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Building Sustainable Education with the Literacy and Research-oriented Cooperative Problem-based Learning: A Bridge in the Activeness of Chemistry Education Students

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Abstract

This study aims to examine the effect of the LIRACLE model (Literacy and Research-Oriented Cooperative Problem-Based Learning) on student activeness in undergraduate chemistry learning. LIRACLE is an innovative instructional model that integrates literacy strategies, cooperative learning, and research-based approaches within a problem-based learning framework. The study employed a quasi-experimental design with two groups: an experimental group (38 students) that received the LIRACLE treatment and a control group (44 students) that followed conventional PBL. Student activeness data were collected through observation sheets over six class meetings and analyzed using the Mann-Whitney test due to the non-normal distribution of the data. The results showed a significant difference in student activeness between the experimental and control groups, with a significance value of 0.000 ($p < 0.05$). Students who participated in LIRACLE-based learning demonstrated higher levels of engagement, both cognitively, socially, and affectively. The implementation of LIRACLE proved effective in creating a participatory and reflective learning environment, encouraging students to take an active role in constructing their understanding. These findings support the importance of developing active learning strategies in higher education, particularly to achieve meaningful chemistry learning outcomes in alignment with Sustainable Development Goal 4.

Keywords: *Activeness, Chemistry education students, LIRACLE learning model, Sustainable education*

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INTRODUCTION

Higher education institutions (HEIs) are increasingly recognized as pivotal agents in promoting sustainable development through education, research, and community engagement. The integration of Education for Sustainable Development (ESD) into curricula fosters critical competencies such as systems thinking, ethical reasoning, and action-oriented learning, preparing students to address complex global challenges (Mondragon et al., 2023). HEIs serve not only as knowledge producers but also as "*living laboratories*" for sustainability, where institutional policies, campus operations, and student-led initiatives collectively model sustainable practices (Mokski et al., 2023; Weiss et al., 2021). Such whole-institution approaches align with UNESCO's SDG target to mainstream sustainability and global citizenship across all educational levels (UNESCO, 2015).

The sustainable education approach is closely aligned with the achievement of Sustainable Development Goal 4 (SDG 4), which emphasizes inclusive, equitable, and quality education for all (Ferguson & Roofe, 2020; Cai & Wolff, 2022). In this context, higher education institutions play a strategic role in supporting the attainment of this goal. This role is manifested through four key dimensions: teaching, research, community engagement, and sustainability-oriented institutional governance (Yong et al., 2024).

Despite these commitments, many chemistry classrooms continue to experience low levels of student activeness, with students often disengaging due to perceived irrelevance of the content, limited interaction, and motivational challenges (Järvelä & Renninger, 2014). Studies consistently show that without active learning strategies such as collaborative problem-solving, contextualized examples, and regular formative feedback, students in STEM subjects are 1.5 times more likely to fail and exhibit reduced persistence (Freeman et al., 2014; Zepke & Leach, 2010). Therefore, aligning educational practices with SDG 4 requires not only institutional commitments but also classroom-level interventions focused on boosting engagement and relevance, especially in chemistry education.

Furthermore, research conducted in undergraduate chemistry classes has revealed that non-instructional factors such as anxiety, lack of sense of belonging, and insufficient academic preparedness also significantly contribute to student disengagement (Keen & Sevian, 2022; Stang & Roll, 2013). Students who are unprepared for the conceptual or procedural demands tend to withdraw and avoid participation. Therefore, improving undergraduate chemistry education requires the design of inclusive, relevant, and supportive learning environments aligned with the principles of SDG 4 to foster interaction, discussion, and sustained student engagement.

These findings are consistent with classroom observation data. A significant proportion of students tend to occupy seats located far from the lecturer's visual range, such as the back rows or corners of the classroom, while seats in the front rows often remain unoccupied. During instructional sessions, several students are observed engaging with their personal electronic devices or exhibiting signs of disengagement, such as falling asleep. More concerning, instances were recorded in which students engaged in inappropriate behavior, including broadcasting live on social media platforms such as TikTok during class sessions.

