Linking Prior Knowledge and Lecture Content through Preparatory Posting Boards: The Role of Peer Engagement

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Abstract

This study examined the educational effects of introducing a preparatory posting board (PPB) within a university learning management system. The research focused on post-lecture reflection quality through one-minute paper analyses, specifically examining how activating and externalizing prior knowledge through pre-lecture postings influences students' understanding of lecture content. Study 1 assigned 286 university students enrolled in on-demand lectures to either a full condition, where the PPB was available from the beginning, or a delayed condition, where it was introduced later. Results showed that students in the full condition engaged in high-quality reflection from the outset, integrating prior knowledge with newly acquired lecture content. In the delayed condition, a level of integrative reflection comparable to that of the full condition was attained following the introduction of the PPB. Study 2 replicated this pattern, but with 141 students attending face-to-face lectures. Both studies found little spontaneous inference or elaboration beyond lecture content. Building upon Study 2, Study 3 explored whether providing opportunities for students to share opinions during face-to-face lecture preparation (beyond the PPB) was associated with enhanced reflection and spontaneous reasoning. Specifically, 234 students were assigned to preparation-only (no peer discussion) or preparation–discussion (five-minute peer discussion) conditions while attending face-to-face lectures. Results found that higher-order reflection improved significantly in the preparation–discussion condition. Collectively, these findings suggest that while externalizing prior knowledge during preparation facilitates integrative understanding, learning environments that encourage comparative thinking and actively engaging with peers' perspectives are essential for fostering spontaneous reasoning in post-lecture reflections.

Keywords: higher education, preparatory activities, reflection, preparatory posting board, peer engagement, learning management system

1. Introduction

1.1 Integrated Understanding of Prior Knowledge and Lesson Content

To enhance learning in academic lectures, newly acquired information should be integrated into a framework of prior knowledge (Mayer, 1996). The quality of learning is intricately linked to the degree to which learners associate new information with pre-existing knowledge, with those possessing extensive prior knowledge employing more sophisticated learning strategies (Alexander, Murphy, Woods, Duhon, & Parker, 1997; Last, O'Donnell, & Kelly, 2001; Moos & Azevedo, 2008). Accordingly, the activation of prior knowledge has been regarded as a crucial process in lecture-based learning (Titsworth & Kiewra, 2004). Previous studies indicate that activating prior knowledge by generating responses to questions before learning facilitates comprehension of subsequent content (Pressley, Tanenbaum, McDaniel, & Wood, 1990), and that students who read texts in relation to their prior knowledge demonstrate superior understanding (Samuelstuen & Bråten, 2005). Activating prior knowledge is also linked to question generation (King, 1992; Van der Meij, 1990), which has been shown to enhance learning quality (Hamilton, 1985), and is believed to influence students' engagement during lectures.

In higher education, preparatory activities, including preparatory study tasks and flipped learning, have been extensively implemented to activate prior knowledge before lectures (Abeysekera & Dawson, 2015; O'Flaherty & Phillips, 2015). However, allocating substantial time to preparatory activities for every lecture and monitoring the preparation of a large number of students remains challenging for instructors. More fundamentally, although prior

knowledge activation has been demonstrated to facilitate comprehension, it remains uncertain whether such activation alone is adequate to foster spontaneous inference and elaboration that enrich or extend understanding during and after lectures.

1.2 Out-of-class Learning in Higher Education

Maximizing effective higher education requires a process that incorporates out-of-class activities (Shinogaya, 2021) to activate prior knowledge before lectures, develop this knowledge during lectures, and engage in reflective practice after lectures. Fostering self-regulated learners is necessary at all educational levels (Zimmerman, 1989; Zimmerman & Schunk, 2001); however, most higher education curricula do not incorporate out-of-class learning opportunities that promote autonomous learning (Alleman et al., 2010). A large-scale survey in Japan reported that approximately 40% of students engage in preparatory activities (Benesse Educational Research and Development Institute, 2021). To address this issue, Shinogaya and Onoda (2021) introduced a preparatory activity in which students record their opinions regarding the theme to be covered in the next lecture; however, it has been reported that this does not sufficiently promote preparation.

Preparation is the first step in the learning process. Activating knowledge related to lecture content encourages students to connect different elements of knowledge and identify points of confusion during the lessons (Shinogaya, 2018). Recent empirical research confirmed that patterns of preparatory activity are linked to self-regulated learning abilities and in-class performance (Omarchevska, van Leeuwen, & Mainhard, 2025) and enhance understanding of lecture content. This study examines the effects of using a preparatory posting board on a learning management system to activate prior knowledge before a lecture, and whether these effects extend to understanding during and reflection after the lecture.

