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The Effect of Providing Lecture Recordings on Self-Regulated Learning in Online Learning

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Abstract: This study aimed to examine the effect of providing lecture recordings on students' self-regulated learning (SRL) in online learning contexts characterized by unstable internet connectivity and limited access to course materials. A quasi-experimental pretest–posttest design was employed involving 52 students from the Biology Education Study Program at Tadulako University, with 26 students assigned to the control group and 26 to the treatment group. SRL data were collected using a questionnaire adapted from the Motivated Strategies for Learning Questionnaire (MSLQ), comprising five subscales: metacognition, time and study environment management, effort regulation, elaboration, and help-seeking. Students in the treatment group received YouTube links to lecture recordings via WhatsApp within 24 hours after each session, whereas those in the control group attended lectures without access to the recordings. Analysis of Covariance (ANCOVA), with pretest scores as the covariate, showed a significant difference in posttest composite SRL scores between the groups ($F(1,49) = 32.806$; $p < 0.001$; $\eta^2p = 0.401$). Significant effects were also found for metacognition ($\eta^2p = 0.394$), time management ($\eta^2p = 0.173$), effort regulation ($\eta^2p = 0.153$), and elaboration ($\eta^2p = 0.100$), while help-seeking showed no significant difference. These findings suggest that providing lecture recordings through familiar and easily accessible platforms is an effective low-cost pedagogical strategy for enhancing students' SRL in online learning environments with infrastructural constraints. Therefore, lecture recordings should be considered by lecturers and study program administrators when designing online instruction that supports students' autonomous learning.
Keywords: Self-regulated learning; lecture recordings; online learning

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INTRODUCTION

Self-regulated learning (SRL) has long been recognized as a key competency for student success in higher education. SRL refers to the process through which students actively plan, monitor, control, and evaluate their own learning in relation to academic goals and contextual demands (Zimmerman, 2000; Pintrich, 2000). It involves strategies such as goal setting, time management, metacognitive monitoring, help-seeking, and self-reflection, all of which enable students to take greater control of their academic development. Previous studies have consistently shown that SRL contributes significantly to students' academic achievement in higher education (Zimmerman & Schunk, 2011; Credé & Phillips, 2011; Caixia et al., 2025). However, many students still struggle to manage independent learning effectively, resulting in suboptimal academic performance and potentially long-term consequences (OECD, 2019). In technology-enhanced learning (TEL) environments, SRL becomes even more critical because students are required to regulate their learning with less direct supervision from lecturers (Broadbent & Poon, 2015; Panadero, 2017). Online and blended learning environments place greater responsibility on students to organize time, monitor comprehension, and sustain motivation, making SRL a central determinant of learning success (Barnard et al., 2009; Wong et al., 2019). Thus, the challenge is not only whether students are motivated to learn independently, but also

whether the learning environment provides adequate support for self-regulation to occur.

SRL was selected as the primary variable in this study for three interrelated reasons. First, SRL is a process-oriented variable rather than an outcome-oriented variable. It reflects how students manage their learning experiences, rather than merely representing final academic products such as grades or examination scores. Measuring SRL therefore allows researchers to examine the learning mechanisms that underlie academic success. Second, in online learning contexts constrained by infrastructure, the ability to regulate one's own learning—including planning when and how to review missed materials—is not simply a supporting factor, but a fundamental prerequisite for learning continuity. Third, Zimmerman (2000) emphasized that SRL is a key factor distinguishing successful students from less successful students in learning environments that demand a high degree of independence. This view is also consistent with research showing that students' capacity to regulate cognition, motivation, behavior, and learning resources is crucial in less structured digital learning environments (Pintrich, 2000; Barnard et al., 2009; Jansen et al., 2020). For these reasons, SRL is a particularly relevant and sensitive variable for examining the impact of lecture recordings, as it provides deeper insight into students' learning processes than conventional outcome indicators such as examination scores or attendance rates.