Several interrelated factors contribute to the prevalent passivity of undergraduate chemistry students in the classroom. Students often report fear of failure, limited self-confidence, and lack of motivation, which inhibit their willingness to participate unless explicitly prompted. Second, large class sizes and insufficient wait time from instructors limit opportunities for student-centered inquiry and reflective thinking. In addition, cultural norms and peer dynamics such as reluctance to speak due to fear of embarrassment and low peer-student social support further reinforce silence and withdrawal (Mai et al., 2024; Rohi & Muslim, 2022).

Moreover, lecturer-centered instruction often exacerbates student passivity. Didactic lecturing rooted in the so-called "banking model" of education positions students as recipients rather than active co-constructors of knowledge, thereby reducing engagement and critical thinking (Freire, 1970; Dietrich & Evans, 2022) . Observational studies in STEM lectures reveal that although instructors may integrate active learning strategies, they frequently dominate classroom discourse and close question segments authoritatively, limiting meaningful student interaction (States et al., 2023; Deslauriers et al., 2019). As a result, the instructional design and facilitation patterns that favor lecture-heavy environments contribute significantly to the persistent disengagement observed in undergraduate chemistry classrooms.

Given the various challenges posed by teacher-centered approaches, there is an urgent need to shift the instructional paradigm toward student-centered learning. This approach positions students as active participants in the construction of knowledge, emphasizing engagement, collaboration, reflection, and the development of critical thinking and problem-solving skills (Prince, 2013). In the context of chemistry education, student-centered learning has been shown to enhance student engagement, promote deeper conceptual understanding, and increase intrinsic motivation to learn (Michael, 2006).

Innovation in chemistry learning must be carried out to prepare students to become professional teachers in the future (Easa & Blonder, 2024). One form of innovation is to develop a new learning model that is specifically aimed at learning in higher education. However, there have not been many developments of learning models that focus on adult learning. The LIRACLE (Literacy and Research-Oriented Cooperative Problem-Based Learning) learning model was developed to be an innovation. LIRACLE was developed specifically to develop chemical literacy skills, get used to scientific thinking, train science process skills, train cooperation, and get students used to research. Currently, LIRACLE is still in the development stage and has six syntaxes that must be run sequentially. The six syntaxes are combined with the concept of adsorption chemistry to create a learning environment that is oriented towards literacy and research to solve problems in everyday life (Pratama et al., 2024)

The advantages of the LIRACLE model are: it can be a learning model that can teach chemical literacy, teach scientific thinking, and hone students' science process skills; it can increase student activity; it can help students work together to solve a problem; it can help students develop new knowledge and be responsible for the learning they do; it can help students transfer the knowledge they have to understand problems in real life; it can introduce students to the world of literacy and the world of research; structured assignment systematics. In addition to its advantages, LIRACLE also has weaknesses: when students do not have interest or do not have confidence that the problem being studied is difficult to solve, they will be reluctant to try; If the materials used by students in making experiments are difficult to find, this will be a challenge to think of substitute materials (Pratama et al., 2025).

Therefore, this study aims to examine the effect of implementing the LIRACLE model on student activeness in chemistry learning at the undergraduate level. Problems related to student inactivity are important to be addressed immediately because they have a direct impact on conceptual understanding, academic achievement, and the achievement of inclusive and quality education goals as stated in Sustainable Development Goal 4 (SDG 4). This study offers a novel contribution through the integration of classroom observation data and direct application of the LIRACLE model in real learning situations, resulting in empirical findings on how active learning strategies can be implemented effectively to create a more participatory and responsive learning environment in higher education.

