyzed and used as a basis for drawing conclusions supported by theory.

In the closing stage, the teacher reinforced the material learned and assigned students assignments. These assignments aimed to gauge students' understanding of the colloidal systems material they had learned. Observations showed that learning using the guided inquiry-based experimental method had a positive impact on student engagement. Students demonstrated high enthusiasm and did not feel burdened in completing the assigned tasks. This was because the questions were contextual and related to their daily experiences.

The final stage of the lesson study activity is reflection (see), which is an evaluation of the learning process that has been implemented. At this stage, the entire team discusses various aspects of the learning process, including both strengths and weaknesses identified during implementation. The discussion also includes suggestions for improvement, areas to maintain, and aspects that need to be improved in future lessons. The model teacher's openness to feedback, criticism, and suggestions is a crucial factor in the success of the reflection activity. This demonstrates a professional attitude and commitment to continuously improving the quality of learning.

Overall, the lesson study implementation in this study demonstrated that all participants were actively involved and demonstrated high dedication. The collaborative activity had a positive impact on improving the quality of learning. However, several aspects still need improvement, such as study group management and the teacher's ability to guide students in formulating hypotheses. Therefore, continuous improvement is necessary to ensure optimal implementation of inquiry-based learning.

3.2. Implementation of Lesson Study with an inquiry-based experimental method in Observation II

During the second observation, lesson study activities continued to be conducted through three main stages: planning (plan), implementation (do), and reflection (see). The planning stage began with a review of the syllabus as a basis for developing the Lesson Plan. This activity aimed to ensure the alignment between the material, methods, and learning objectives to be achieved. The results of the planning stage were learning tools consisting of a Lesson Plan based on an experimental method with an inquiry approach, student activity sheets, and learning assessment instruments. These tools were then used as a reference for classroom learning.

The implementation stage (do) was the implementation of the previously developed plan. The teacher conducted the lesson according to the steps outlined in the Lesson Plan. The activity began with an apperception through prompting questions that guided students' attention to the material to be studied. This apperception played a crucial role in building learning readiness and increasing student motivation. This significantly supported the implementation of inquiry learning, particularly for the topic of colloidal systems, which requires active student involvement in understanding the concepts.

Furthermore, in the core learning activities, the teacher implemented a guided inquiry approach. This approach was chosen to address the needs of students who still needed guidance in implementing inquiry-based learning. The learning process includes asking questions, formulating hypotheses, collecting and analyzing data, and drawing conclusions. Inquiry activities are carried out in two stages: an initial stage, which involves formulating hypotheses, and a follow-up stage, which involves conducting experiments to test the hypotheses. Through these activities, students gain hands-on experience in discovering concepts based on experimental results supported by theory.

In the closing stage, the teacher reinforces the material learned and assigns students assignments to assess their level of understanding. Observations indicate that learning using the guided inquiry-based experimental method has a positive impact on students. Students appear more enthusiastic and less burdened in completing the assigned tasks. This is because the tasks are contextual and related to everyday life. This makes learning more meaningful and easier for students to understand.

The reflection (see) stage involves openly discussing the learning process. In this activity, all participants identify the strengths and weaknesses of the learning process and provide suggestions for improvement. The model teacher's openness to feedback was a crucial factor in the success of the reflection activity. Furthermore, all participants demonstrated a high level of commitment and commitment to each stage of the lesson study. This demonstrates that lesson study activities can foster collaborative teacher professional development.

Interviews with students revealed that guided inquiry-based experimental learning provided a more engaging and understandable learning experience. Students stated that the practical activities helped them understand the material because they could observe it directly. Furthermore, the assignments given by the teacher did not feel burdensome because they related to phenomena frequently encountered in everyday life. During the learning process, students also became more active and had the opportunity to work collaboratively in groups. This activity indirectly fostered communication and collaboration skills among students.

Overall, the ongoing implementation of lesson study activities positively contributed to improving the quality of learning. Lesson study enabled teachers to review, evaluate, and develop teaching practices collaboratively, resulting in more effective learning. Observation and reflection results indicate an increase in teachers' abilities in guiding the learning process, including the ability to guide problem formulation by 73.75%, guide the implementation of experiments by 79.28%, guide the analysis and presentation of results by 78.33%, and guide student communication by 78.75%. Although this increase has not been measured through quantitative learning outcomes, these findings indicate that lesson study has the potential to significantly improve the quality of learning. The difference in results before and after the lesson study activities can be seen in Table 3.