The relevance of this issue becomes more pronounced when online learning is no longer implemented as a pedagogical choice, but as the only feasible instructional mode due to limited physical classroom facilities. This situation has been experienced by the Biology Education Study Program at Tadulako University, Central Sulawesi, where several courses have had to be delivered fully online. Under such conditions, the stages of SRL proposed by Zimmerman (2000)—planning, performance, and reflection—are confronted with concrete structural barriers. These stages depend on a basic prerequisite: students must be able to access lecture materials fully and continuously. When access is disrupted by unstable internet connectivity, the SRL cycle is also interrupted. Studies on online learning in Indonesia have consistently identified connectivity problems, unequal digital access, and regional disparities in infrastructure as major barriers to effective online learning (Hidayah, 2022; UNICEF Indonesia, 2021). Similar challenges have also been reported in broader international contexts. Sangster et al. (2020) highlighted connectivity-related barriers across countries during the pandemic, while Aboagye et al. (2020) identified comparable problems among students in Africa, and Diab & Elgahsh (2020) reported their impact in higher education in Egypt. These conditions make the present research context highly relevant for examining whether lecture recordings can function as a practical intervention to support students' SRL.

Connectivity disruptions can significantly affect students' learning processes. In an online lecture session lasting up to 100 minutes, students with unstable internet access may miss key explanations, conceptual transitions, or important examples, often without an immediate way to recover the lost information. This differs from face-to-face learning, where students can usually address momentary lapses in attention by asking the lecturer or classmates for clarification. In online learning, however, network disruptions may create gaps in understanding that are not immediately visible but continue to affect learning after the session ends. Students may be left with incomplete understanding and, more importantly, without access to the missing parts of the lecture. This condition poses a serious challenge to SRL because effective self-regulation requires access to learning resources that students can revisit, monitor, and evaluate independently (Zimmerman, 2000; Azevedo & Hadwin, 2005). Even highly

motivated students may find it difficult to regulate their learning when the materials they need to review are no longer accessible. Without supplementary learning resources, online learning may not only become more demanding but may also weaken the conditions necessary for meaningful self-regulated learning.

In this context, lecture recordings represent a potentially valuable pedagogical intervention. Lecture recordings can support SRL by enabling students to revisit learning materials according to their own time, needs, and pace, as well as to replay difficult segments for deeper understanding (Topale, 2016; Nordmann et al., 2022). Previous reviews have shown that recorded lectures and video-based learning resources are widely used in higher education to increase flexibility, support revision, and improve access to instructional content (Kay, 2012; O'Callaghan et al., 2017). Theoretically, this aligns with Zimmerman's (2000) cyclical model of SRL, particularly the self-reflection phase, in which students review and evaluate their understanding of learning materials. When recordings are available, students are better positioned to complete this cycle. The ability to pause, replay, and re-engage with recorded material should not be viewed merely as an additional convenience. In contexts marked by infrastructural instability, it may become an essential condition for meaningful self-regulation. Moreover, because SRL is a strong predictor of success in online and independent learning environments, examining students' self-regulatory capacity is crucial for understanding the effectiveness of online learning interventions (Nordmann et al., 2020; Nordmann et al., 2022).

Nevertheless, the assumption that lecture recordings automatically promote independent learning should be treated with caution. Mayer's (2009) Cognitive Theory of Multimedia Learning suggests that students learn more effectively when they can control the pace of information processing, a principle that supports the potential value of lecture recordings for SRL. Similarly, TEL theory emphasizes the role of technology as external scaffolding that can facilitate students' self-regulatory processes (Azevedo & Hadwin, 2005; Järvelä & Hadwin, 2013). In this sense, lecture recordings may function not only as content repositories but also as learning supports that help students plan review activities, monitor comprehension, and evaluate their understanding. However, previous research has also shown that students may use lecture recordings passively, such as by rewatching sessions while taking notes verbatim, leaving limited opportunity for deeper cognitive engagement (Voelkel et al., 2023). Other studies have similarly warned that lecture capture does not automatically improve learning unless students use recordings strategically as part of broader study practices (O'Callaghan et al., 2017; Nordmann et al., 2020). These findings indicate that the relationship between the availability of lecture recordings and SRL behavior is not automatic, but requires direct empirical examination.

Despite growing interest in lecture recordings, the empirical literature has paid limited attention to their direct relationship with SRL as a primary dependent variable. Most studies have examined the effects of lecture recordings using grades, examination scores, satisfaction, or attendance as indicators of success (Kay, 2012; O'Callaghan et al., 2017; Banerjee, 2021). Although important, these indicators represent learning outcomes or participation patterns rather than the learning processes through which such outcomes are produced. Correlational and descriptive studies still dominate this field, while causal evidence based on quasi-experimental designs remains relatively scarce (Banerjee, 2021). Moreover, studies that specifically investigate the effect of lecture recordings on SRL in online learning contexts within developing countries, particularly those affected by infrastructural constraints, remain limited. This gap is important because if SRL is one mechanism through which lecture

recordings may improve learning, then SRL must be measured directly rather than inferred from outcome variables alone.