1.3 Preparatory Tasks and Preparatory Posting Board

In this study, a preparatory posting board (PPB) is defined as a learning management system (LMS)-based instructional tool that requires students to submit short written responses to instructor-provided prompts prior to a lecture. The primary purpose of a PPB is to activate students' prior knowledge related to the upcoming lecture topic and prepare them cognitively for subsequent in-class learning. Posting boards can be implemented in various ways depending on instructional design choices and technological affordances. In the present study, the PPB was designed as a simple and low-cost preparatory task integrated into regular university lectures. Students individually posted their opinions regarding an upcoming lecture topic on the LMS before attending the lecture and their postings were shared with classmates prior to the lecture.

Importantly, this design choice reflects a practical constraint in higher education: preparatory activities must be feasible for instructors and sustainable within existing curricula. Considering that preparation is not sufficiently integrated into university curricula (Alleman et al., 2010) and that student engagement in preparatory activities is low (Benesse Educational Research and Development Institute, 2021) and challenging to promote (Shinogaya, 2021), costly preparation activities are unlikely to achieve sufficient results. From the instructor's perspective, implementing a complex task that requires detailed feedback from many students is challenging, making ease of implementation important. Recent advances in educational technology reduce the burden on instructors while maintaining student engagement (Bellhäuser, Dignath, & Theobald, 2023; Cavalcanti et al., 2021). Even without these technologies, using an LMS to extract and share student opinions and encourage them to activate their prior knowledge before attending lectures has the potential to enhance the feasibility and effectiveness of preparation. Similar to Shinogaya and Onoda (2021), the preparation task in this study involved students writing their opinions about an upcoming lecture. For example, on the theme of collaborative learning, the question was: "When evaluating potential solutions to a problem, is it more advantageous to work in a group or individually? Please select your stance (agree/disagree) and articulate your perspective." The rationale for this method was to facilitate conflict and questions during opinion sharing. The opinions presented in the preparation tasks had to meet three criteria: (a) they were related to the topic of the next lecture; (b) each position was supported by findings, with no absolute correct answer; and (c) students could easily imagine the advantages and disadvantages of each position. This task can be completed quickly and at low cost as there is no need to prepare special materials. Consequently, instructors can implement it easily.

From a learning-process perspective, the PPB was intended to serve as a repository of preparatory responses as well as a mechanism for activating prior knowledge through social comparison and question generation. Generating questions before learning and comparing them with prior knowledge promotes learning (King, 1992). Therefore, sharing others' opinions may be an effective learning support strategy. Including classmates as audience members is expected to stimulate students' audience awareness and promote their preparatory efforts; the writing differs

depending on the audience (Midgette, Haria, & MacArthur, 2008). The aim was also to activate students' prior knowledge related to lecture content by encouraging them to express opinions to persuade students with different viewpoints or to refute others' opinions.

1.4 Monitoring Engagement in Lectures with One-minute Papers

Students were asked to reflect on the one-minute paper (OMP) after lectures, and the content of their reflections was used to measure their engagement with the lectures. The OMP is a tool for students to reflect on their learning after class and is widely used in higher education (Holtzman, 2007; Stead, 2005). In Japan, OMPs help bridge the gap in teacher–student dialogue through various statements such as impressions and questions (Onoda & Shinogaya, 2014). Reflecting on learning after class facilitates the integration of knowledge and the development of higher-order thinking skills (Onodipe, Romanow, & Robbins, 2025; Roscoe & Chi, 2007). OMPs are also useful for instructors, as they allow for monitoring students' understanding and engagement (Onoda & Shinogaya, 2014). The content of an OMP can be determined according to its purpose. To measure the degree of integrated understanding between prior knowledge and lesson content—the aim of this study—students were asked to describe changes in their thinking before and after the lecture. If PPBs promote integrated understanding of prior knowledge and lecture content, this should be evident in the descriptions provided in the OMPs.

To create a meaningful link between prior knowledge and lecture content, students must reason about the lecture content based on their prior knowledge or reason about their prior knowledge based on the lecture content. However, it is often challenging for students to be aware of these associations and to engage in spontaneous reasoning (Agavekar, Bhore, Kadam, & Moharir, 2023; Onoda & Shinogaya, 2014). Accordingly, the following questions were posed to students: "Did your thoughts on the topic of preparation change before and after the lecture? Please clarify whether your thoughts have changed and write the reasons for this in relation to the lecture content." These prompts were intended not only to capture whether students integrated prior knowledge with lecture content, but also to examine the extent to which post-lecture reflections revealed different levels of learning processes, ranging from integrative understanding to higher-order inference.

