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SCL LEAD to Improve quality of Student-Centered Learning Process in the Class of Discrete Mathematics

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Abstrak

Semakin banyak mahasiswa yang kurang tertarik pada beberapa mata kuliah di universitas, terutama matematika. Studi ini meneliti dampak pendekatan Student-Centered Learning (SCL) dalam pembelajaran Matematika Diskrit. Kami memperkenalkan metode SCL - Lecture's Encouragement, Assistance, and Stimulating-Deliverance (SCL LEAD) untuk meningkatkan keterampilan belajar dengan mendorong interaksi dan kerja sama mahasiswa. Penelitian ini menggunakan pendekatan kuantitatif melalui pre-test dan post-test untuk mengukur keterlibatan dan kinerja mahasiswa. Data dikumpulkan melalui observasi terstruktur, jaminan kesiapan, dan diskusi kelompok, kemudian dianalisis untuk menilai dampaknya terhadap keterampilan kognitif dan kolaboratif mahasiswa. Perbandingan antara ujian tengah dan akhir semester digunakan untuk mengukur efektivitas SCL LEAD, dengan statistik deskriptif dan inferensial untuk mengidentifikasi perubahan keterampilan dan pencapaian. Temuan menunjukkan bahwa SCL LEAD memotivasi mahasiswa untuk berpartisipasi aktif serta meningkatkan kompetensi dan kinerja dalam Matematika Diskrit, memberi wawasan berharga bagi pengembangan strategi pembelajaran berpusat pada mahasiswa di pendidikan matematika.
Kata Kunci: SCL LEAD; Matematika Diskrit; keterlibatan mahasiswa; kompetensi; pengembangan kognitif.

Abstract

The increasing disengagement of students in certain university courses, particularly in mathematics, is a growing concern. This study investigates the impact of the Student-Centered Learning (SCL) approach on the learning process for Discrete Mathematics. We introduce the Student-Centered Learning - Lecture's Encouragement, Assistance, and Stimulating-Deliverance (SCL LEAD) method to enhance learning skills by fostering increased student interaction and cooperation. The study employs a quantitative approach, using pre-tests and post-tests to measure students' engagement and performance. Data were gathered through structured observations, readiness assurance processes, and group discussions, all of which were documented and analyzed to assess their impact on students' cognitive and collaborative skills. Comparative metrics between mid-term and final exams were used to determine the effectiveness of the SCL LEAD model, with descriptive and inferential statistics applied to identify changes in students' skills and achievements following the implementation of SCL LEAD. The findings suggest that SCL LEAD motivates active participation and enhances both competence and performance in Discrete Mathematics, offering valuable insights for advancing student-centered strategies in mathematics education.
Keywords: SCL LEAD; Discrete Mathematics; student engagement; competence; cognitive development.

I. INTRODUCTION

Bloom's Taxonomy, a framework for categorizing educational goals, organizes learning objectives established by educators into a hierarchical system that reflects the level of a student's comprehension of the material (Highley, 2009; Pantaleon et al., 2024). In recent years, higher education teaching has experienced a pedagogical shift, adopting new methods to enhance student engagement and, consequently, learning outcomes (Singhal, 2017; Afifi & Ali, 2023). Student-centered learning (SCL) enhances lecture competencies through active engagement, personalized learning, collaboration and communication, motivation, and enhanced understanding. SCL transforms education into an active, engaging, and personalized experience, improving lecture competencies and preparing students for future challenges (Corkin, 2019).

Constantinou (2020) provides a reflexive GOAL framework for achieving student-centered learning in European higher education: From class learning to community engagement. Meanwhile, Apriliana, et al. (2019), describe .the effect of a problem-centered learning on student's mathematical critical thinking. The effectiveness of student-centered teaching applications used in determining motivation toward science learning. Sağlam & Mutlu (2023) use quantitative meta-analysis to examine the impact of student-centered teaching on student motivation in science, providing a synthesis of studies comparing SCL with traditional methods.