The present study addresses this gap by examining the effect of lecture recordings on students' SRL in an online biology education course at Tadulako University. The study was conducted in a context where face-to-face instruction could not be fully implemented due to limited classroom facilities. Two intact classes were compared using different instructional conditions. One class participated in online lectures without access to post-session recordings, whereas the other class received access to lecture videos uploaded to YouTube, with the links distributed through the course WhatsApp group. Students' SRL in both classes was measured using the Motivated Strategies for Learning Questionnaire (MSLQ), an internationally recognized instrument for assessing motivational and self-regulated learning strategies.

Therefore, this study aims to determine whether access to lecture recordings has a significant effect on students' self-regulated learning in an online biology education course. More specifically, it seeks to examine whether students who are provided with lecture recordings demonstrate higher levels of SRL than students who participate in online lectures without access to recordings. Conceptually, this study contributes to the application of Zimmerman's (2000) cyclical model of SRL in online learning environments characterized by infrastructural limitations, while integrating a TEL perspective to explain the role of lecture recordings as learning support. Practically, the findings are expected to inform academic decision-makers in designing online and distance learning systems that more effectively promote students' learning autonomy.

METHOD

Study Design

This study employed a quasi-experimental design with pre-test and post-test measurements to examine whether access to lecture recordings influenced students' self-regulated learning (SRL). A quasi-experimental design was selected because participants had already been assigned to their respective classes before the study began; therefore, random assignment was not feasible for ethical and practical reasons in the field setting (Creswell, 2014; Campbell & Stanley, 1963). This design is also appropriate for educational research conducted in natural classroom contexts where existing instructional groups must be maintained (Shadish et al., 2002).

The study involved two groups. The control group attended online lectures without access to recordings after each session, whereas the intervention group attended the same lectures and received recordings of each meeting. SRL was measured in both groups at two time points: before the intervention and at the end of the eighth meeting. The same instrument was used at both measurement points. The pre-test was administered to assess baseline SRL and to verify the initial comparability of the two groups, thereby allowing post-test differences to be interpreted more cautiously in relation to the intervention (Cook & Campbell, 1979).

Participants

The participants were students enrolled in the Biology Education Study Program at Tadulako University. Two classes from the same semester and course were used as the units of analysis. Class allocation had been determined by the study program before the research was conducted; therefore, the researchers did not implement random assignment. The two classes were considered academically comparable because they belonged to the same cohort and were enrolled in the same course.

To reduce potential between-group bias, several controls were applied. First, both classes were taught by the same lecturer using identical instructional materials

and lesson plans. Second, both classes used the same online learning platform, namely Google Meet. Third, each lecture session lasted 100 minutes. Fourth, the only intentionally introduced difference between the two groups was the availability of lecture recordings. Nevertheless, prior academic ability, digital literacy, and intrinsic motivation were not explicitly measured and are therefore acknowledged as study limitations. Initial group equivalence was statistically examined using pre-test scores before the main analysis was conducted. Students who did not complete both the pre-test and post-test were excluded from the final analysis to ensure data consistency.

Procedures and Intervention

1. Study timeline

The study was conducted over eight meetings. All sessions in both groups were delivered online through Google Meet, with each session lasting approximately 100 minutes. The same lecturer taught both groups using identical learning objectives, instructional materials, and lesson plans throughout the study. This consistency was maintained to ensure that the availability of lecture recordings was the primary instructional difference between the groups.

2. Pre-test administration

Before the course material was introduced in the first meeting, students in both groups completed an SRL questionnaire adapted from the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich et al., 1991). The questionnaire was distributed digitally through Google Forms, and students were given approximately 20 minutes to complete it.

The questionnaire introduction explained that the items were intended to reflect students' learning habits and that there were no right or wrong answers. Participants were also informed that their responses would be used solely for scientific analysis and would not affect their academic grades in the course. This initial administration served as the pre-test to assess students' baseline SRL before the intervention.

3. Intervention: lecture recordings

After the pre-test, the intervention was implemented only in the intervention group. The lecturer recorded each Google Meet session in full across the eight meetings. Within 24 hours after each session, the recording was uploaded to YouTube as an unlisted video, and the link was shared with the intervention group through the course WhatsApp group. Students were allowed to access the recordings at any time and as often as needed during the study period.