RESEARCH METHOD

This study employed a quasi-experimental design, involving two groups: an experimental group, which received instruction using the LIRACLE learning model, and a control group, which was taught using the Problem-based Learning (PBL) model. The population consisted of all third-semester students enrolled in Chemistry Education programs at universities located in the Special Region of Yogyakarta. Based on an initial survey, four universities offering Chemistry Education programs were identified.

Samples were selected using a simple random sampling technique from the target population, based on data availability and institutional access. A total of 38 students were assigned to the experimental group, while 44 students were assigned to the control group. Student activity was observed and recorded for six classroom sessions. The overall research design is outlined in Table 1.

Table 1. Research design

Group	Learning Model	Activeness Observation
Control	PBL	V
Experiment	LIRACLE	V

Data were collected using a non-test instrument in the form of a student activity observation sheet. Before its application, the instrument underwent content validation by two experts in chemistry education. The indicators used to assess student activeness are presented in Table 2.

Table 2. Student activeness assessment indicators

Indicator	Score
The students solve problems presented at the front of the class	1
The students asked a question to the lecturer	1
The student asked a question to the presenter	1
The student answer questions during scientific discussions	1

Data analysis began with testing for normality and homogeneity to determine the appropriate statistical approach. If both assumptions were met, a parametric test specifically, the independent samples t-test was employed. If one or both assumptions were violated, the non-parametric Mann Whitney U test was applied instead.

The hypotheses tested in this study were as follows:

- H_0: There is no significant difference in student activeness between the experimental and control groups after learning the topic of adsorption.
- H_1: There is a significant difference in student activeness between the experimental and control groups after learning the topic of adsorption.

Hypothesis testing was conducted using SPSS statistical software, with a significance level set at $p < 0.05$.

RESULT AND DISCUSSION

This study aims to analyze the effect of implementing the LIRACLE learning model on students' activeness in chemistry learning. Data on student activeness were collected through observations conducted over six classroom meetings and were analyzed using statistical techniques appropriate to the results of normality and homogeneity tests. The findings were then discussed by integrating the empirical results with relevant learning theories and previous research, particularly within the context of active and innovative learning in chemistry education. Table 3 presents the descriptive statistics of student activeness scores, while Table 4 provides the results of assumption testing for statistical analysis.

Table 3. Students score results

Group	N	Average	Highest Score	Lowest Score
Control	44	2.5	9	1
Experiment	38	3.079	8	1

Table 4. Assumption test result

Group	N	Normality Test (Sig)	Homogeneity Test (Sig)
Control	44	0.000	0.925
Experiment	38	0.000	

Based on the results of the assumption tests, both the control and experimental groups showed significance values below 0.05 in the normality test, indicating that the data were not normally distributed. In contrast, the homogeneity test produced a significance value above 0.05, suggesting that the variances of the two groups were homogeneous. As only the homogeneity assumption was met, the data were analyzed using the non-parametric Mann–Whitney U test.

The Mann–Whitney U test was conducted to determine whether there was a significant difference in student activeness between the experimental group and the control group. The analysis yielded an asymptotic sig value of 0.023, which is less than the significance threshold of 0.05. This result indicates a statistically significant difference in student activeness between the two groups.

Problem-based Learning (PBL) is widely recognized as an effective instructional approach to enhance student activeness in higher education, including in the context of chemistry education. In PBL, students are presented with complex, real-world problems as the starting point for learning. This method encourages students to actively identify problems, formulate hypotheses, gather information, engage in group discussions, and collaboratively develop solutions (Hmelo-Silver, 2004). The process requires not only cognitive involvement but also stimulates students' social and emotional engagement throughout the learning experience.

A meta-analysis by Dochy et al. (2003) found that PBL significantly improves student engagement, particularly through collaborative discussions and self-directed exploration, which foster a sense of ownership and responsibility over their learning. Furthermore, PBL prompts students to ask questions, express opinions, and contribute to problem-solving activities, creating a more dynamic and interactive classroom environment (Yew & Goh, 2016). In chemistry education where students often struggle with abstract concepts PBL provides opportunities to construct conceptual understanding through dialogue, inquiry, simple experimentation, and connecting theory with real-world applications (Arifani et al., 2025).