Table 3. Differences Before and After Lesson Study

Rated aspect	Before Lesson Study is Conducted	After Lesson Study (Observation I)	After Lesson Study (Observation II)
The ability to guide students in formulating problems	41.25%	53.75%	73.75%
The ability to guide students in conducting experiments	49.28%	59.28%	79.28%
The ability to guide students in analyzing and presenting results	41.67%	65%	78.33%
The ability to guide students in communicating	50%	58.75%	78.75%

The success of lesson study cannot be viewed as an instant result achieved by individuals in a short time, but rather as the result of a collaborative process involving various parties, such as teachers, principals, and other stakeholders who share the common goal of improving the quality of education. A collaborative process based on openness, togetherness, and commitment is a key factor in the success of lesson study activities. Positive interactions between participants enable the constructive exchange of ideas and experiences. Thus, lesson study is an effective means of building a culture of collaborative learning among educators.

As previously explained, lesson study is a collective activity that is ideally carried out over a long and sustainable period. However, the lesson study implementation in this study was relatively short, lasting only approximately one month. This situation led most participants to feel that the activity was not optimal and needed to be continued. Ideally, lesson study is designed systematically based on real-life problems encountered in learning. Nevertheless, evaluation results indicate that this activity has had a positive impact on improving teacher competency.

The results indicate that lesson study can improve teacher competency, particularly in pedagogical and professional aspects. Improved pedagogical competency is evident in teachers' ability to design and implement more structured and effective learning. Meanwhile, teachers' professional competence also improved, particularly in their mastery of learning materials. This demonstrates that lesson study focuses not only on teaching practice but also on the comprehensive development of teachers' knowledge and skills. Thus, lesson study serves as a means of continuous professional development.

In the final reflection phase, all participants expressed their commitment to continuing lesson study activities. The teachers agreed to maintain collaboration and make classroom learning practices an object of joint study that is continually developed. This process is expected to result in continuous improvement in both the learning process and outcomes. If lesson study activities are implemented consistently, teacher competence will continue to develop over time. Therefore, lesson study can be used as a strategic program to improve teacher professionalism and the quality of learning in schools.

Guided inquiry-based learning integrated with experimental activities provides students with opportunities to develop a more meaningful understanding of concepts through hands-on experience [15]. In the context of abstract colloidal systems involving microscopic representations, student involvement in the scientific investigation process allows for connections between observed macroscopic phenomena and underlying theoretical concepts. This aligns with the view that effective chemistry learning must bridge the three levels of chemical representation: macroscopic, microscopic, and symbolic, so that students not only memorize concepts but also fully understand the relationships between these representations.

Furthermore, the application of guided inquiry in experimental learning also encourages the development of students' science process skills, such as formulating problems, formulating hypotheses, and analyzing experimental data. These skills are an essential part of modern chemistry learning, which emphasizes not only conceptual mastery but also scientific thinking skills [41]. With teacher guidance, students receive sufficient direction so that the inquiry process can proceed in a structured manner without compromising their opportunities for independent thinking. This demonstrates that guided inquiry is an appropriate approach for students who are still in the early stages of developing inquiry skills.

From a teacher professional development perspective, the implementation of lesson study provides a space for systematic and ongoing reflection on learning practices [42], [43]. Through collaboration in the planning, implementation, and reflection stages, teachers can identify learning weaknesses more objectively and formulate more appropriate improvement strategies. This process not only directly improves the quality of learning but also contributes to the long-term enhancement of teachers' pedagogical and professional competencies. Thus, lesson study serves as a crucial mechanism for integrating learning innovations into real-world classroom practice.

Furthermore, the integration of lesson study with experiment-based guided inquiry demonstrates the synergy between developing learning methods and improving the quality of their implementation. This approach

enables teachers not only to implement innovative learning strategies but also to collaboratively evaluate their effectiveness. In the context of chemistry education, this is crucial because learning success is determined not only by the methods used but also by how consistently and reflectively they are implemented. Therefore, combining these two approaches can be a strategic alternative for sustainably improving the quality of chemistry learning.