During the first meeting, the lecturer explained the mechanism for accessing the recordings and demonstrated how students could open the links shared through WhatsApp. In contrast, the control group attended the same online lectures but did not receive lecture recordings or additional learning resources after the sessions ended. The control group was not informed that the intervention group received recordings in order to minimize possible social comparison effects that could influence students' motivation or learning behavior.

4. Post-test administration

At the end of the eighth meeting, after the final lecture session, both groups completed the same SRL questionnaire used in the pre-test. The post-test was distributed through Google Forms and completed individually. The post-test scores served as the primary outcome variable in the data analysis.

Instrument

SRL was measured using a questionnaire adapted from the Motivated Strategies for Learning Questionnaire (MSLQ), originally developed by Pintrich and colleagues in 1991. The MSLQ is one of the most widely used instruments for assessing SRL and has been validated in various higher education contexts (Duncan & McKeachie, 2005; Credé & Phillips, 2011). Its reliability has been reported to be generally acceptable, with Cronbach's alpha coefficients ranging from 0.52 to 0.93 across subscales (Pintrich et al., 1993). The instrument has also been used across diverse cultural and instructional contexts, including Asian higher education settings and distance-learning environments (Broadbent & Poon, 2015).

Five subscales from the Learning Strategies section of the MSLQ were selected because of their conceptual relevance to the availability of lecture recordings. The first subscale, metacognitive self-regulation, was included because recordings allow students to review course content and monitor their understanding. The second, time and study environment management, was selected because recordings provide flexibility for organizing independent study. The third, effort regulation, was included because the ability to replay explanations may support persistence when students encounter difficult material. The fourth, elaboration strategies, was selected because recordings may help students connect course information with other learning resources. The fifth, help seeking, was included to examine whether access to recordings influenced students' tendency to seek assistance from others.

Other subscales, such as self-efficacy and organization strategies, were not included because their conceptual relationship with lecture recordings was considered less direct. The final instrument consisted of 29 items. Responses were recorded on a seven-point scale, ranging from 1, indicating that the statement did not describe the respondent at all, to 7, indicating that the statement described the respondent very well. Five items were reverse-scored before analysis, namely items 10, 15, 16, 18, and 26.

Data Analysis

All data were analyzed using IBM SPSS Statistics version 26. Before the main analysis, the data were screened for missing values, outliers, and violations of statistical assumptions. Participants who did not complete both the pre-test and post-test were excluded using listwise deletion.

Analysis of covariance (ANCOVA) was used as the main analytical procedure. Pre-test scores were entered as the covariate, group membership was entered as the between-group factor, and post-test scores were entered as the dependent variable. ANCOVA was used to estimate post-test differences between groups after controlling for initial SRL levels, thereby strengthening the internal validity of the comparison in a quasi-experimental design (Field, 2018; Shadish et al., 2002). The analysis was conducted for both the composite SRL score and each SRL subscale.

Verification of Initial Group Equivalence

Initial group equivalence was examined to determine whether the control and intervention groups differed significantly in SRL before the intervention. An independent-samples t-test was conducted using the composite SRL pre-test score as the comparison variable. The Shapiro–Wilk test was used to assess normality because it is recommended for sample sizes below 50 (Field, 2018). If the normality assumption was not met, the Mann–Whitney U test was used as a non-parametric alternative.

A non-significant result at this stage, indicated by a p-value greater than 0.05, was interpreted as evidence that the two groups did not differ significantly in baseline

SRL. This verification supported a more cautious interpretation that subsequent post-test differences were less likely to be explained by pre-existing differences in SRL.

Main Analysis: Between-Group Comparison at Post-test

The main research question was addressed using ANCOVA, with pre-test scores entered as the covariate. Adjusted means were reported to show between-group differences after controlling for baseline SRL. As a supplementary analysis, independent-samples t-tests were also conducted to examine the consistency of the between-group comparison. These analyses were performed for both the composite SRL score and each subscale.

Within-Group Changes Over Time

As supporting analyses, paired-samples t-tests were conducted separately for each group to examine whether SRL scores changed significantly from pre-test to post-test. When the data did not meet the normality assumption, the Wilcoxon signed-rank test was used instead. These analyses were conducted to determine whether the intervention group showed significant improvement over time and whether a similar pattern was observed in the control group.