The Discrete Mathematics course is a fundamental subject in the engineering faculty (Alvarez et al., 2020), particularly in the field of informatics, as it is a prerequisite for several advanced courses. Therefore, discrete mathematics is made a compulsory course with a weight of three credits. Discrete mathematics covers important material from several fields such as set theory, relations, combinatorics, and graph theory (Silalahi, 2022). This course equips students to think logically and analytically.

According to the curriculum in several study programs, such as the Faculty of Informatics, Industrial Engineering, and Electrical Engineering, discrete mathematics is a mandatory course for second-year students. For the undergraduate program in Computational Science, Faculty of Informatics, it consists of four parallel classes for third-semester students. The number of students per parallel class is approximately 40.

The topics of discrete mathematics covered in this course include logic, set theory, relations and functions, number theory, combinatorics, graph theory and its applications, as well as graph coloring with its applications in optimization. The material is structured and delivered following the Student-Centered Learning (SCL) approach.

One of the main factors is the interaction in the learning process, namely inappropriate teaching methods or strategies, and an unsupportive learning environment (Sukmaningthias et al., 2023; Qolbi & Afriansyah, 2024). Therefore, it is important to: (1) encourage interaction between lecturer and students, (2) develop collaboration among students, (3) promote active learning, (4) provide continuous feedback, (5) emphasize assignments, (6) communicate student expectations, and (7) facilitate different learning styles. This indicates that lecturers must be able to design learning plans that meet these seven principles of effective teaching practices in higher education.

As an initial analysis, the discrete mathematics course for the bachelor's program in computer science consists of four parallel classes. Each class is taught by a lecturer and a teaching assistant. This setup is expected to facilitate the planned learning process. In this paper, we propose the Student-Centered Learning - Lecture’s Encouragement, Assistance, and Stimulating-Deliverance (SCL LEAD) method to enhance learning skills by fostering increased interaction and cooperation among students in the Discrete Mathematics classroom.

II. METHOD

In this section, we describe how the study was conducted. According to Bloom's taxonomy in the cognitive domain, thinking abilities are grouped into two levels: lower-order thinking skills and higher-order thinking skills. Lower order thinking skills include knowledge, comprehension, and application. Higher-order thinking skills include analysis, synthesis, and evaluation. Achieving higher-order thinking skills among students is not an easy task (Zain, 2012).

To address this challenge, we developed the SCL LEAD model aimed at improving the SCL process. In this model, the lecturer functions as a facilitator, actively involving students in constructing new knowledge during lectures. This approach provides students with valuable learning experiences through reciprocal interactions between lecturers and students, as well as among students themselves, facilitated by discussions and group assignments that are later reviewed together in class (Cevikbas, 2022).

There is a correlation between a positive student-centered attitude toward mathematics and improved academic achievement, (Chen & Bae, 2021) convey the importance of addressing students’ attitudes and individual needs in mathematics through SCL practices. Mahmud et al. (2022), SCL enhances student engagement, motivation, and confidence while developing critical thinking skills necessary for tackling complex mathematical problems.

Moreover, Vale and Barbosa (2023) explore active learning strategies for mathematics education within an SCL framework. They found that hands-on, problem-based learning encourages critical thinking, problem-solving, and student engagement, which are essential for success in mathematics. Meanwhile, Thanheiser and Melhuish (2023), describe specific routines in student-centered mathematics instruction, emphasizing structured student dialogue and collaborative learning strategies. This approach enhances students’ ability to critically analyze mathematical concepts, leading to improved engagement and understanding in mathematics classrooms.

In this paper, students are encouraged to actively participate during lectures, with the expectation that this active learning approach will increase their motivation, enable higher-level cognitive engagement, and improve long-term knowledge retention. Additionally, these activities foster critical thinking, preparing students as lifelong learners capable of continuous self-improvement after graduation.