In addition to impacting cognitive aspects, experiment-based and inquiry-based learning also contributes to increased student engagement and motivation. Contextualized and experiential learning activities enable students to see the relevance of chemical concepts in everyday life [44], [45]. This is crucial to reduce the perception that chemistry is a difficult and abstract subject. By increasing student engagement, the learning process becomes more interactive and meaningful, which ultimately supports the development of positive attitudes toward chemistry learning.

However, implementing this approach requires careful planning and adequate support, including time, facilities, and teacher readiness. Without such support, inquiry-based and experimental learning has the potential to fail. Therefore, ongoing commitment from various parties is needed to ensure that the implemented learning innovations have the maximum impact. With this in mind, the development of a sustainable lesson study program can be a solution to maintain the consistency and quality of innovative learning implementation in the classroom [46], [47].

This research has important implications for the development of chemistry learning, particularly in improving the quality of the teaching and learning process through the integration of lesson study with experiment-based guided inquiry. This approach not only contributes to improving teachers' pedagogical skills but also encourages more student-centered learning based on scientific activities. In the context of chemistry education, the application of this method helps students construct a deeper understanding of concepts through direct involvement in the experimental process, making abstract concepts such as colloidal systems easier to grasp [48], [49]. Furthermore, collaborative activities in lesson study also play a role in fostering a culture of reflection and continuous improvement among teachers, which ultimately can systematically enhance professionalism and the quality of learning [50], [51]. Therefore, this research has the potential to serve as an alternative model for developing innovative chemistry learning at the secondary school level.

However, this study has several limitations that require attention. First, the relatively short duration of lesson study limited the optimization of the reflection and continuous improvement processes that should be the main characteristics of this approach. Second, this study did not directly measure improvements in student learning outcomes quantitatively, so the impact on students' cognitive aspects cannot be strongly generalized. Third, the limited number of subjects and research context within a single school limit the generalizability of this study to broader contexts. Furthermore, external factors such as student readiness, availability of laboratory facilities, and teacher experience in implementing inquiry-based learning may also influence the results. Therefore, further research is recommended to be conducted over a longer period of time, involving more subjects, and combining qualitative and quantitative approaches to obtain a more comprehensive picture of the effectiveness of lesson study and inquiry-based learning in chemistry education.

4. CONCLUSION

Based on the research conducted, it can be concluded that lesson study activities consist of three main stages: planning (plan), implementation (do), and reflection (see). Prior to the lesson study, initial observations were conducted to compare learning conditions before and after the lesson study. The results showed an increase in teacher skills in various aspects of learning after the implementation of lesson study. Teachers' ability to guide problem formulation increased from 41.25% in the initial condition to 53.75% in observation I, and reached 73.75% in observation II. Improvements were also seen in teachers' ability to guide the implementation of experiments, from 49.28% before the lesson study to 59.28% in observation I, and 79.28% in observation II. Furthermore, teachers' ability to guide the analysis and presentation of results increased from 41.67% in the initial condition to 65% in observation I, and 78.33% in observation II. Similarly, teachers' ability to guide student communication increased from 50% before lesson study to 58.75% in observation I, and 78.75% in observation II. Based on this overall data, it can be concluded that implementing lesson study with a guided inquiry-based experimental method can improve the quality of learning. This improvement is evident in the development of teachers' abilities to manage and guide the learning process more effectively. Thus, lesson study can be an effective alternative strategy for improving the quality of classroom learning. Further research is recommended to test the effectiveness of implementing guided inquiry-based lesson study more broadly by involving a larger and more diverse number of subjects, so that the research results can be more strongly generalized.

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AUTHOR CONTRIBUTIONS

Conceptualization, U.W. and I.N.; Methodology, U.W.; Software, U.W.; Validation, U.W., I.N., and N.S.; Formal Analysis, U.W.; Investigation, U.W.; Resources, I.N.; Data Curation, U.W.; Writing – Original Draft Preparation, U.W.; Writing – Review & Editing, N.S.; Visualization, U.W.; Supervision, I.N.; Project Administration, U.W.; Funding Acquisition, I.N.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

Not applicable.

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