Effect Size

For ANCOVA, effect size was reported using partial eta squared, or η^2p. Based on Cohen's (1988) conventional guidelines, η^2p values of 0.01, 0.06, and 0.14 were interpreted as small, medium, and large effects, respectively. For t-test analyses, Cohen's d was reported, with values of 0.20, 0.50, and 0.80 interpreted as small, moderate, and large effects, respectively.

Effect sizes were reported alongside p-values to provide information about both statistical significance and the practical magnitude of the intervention effect. In educational research, practical significance is particularly important because an intervention may be statistically significant but have limited instructional relevance. Hattie's (2009) benchmark of d = 0.40 was used as an additional reference point for interpreting whether the observed effect was educationally meaningful. Reporting effect sizes together with significance values is also consistent with recommended standards for educational research publications (American Psychological Association, 2020).

Instrument Reliability

Cronbach's alpha was calculated for each of the five subscales using both pre-test and post-test data to assess the internal consistency of the adapted instrument in the present sample. An alpha coefficient of ≥ 0.70 was considered acceptable (Nunnally & Bernstein, 1994).

Ethical considerations

To protect participant confidentiality, all data were anonymized during analysis and reported only in aggregate form. No student was individually identified. Lecture recordings were shared only with students in the intervention group and were not distributed to parties outside the study.

RESULTS AND DISCUSSION

This section presents the findings of a quasi-experimental pre-test–post-test study examining the effect of providing lecture recordings on the self-regulated learning (SRL) of Biology Education students. A total of 52 students participated in the study, with 26 students assigned to the control group and 26 to the treatment group. The findings are organized around four analytical stages: instrument reliability, baseline

equivalence at the pre-test, between-group comparison at the post-test, and within-group changes across the intervention period. The statistical results are interpreted in relation to SRL theory, online learning research, and prior evidence on the pedagogical use of lecture recordings.

Before the main analysis was conducted, the internal consistency of the adapted Motivated Strategies for Learning Questionnaire (MSLQ) was examined using Cronbach's alpha for each of the five subscales, based on the pooled pre-test sample. As shown in Table 1, all subscales demonstrated excellent reliability, with α coefficients ranging from 0.934 to 0.977. These values substantially exceeded the recommended threshold of α ≥ 0.70 for educational research instruments (Nunnally & Bernstein, 1994) and are consistent with previous psychometric evidence supporting the reliability of the MSLQ in educational contexts (Pintrich et al., 1993; Credé & Phillips, 2011). The alpha values also remained high at the post-test stage, ranging from 0.889 to 0.950, indicating that the instrument functioned consistently across both measurement points. This reliability evidence strengthens confidence that subsequent differences in SRL scores reflect meaningful variation in students' learning regulation rather than measurement instability.

Table 1. Internal consistency (Cronbach's Alpha) of the adapted MSLQ subscales

Subscale	Number of Items	Pre-test α	Post-test α	Interpretation
Metacognitive Self-Regulation	10	0.977	0.950	Accepted
Time and Study Environment	6	0.945	0.891	Accepted
Effort Regulation	4	0.934	0.889	Accepted
Elaboration Strategies	5	0.953	0.895	Accepted
Help Seeking	4	0.952	0.907	Accepted
Overall SRL Composite	29	—	—	—

Note. α = Cronbach's alpha. Values of α ≥ 0.70 indicate acceptable reliability (Nunnally & Bernstein, 1994). Excellent = α > 0.90; Good = α > 0.80.

The normality of the pre-test SRL composite scores was examined using the Shapiro–Wilk test. The results showed that the assumption of normality was met for both the control group (W = 0.979, p = 0.856) and the treatment group (W = 0.971, p = 0.637). Therefore, independent-samples t-tests were used for the baseline comparisons.

Table 2 presents the pre-test descriptive statistics and group comparisons used to verify initial equivalence between the two groups. The results indicated no statistically significant differences between students in the control group and those in the treatment group across all SRL dimensions. At the composite-score level, the control group obtained a mean score of 4.01 with a standard deviation of 0.38, whereas the treatment group obtained a mean score of 3.96 with a standard deviation of 0.35. The independent-samples t-test yielded t(50) = 0.446, p = 0.658, confirming that the two groups had statistically comparable SRL levels before the intervention. This baseline equivalence is important in a quasi-experimental design because it increases confidence that subsequent post-test differences can be more plausibly attributed to the intervention rather than to pre-existing differences between groups.