Johnson and Smith (2023) explain how group-based problem-solving strategies in STEM education improve student engagement and collaborative skills, which aligns with your emphasis on structured group work and peer-led learning in Discrete Mathematics. This would support the section discussing collaborative group activities and could provide comparative insights for your structured group model. Next, Park and Cho (2023) describe an impact of the readiness assurance process (RAP) as a tool to enhance student engagement and understanding, which aligns with your study's use of RAP for Discrete Mathematics. Moreover, Kim and Lee (2021) study evaluate the effectiveness of collaborative learning in undergraduate mathematics using quantitative data, aligning with your approach in measuring increases in student engagement and cognitive outcomes after applying collaborative learning.

The stages of activities in this learning process are as follows:

1. Preparing all materials that support the learning strategy, including laptops, teaching materials and evaluations, speakers, and video materials related to the application of the material to be taught
2. Implementing all the prepared plans and documenting each learning outcome.
3. Observing the learning outcomes based on the previously established learning objectives, and
4. Reflecting based on observations for continuous improvement in future learning processes.
5. Conduct a continuous cycle that includes the processes of planning, implementation, evaluation, and follow-up (improvement of learning quality).

In the SCL LEAD model, students are divided into fixed groups for the entire semester, and the course content is divided into five chapters. Before each class, students must study the assigned material, as each session begins with a Readiness Assurance Process (RAP). The RAP includes a short individual test on the key concepts students have studied, followed by the same test taken in groups, with answers agreed upon by group members. Students receive immediate feedback on their group test and have the opportunity to appeal if they believe a marked incorrect answer is correct, provided they can present supporting evidence. The final step of the RAP is a brief lecture that addresses any misconceptions identified during the group test or appeal process.

The implementation of this learning model occur after the middle-term exam, allowing for a quantitative comparison between students' middle-term and final exam scores. This comparison assesses the effectiveness of the model in enhancing the SCL process within the classroom.

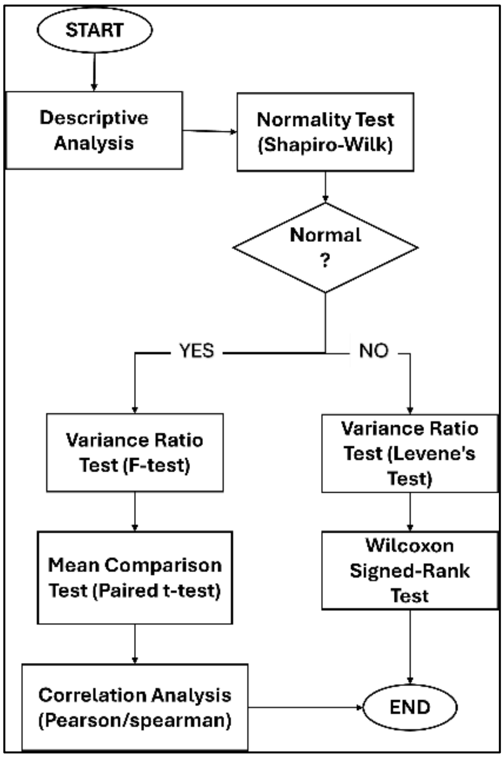


Figure 1. Flowchart of Statistical Analysis Steps

Figure 1 outlines the structured approach to analyzing the middle and final exam dataset. Starting with descriptive statistics, it guides through normality testing to determine the appropriate statistical methods. Depending on the data's normality, it progresses to variance ratio testing, mean comparison testing, and concludes with correlation analysis to assess the relationship between two exam scores. We use paired t-tests and ANOVA for analyzing pre-test and post-test data, which aligns with the statistical methods applied in your study to measure changes in student performance from midterm to final exams (Zhang & Luo, 2022).

III. RESULT AND DISCUSSION

We provide some results of data analysis and discussion by linking the research. As mention by Lee and Wang (2022), we can directly supports your findings on increased engagement and academic performance from pre- to post-SCL implementation by providing a quantitative assessment of SCL in mathematics, focusing on cognitive and collaborative skills development. Implementation of Student-Centered Learning (SCL) to enhance problem-solving skills and improve the students' analytical and collaborative skills following the application of the SCL LEAD model (Swan & Burkhardt, 2023).