PBL shares fundamental principles with cooperative learning, particularly in promoting student engagement through collaboration, dialogue, and shared problem-solving. Both approaches shift the learning process from passive absorption of information to active participation in constructing knowledge. Cooperative learning emphasizes structured group interactions, positive interdependence, and individual accountability, all of which create a learning environment where students are encouraged to contribute, question, and reflect together (Johnson & Johnson, 2009).

When integrated into chemistry education, cooperative learning strategies such as group investigations, peer teaching, and think-pair-share activities have been shown to significantly increase student activeness, especially among those who are typically passive in traditional lecture settings (Gillies, 2016). These strategies help reduce anxiety, build communication skills, and promote deeper engagement with complex scientific concepts. In a PBL setting, cooperative learning becomes a natural mechanism through which students tackle ill-structured problems collaboratively, negotiate meaning, and develop both cognitive and interpersonal skills (Hmelo-Silver, 2004; Slavin, 2014).

Furthermore, the integration of Research-oriented (RO) adds significant value in fostering an active, reflective, and contextual learning environment. RO encourages students to design, implement, and reflect on scientific investigations, either independently or collaboratively. Through this process, students not only gain theoretical understanding but also develop scientific attitudes, inquiry skills, and a stronger sense of ownership over their learning (Healey & Jenkins, 2009). When PBL, cooperative learning, and RBL are applied in synergy, students are more engaged as novice researchers who think critically, collaborate meaningfully, and connect scientific knowledge with real-world applications. This combination has proven to be particularly effective in enhancing student activeness, especially in disciplines like chemistry, which demand both conceptual understanding and procedural competence simultaneously (Spronken-Smith et al., 2012).

In addition, integrating literacy-oriented learning into higher education classrooms has been shown to enhance student activeness significantly. This approach emphasizes students' ability to access, interpret, evaluate, and communicate scientific information through reading, writing, speaking, and visual representation (Yore, Pimm, & Tuan, 2007). In chemistry education, where abstract concepts often require multiple modes of representation, literacy-oriented strategies help students engage more deeply with content, ask questions, and construct meaning actively rather than passively consuming information (Shanahan & Shanahan, 2008).

When combined with Problem-Based Learning (PBL), cooperative learning, and Research oriented, literacy-based strategies further empower students to become active participants in the learning process. For example, engaging students in scientific reading, writing concept maps, constructing arguments, and presenting findings not only reinforces conceptual understanding but also fosters self-expression, reflection, and collaborative inquiry (Norris & Phillips, 2003). These combined approaches cultivate a classroom environment that promotes inquiry, critical literacy, and knowledge co-construction key elements in supporting Sustainable Development Goal 4 (SDG 4) on inclusive and quality education. Thus, literacy-oriented learning plays a pivotal role in activating students intellectually, socially, and emotionally in higher education.

CONCLUSION

This study concludes that the implementation of the LIRACLE model has a significant positive effect on increasing student activeness in undergraduate chemistry learning. The findings from statistical analysis, supported by classroom observations, show that students who participated in LIRACLE-based instruction demonstrated higher levels of engagement compared to those in the PBL control group. LIRACLE successfully integrates literacy-oriented strategies, cooperative interaction, and research-based inquiry, creating a participatory learning environment that supports deeper conceptual understanding and academic involvement. The model's effectiveness lies in its capacity to position students as active constructors of knowledge, while also nurturing scientific reasoning, collaboration, and reflective skills—attributes essential for future science educators. Moreover, the application of LIRACLE contributes directly to the realization of Sustainable Development Goal 4 (SDG 4), which emphasizes inclusive, equitable, and quality education for all. This study provides empirical evidence supporting the need to adopt innovative, student-centered approaches like LIRACLE in higher education, especially within the context of chemistry education.

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