Table 2. Pre-test descriptive statistics and group comparisons for SRL subscales and composite score

Subscale	Control Group M	Control Group SD	Treatment Group M	Treatment Group SD	t	p	Sig.
Metacognitive Self-Regulation	3.74	0.70	3.69	0.92	0.21	.837	ns
Time and Study Environment	4.00	0.73	4.03	0.61	-0.20	.839	ns
Effort Regulation	4.23	0.80	4.23	0.77	0.01	.993	ns
Elaboration Strategies	3.99	0.76	3.93	0.88	0.29	.775	ns
Help Seeking	4.08	0.89	3.94	0.93	0.59	.558	ns
Overall SRL Composite	4.01	0.38	3.96	0.35	0.45	.658	ns

Note. M = mean; SD = standard deviation; ns = not significant ($p > 0.05$).

The main analysis employed analysis of covariance (ANCOVA), which was selected because it enables comparison of post-test SRL scores between the control and treatment groups while statistically controlling for baseline scores. Prior to the ANCOVA, the relevant statistical assumptions were examined. The Shapiro–Wilk test confirmed that the post-test SRL composite scores were normally distributed within each group, with probability values exceeding the 0.05 threshold. In addition, the assumption of homogeneity of regression slopes, or parallel slopes between groups, was met. The ANCOVA results are therefore interpreted using adjusted means, which represent the estimated mean scores for each group after controlling for baseline differences.

After controlling for pre-test scores, the ANCOVA revealed a significant difference in students' SRL achievement between the two groups, $F(1,49) = 32.806$, $p < 0.001$, $\eta^2p = 0.401$. This result indicates that the provision of lecture recordings made a strong contribution to students' SRL composite scores. The effect size was large and exceeded the threshold commonly interpreted as educationally meaningful in pedagogical intervention research (Hattie, 2009). The adjusted means showed that the treatment group ($M = 4.249$) outperformed the control group ($M = 3.953$) after baseline differences were controlled, with a mean difference of 0.296 points on a seven-point scale.

At the subscale level, the ANCOVA showed that the treatment group performed significantly better on four SRL dimensions, while one dimension did not show a significant between-group difference. The largest effect was found for metacognitive self-regulation, $F(1,49) = 31.896$, $p < 0.001$, $\eta^2p = 0.394$. This was followed by time and study environment management, $F(1,49) = 10.250$, $p = 0.002$, $\eta^2p = 0.173$, and effort regulation, $F(1,49) = 8.861$, $p = 0.005$, $\eta^2p = 0.153$. After controlling for pre-test variance, elaboration strategies also showed a significant difference, $F(1,49) = 5.474$, $p = 0.023$, $\eta^2p = 0.100$. In contrast, help seeking was the only dimension that did not differ significantly between groups, $F(1,49) = 0.062$, $p = 0.804$, $\eta^2p = 0.001$. These results suggest that lecture recordings primarily strengthened individual regulatory processes, particularly planning, monitoring, persistence, and cognitive processing, rather than socially mediated forms of regulation such as seeking help from others.

Table 3. Post-test descriptive statistics and between-group comparisons

Subscale	Control Group M	Control Group SD	Treatment Group M	Treatment Group SD	t	p	d
Metacognitive Self-Regulation	3.74	0.51	4.27	0.53	3.68	.001	1.02 **

Subscale	Control Group M	Control Group SD	Treatment Group M	Treatment Group SD	t	p	d
Time and Study Environment	3.93	0.54	4.26	0.42	2.44	.018	0.68 *
Effort Regulation	4.15	0.57	4.50	0.59	2.21	.032	0.61 *
Elaboration Strategies	3.88	0.48	4.10	0.61	1.40	.168	0.39 (ns)
Help Seeking	4.11	0.69	4.06	0.56	-0.25	.806	0.07 (ns)
Overall SRL Composite	3.96	0.26	4.24	0.21	4.21	< .001	1.17 **

Note. M = mean; SD = standard deviation; d = Cohen's d. Effect-size classifications follow Cohen's (1988) guidelines. *p < 0.05; **p < 0.01; ns = not significant, p > 0.05.