At the beginning of the chapter (about sets), an illustration is provided that depicts how the application of the material in that chapter is applied in real life. Additionally, we also present several motivational videos. In Figure 2, students are watching a video about a dance performed by two disabled individuals. This has made the students more motivated to learn, ready to work in groups with anyone, and fostered a mentality of mutual trust.

Figure 2. Students Enthusiastically Pay Attention to Motivational Videos

According to the plan, after the material explanation is given (at the beginning of the chapter), a pretest is administered to measure the students' initial understanding.

The pretest also encourages students to concentrate on the explanations provided by the lecturer. The pretest questions are formatted as True-False Questions. A sample of the pretest results can be seen in Figure 3.

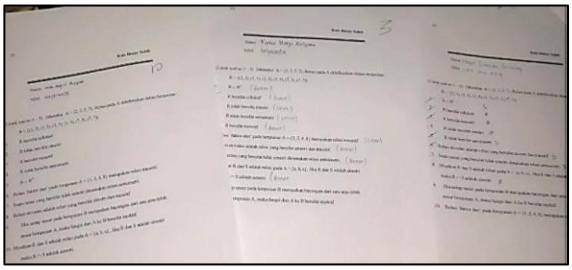


Figure 3. Some Samples of Pre-test Result

Collaborative learning is a situation where two or more people learn or attempt to learn something together. Therefore, we formed groups of five students to discuss the material and solve problems presented by the lecturer. Everyone involved in collaborative learning can utilize each other's resources and skills (asking each other for information, evaluating each other's ideas, monitoring each other's work, etc.).

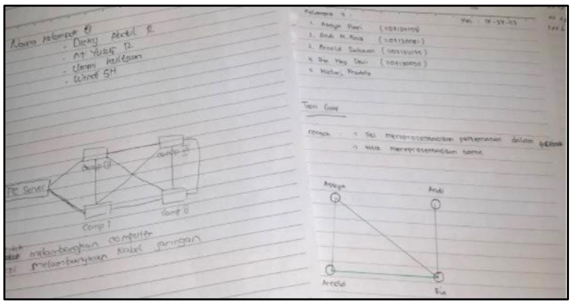


Figure 4. Samples of Group Work Results after Midterm Exam

Collaborative learning refers to a methodology where everyone is responsible to one another in their group. We monitor and correct any errors in problem analysis that occur during the collaborative learning process. One sample of the students' group work is presented in Figure 4. This group work represents the outcome of the learning (post-test).

The analysis of students' test results reveals significant improvement in their problem-solving skills following the implementation of the SCL LEAD approach. Figure 3 and Figure 4 respectively compare two sets of test results, one conducted individually before the midterm exam and another conducted in groups following the SCL LEAD treatment. Before the SCL LEAD intervention, the students completed the test individually, with limited success in both the number of correct answers and the depth of reasoning in their responses. However, after receiving SCL LEAD guidance and working collaboratively, the group test results showed significant gains. Not only did the students solve more problems correctly, but their answers also demonstrated a more thorough and elaborated reasoning process.

These findings suggest that the SCL-LEAD method positively impacts students' ability to approach problems with greater accuracy and critical thought. This improvement highlights the effectiveness of collaborative learning in enhancing students' analytical skills and depth of understanding in Discrete Mathematics.

After assessing the post-test, we grouped the students based on their individual achievement levels in the chapter into two groups: Green and Yellow. Students in the Green group are considered to have mastered the material in the chapter and are allowed to further enhance their skills with practice questions alongside the teaching assistant. Students in the Yellow group have not yet sufficiently mastered the material and thus require special treatment from the lecturer.

Figure 5 presents the results of the Midterm Exam (UTS) of students, classified according to their score ranges.