The significant difference in the post-test SRL composite score provides strong support for the hypothesis that access to lecture recordings promotes students' self-regulated learning in online learning contexts. This finding is consistent with studies showing that recorded lectures provide students with greater flexibility to revisit instructional materials, pause and replay difficult explanations, and learn at a pace that is better aligned with their individual needs (Topale, 2016; Nordmann et al., 2022). More broadly, the result aligns with research on technology-supported SRL, which emphasizes that digital learning resources can support planning, monitoring, reflection, and strategic control when students are given opportunities to regulate their own engagement with learning materials (Broadbent & Poon, 2015; Wong et al., 2019; Faza & Lestari, 2025). The present study extends this literature by positioning SRL not merely as a predictor of online achievement, but as the primary outcome of an instructional intervention.

The strongest effect was observed in metacognitive self-regulation, suggesting that lecture recordings were particularly beneficial for processes such as monitoring comprehension, evaluating understanding, and adjusting learning strategies. This finding is theoretically coherent with Zimmerman's (2000) cyclical model of SRL, in which learners move through forethought, performance, and self-reflection phases. In the present context, recordings enabled students to return to difficult parts of a lecture, compare their understanding with the original explanation, and modify their learning approach for subsequent sessions. This reflection–action cycle is central to metacognitive regulation and may explain why this dimension showed the largest between-group difference. Similar arguments have been made in online learning research, which suggests that students' ability to monitor and regulate their understanding becomes especially important when direct instructor supervision is reduced (Barnard-Brak et al., 2010; Broadbent & Poon, 2015).

The significant improvement in time and study environment management can be understood in relation to the temporal flexibility provided by lecture recordings. Unlike synchronous sessions, recordings allow students to decide when, where, and how long they engage with specific content. This flexibility may support more deliberate study planning, particularly for students who face unstable internet access, competing responsibilities, or limited opportunities to attend live sessions consistently. Prior studies have similarly shown that asynchronous learning resources can help students distribute their study time more flexibly and revisit materials when they are cognitively prepared to learn (O'Callaghan et al., 2017; Nordmann et al., 2022). However, flexibility alone does not automatically produce effective learning; it becomes beneficial when students use it strategically. Therefore, the observed improvement in time

management suggests that the treatment group did not merely access recordings passively, but used them as a resource for organizing their learning activities.

The improvement in effort regulation indicates that lecture recordings may also help students persist when facing difficult material. In online learning, students may disengage when they fail to understand content during a live session, especially when opportunities for immediate clarification are limited. The availability of recordings reduces this risk by allowing students to replay confusing explanations, slow down their engagement with complex material, and continue learning despite initial difficulty. This interpretation is consistent with research showing that effort regulation is a key component of successful online learning because it enables students to sustain engagement in environments that require greater autonomy (Broadbent & Poon, 2015; Li et al., 2022). In this study, the recordings appeared to function as a form of learning support that helped students maintain persistence rather than abandon difficult content.

The significant ANCOVA result for elaboration strategies further suggests that lecture recordings supported students' ability to connect new information with prior knowledge, course materials, and other learning resources. Although the simple post-test comparison did not show a significant difference for this subscale, the ANCOVA result became significant after pre-test variance was controlled. This pattern indicates that the effect of lecture recordings on elaboration may be more subtle than their effect on metacognitive regulation or effort regulation. Students may need repeated exposure to recorded explanations before they can use them to build conceptual connections, compare ideas across sources, and integrate information into a more coherent understanding. This interpretation is consistent with cognitive theories of learning that emphasize elaboration as a deeper processing strategy requiring time, repeated engagement, and active meaning-making (Pintrich et al., 1993; Mayer, 2009).

In contrast, help seeking did not differ significantly between the control and treatment groups. This finding suggests that the availability of lecture recordings alone may not be sufficient to increase socially oriented regulatory behaviors. Help seeking is often shaped by interpersonal, motivational, and contextual factors, including students' confidence, perceived instructor availability, peer norms, and willingness to disclose difficulties (Newman, 2002; Karabenick & Gonida, 2018). Therefore, although recordings may support independent review and individual regulation, they do not necessarily encourage students to seek assistance from lecturers or peers. This result highlights an important limitation of recording-based interventions: they may strengthen individual learning regulation but need to be complemented by structured interaction, peer discussion, or instructor prompts to promote help-seeking behavior.

As an additional analysis, paired-samples t-tests were conducted within each group to examine changes before and after the intervention across eight class meetings. In the treatment group, the SRL composite score increased significantly from $M = 3.96$ to $M = 4.24$, $t(25) = 5.11$, $p < 0.001$, $d = 1.002$, indicating a large effect. By contrast, the control group did not show a significant improvement during the study period, $p = 0.442$, $d = 0.16$. This contrasting pattern provides additional evidence that the observed improvement was not simply a result of time passing or students becoming more familiar with online lectures. Rather, it suggests that the availability of lecture recordings served as a concrete self-regulatory resource that supported students' development over the course of the intervention.