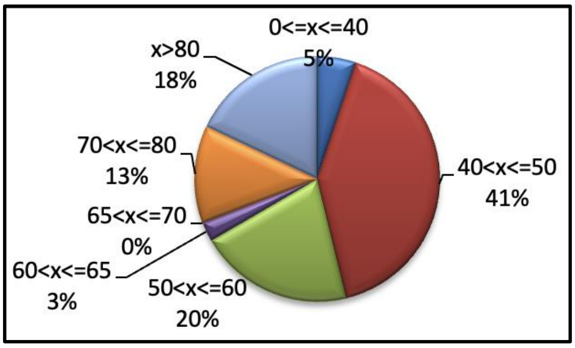
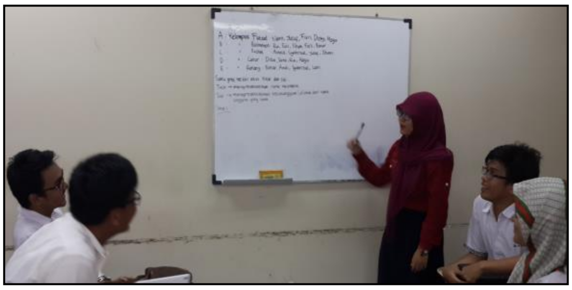


Figure 5. Distribution of Mid-Term Exam Scores

After the Mid-Semester Exam (UTS), a change in the learning approach was implemented. We recruited several students who had the best scores from the UTS and previous quizzes and appointed them as leaders in their groups. To solidify the understanding of the learning outcomes, group assignments were given to the students. In completing practice questions or assignments, each step was carried out in detail by the group leaders, with the lecturer and assistants monitoring the process.

This activity received very positive feedback from the students, as demonstrated by their enthusiasm during the group work and discussions with their peers. This activity can be seen as presented in Figure 6. In group discussions, we prioritize teamwork for case studies that refer to the course competencies. The results of the students' group work also can be seen in the Final-Semester Exam (UAS) results.



(a)

(b)

Figure 6. Group Leaders Explaining to Their Group Members

In Figure 7, we show the performance outcomes of the post-UTS learning approach. The improvement in student learning outcomes is presented in Figure 7, a comparison between the UTS and UAS scores.

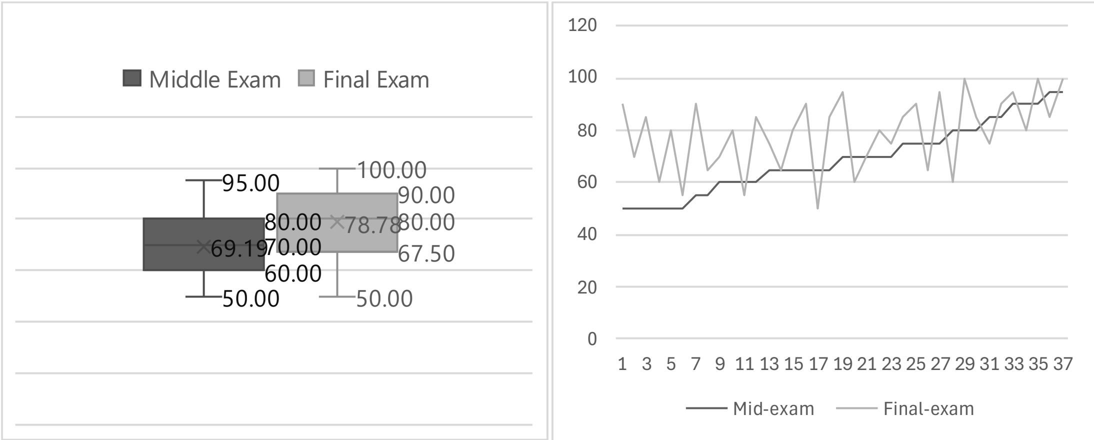


Figure 7. Comparison of Mid-Term and Final Exam Scores per Student

Normality test results

The Shapiro-Wilk test was applied to assess the normality of the middle-exam and final-exam scores. The results are as follows:

Table 1.
Normality test

H_0: The distribution of exam scores is normal		
Score	Statistic value	p-value
Middle-exam	0.943	0.061
Final-exam	0.954	0.138

As can be seen in Table 1, at the 5% significant level, the results of the Shapiro-Wilk test suggest that both the middle and final exam scores follow a normal distribution. The next step is to conduct the variance ratio test to assess the consistency of variability between the middle and final exam scores.