These findings have important implications for online learning design, especially in higher education contexts where infrastructure and access remain uneven. Although some studies have cautioned that lecture recordings may encourage passive learning

or reduce live attendance when not accompanied by appropriate guidance (Voelkel et al., 2023), the present findings indicate that recordings can have substantial benefits when they are used to support students' regulatory processes. The key issue, therefore, is not merely whether recordings are provided, but how students are encouraged to use them. Lecture recordings should be positioned not as substitutes for active learning, but as flexible resources that support review, reflection, planning, and persistence.

From a policy perspective, the results provide an empirical basis for incorporating lecture recordings as a standard component of online course design. The intervention is relatively low cost and technically feasible, requiring only basic recording tools, internet access, and a free video-sharing platform such as YouTube. Several practical measures can be considered: encouraging lecturers to record online sessions consistently, developing student guidelines on how to use recordings strategically for SRL, and providing lecturer training on how to integrate recordings into broader learning activities. These steps are particularly relevant in resource-constrained educational environments, where sophisticated learning management systems may not be consistently available.

From a practical teaching perspective, the findings are directly relevant for Biology Education lecturers who teach online under limited-resource conditions. Uploading lecture recordings to YouTube and sharing the links through WhatsApp is a simple and immediately applicable strategy that does not require specialized infrastructure. Lecturers can strengthen the pedagogical value of this practice by sharing recordings within 24 hours after each session, demonstrating how to access and use them during the first meeting, and encouraging students to engage with recordings strategically. For example, students can be guided to rewatch difficult segments, use recordings as references when completing assignments, write short reflection notes after reviewing key explanations, or mark specific timestamps for examination preparation. These practices may help transform lecture recordings from passive archives into active tools for self-regulated learning.

Overall, this study demonstrates that lecture recordings significantly improve students' SRL in online learning, particularly in metacognitive self-regulation, time and study environment management, effort regulation, and elaboration strategies. The large effect size for the SRL composite score, $\eta^2p = 0.401$, confirms both the statistical and practical significance of the intervention. While the findings are based on one academic program and should therefore be generalized with caution, they suggest that lecture recordings represent a feasible, low-cost, and pedagogically meaningful strategy for supporting learner autonomy in online higher education. Further studies involving larger samples, different disciplines, and longer intervention periods are needed to examine whether these effects remain stable across broader educational contexts.

CONCLUSION

This study provides empirical evidence that the provision of recorded lectures in online learning significantly enhances students' self-regulated learning (SRL). Three key findings can be drawn from the analysis. First, the ANCOVA results revealed a significant difference in post-test SRL composite scores between the treatment and control groups after controlling for pre-test scores, indicating that access to recorded lectures contributed meaningfully to students' SRL development. Second, four of the five SRL subscales showed significant differences, namely metacognitive self-regulation, time and study environment management, effort regulation, and elaboration

strategies. However, no significant difference was found in the help-seeking subscale. Third, students in the treatment group demonstrated significant improvement in SRL over the course of the study, whereas those in the control group showed no substantial change. These findings suggest that recorded lectures can serve not only as supplementary learning materials but also as a practical mechanism for promoting students' autonomy, persistence, and strategic engagement in online learning. In particular, the use of accessible platforms such as YouTube and WhatsApp offers a low-cost and feasible intervention for supporting independent learning, especially in educational contexts where digital infrastructure remains limited.

RECOMMENDATION

Based on the findings of this study, future research should involve larger and more representative samples, longer intervention periods, and additional behavioral data, such as video access logs and replay frequency, to strengthen the validity and generalizability of the results. Further studies across different disciplines are also recommended to examine whether the effect of recorded lectures on SRL extends beyond Biology Education. For lecturers, recorded lectures should be provided consistently, shared promptly, and integrated into learning activities rather than used merely as passive archives. Students should also be guided on how to use recordings effectively to review concepts, manage study time, and support independent learning. For institutions and policymakers, the provision of recorded lectures should be considered part of online learning quality standards. In addition, technology-supported SRL training should be included in lecturer professional development programs to promote more effective and student-centered online learning.

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