Table 2.
Variance ration test

H_0: The variances of the middle and final exam scores are equal			
Df mid-exam	Df final-exam	F-statistic	p-value
36	36	0.9717	0.4659

Variance ratio test helps determine whether the variances of the two groups are significantly different. In Table 2, since the p-value is greater than the 0.05 significance level, we fail to reject the null hypothesis, indicating that there is no significant difference between the variances of the two groups. Thus, next we use t-test to compare the mean scores of the middle and final exams.

Table 3.
t-test values to test the improvement in students' performance after SCL LEAD treatment

Compare	Mean		t-value	p-value	Sig. level
	mid	Final			
Midterm vs. Final	69.189	78.784	3.0086	0.0018	0.05

The t-test analysis in Table 3 shows a significant improvement in student performance from midterm to final-term scores, with a p-value of 0.0018. This value, being lower than the standard significance level of 0.05, supports the alternative hypothesis that final-term scores are significantly higher than midterm scores. This outcome suggests that the SCL LEAD approach has positively impacted students' learning and retention, enhancing their performance by the end of the term.

The method developed after the UTS has played a significant role in enhancing students' discussion skills and their overall abilities. However, it should be noted that

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some students who were appointed as group leaders experienced a decline in their UAS scores. Despite this, it did not significantly affect their final grade rubric. After evaluating the results, we will focus more on developing group work by utilizing the presence of group leaders to facilitate communication within the groups. Additionally, there will be special training for the group leaders regarding standardizing understanding and techniques or skills for conveying material to their group members. This training will be conducted outside of class hours.

In group work, the process of SCL-LEAD is more evident and can improve learning outcomes. During these discussions, students were enthusiastic about working on group assignments and were not hesitant to ask questions or discuss with their peers in their own 'student language' (Li et al., 2020). The lecturer and assistants monitored the groups (Kok et al., 2020), especially those that made analytical errors. They could immediately correct any mistakes in problem analysis during the learning process.

The lecturer’s efforts in managing the class with the SCL-LEAD approach extend beyond ordinary classroom management. Several aspects need to be considered, including the preparation of course materials (pre-test, post-test, and assignments), management of group leaders, and group discussion strategies. Clear rubrics must be given attention (Krebs et al, 2022), especially regarding how to evaluate group performance and individual grades.

IV. CONCLUSION

The Student-Centered Learning - Lecture’s Encouragement, Assistance, and Stimulating-Deliverance (SCL LEAD) method has proven effective in enhancing student engagement and performance in Discrete Mathematics. This approach not only motivates students to participate actively but also fosters collaboration and cognitive skill development through structured group work and interactive learning activities. By implementing SCL LEAD, students are encouraged to become critical thinkers and problem-solvers, which are essential skills in their academic and professional journeys.

For students, the SCL LEAD method provides a more engaging and supportive learning environment, allowing them to develop communication skills, enhance teamwork abilities, and gain a deeper understanding of mathematical concepts through peer discussions and feedback. This approach also prepares students for lifelong learning by encouraging self-motivation and the ability to tackle complex problems independently. For lecturers, this method offers a framework that makes teaching more interactive and rewarding. By facilitating discussions and observing peer-led activities, lecturers can gain insights into student progress and areas where further support is needed. Additionally, the SCL LEAD model encourages lecturers to adopt a facilitative role, enhancing their teaching skills and fostering a more student-centered classroom atmosphere that aligns with modern educational practices.

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