1.5 Purpose of this Study

This study aimed to examine whether PPBs in university lectures promote an integrated understanding of prior knowledge and lecture content. In addition, it sought to clarify the extent to which such preparation facilitates varying levels of post-lecture reflection and to identify the conditions under which reflective engagement can be enhanced. In this study, learning was operationalized in terms of the quality of students' reflection, focusing on how they articulated and integrated their understanding of prior knowledge and lecture content, rather than relying on objective achievement outcomes such as test scores or grades. This study specifically examined the distinction between integrative understanding, where students connect prior knowledge with newly acquired lecture content, and higher-order reflection, which entails inference and elaboration beyond the lecture material. To address these objectives, this paper presents three studies. Study 1 examined the effects of PPBs on on-demand video lectures. Study 2 investigated their effectiveness in face-to-face lectures and explored the characteristics of students who derived the greatest benefit from PPB-based preparation. Expanding upon the results of Studies 1 and 2, Study 3 examined whether incorporating peer discussion activities enhanced forms of reflection that were less consistently supported by preparation alone.

Empirical evidence regarding the effectiveness of preparatory learning and posting boards in higher education is scarce, particularly concerning their differential impact on learning processes. Moreover, methods demonstrating significant practical feasibility and scalability have yet to be adequately proposed. This study examines both the potential and the limitations of PPBs, thereby contributing to the development of widely implementable approaches for enhancing out-of-class learning in lecture-based courses. Students frequently encounter difficulties in integrating prior knowledge with lecture content in their reasoning and in performing spontaneous inference during post-lecture reflection (Onoda & Shinogaya, 2014). By integrating preparatory activities, lectures, and structured reflection via OMPs, this study offers empirical evidence on the timing and mechanisms by which PPBs facilitate deeper learning. These findings enhance the theoretical understanding of preparatory learning in higher education and offer practical implications for the design of effective preparatory and reflective activities in university lectures.

2. Study 1

2.1 Purpose

Study 1 aimed to introduce a PPB for on-demand university lectures and verify whether it promoted integrated understanding of prior and new knowledge gained during the lecture. This was assessed by analyzing the OMP descriptions.

2.2 Method

2.2.1 Participants and Analysis Targets

To control for instructor-related variability, all lectures were delivered by the same instructor (the author) across four Japanese universities. Of the 300 students (aged 18–22) enrolled in these lectures, those who agreed to participate in the research and had attended all seven sequential lectures were selected for the analysis. A total of 286 students were analyzed. These students included 73 from University A (48 women, 25 men), 51 from University B (24 women, 27 men), 62 from University C (29 women, 33 men), and 100 from University D (42 women, 58 men).

2.2.2 Conditions

Intervention effects are typically examined by comparing a control group (without intervention) with an experimental group. However, not engaging in preparation can be viewed as an unequal educational opportunity. Therefore, Study 1 used a design with two conditions: "full condition," in which the PPB was introduced from the beginning, and "delayed condition," in which it was introduced partway through the course. Universities A and B were assigned the full condition using the PPB from the first session. Universities C and D were assigned the delayed condition, introducing the board from the fourth session onward.

2.2.3 Lectures to be Analyzed

The lectures comprised 15 sessions of 90 minutes each, delivered on demand via the LMS, using the author's voice in PowerPoint slides and videos. Each lecture video was divided into three or four sections to facilitate student engagement. The same videos and materials were used across all universities; however, the content of the review of preparation tasks at the beginning of the lectures differed. The lectures were based on educational psychology theory and empirical findings, incorporating insights from developmental psychology and teaching methods. These sessions focused on the application of teaching and learning theories to educational practices. Table 1 lists the lectures and preparatory topics used for each analysis. In the full condition, starting from the second session, and in the delayed condition, starting from the fifth session, the first 10 minutes of each session introduced the PPB content, including opinions related to the lecture content. Before starting the lecture, the instructor explained how the preparation content was connected to the lecture content. Beginning with the eighth session, the absenteeism among students attributed to teaching practices escalated, prompting the introduction of lecture formats distinct from those in the initial half, including psychological methodology and survey experience. Therefore, these sessions were excluded from analysis.

Table 1. Design of lectures and preparatory topics

		Lecture themes	Preparatory topics*
Pre-phase	Week 1	Guidance	Children can be cruel.
	Week 2	Cognitive development	Love can be measured.
	Week 3	Attachment and parenting	A smart person is someone with a good memory.
	Week 4	Memory	In the modern era, where information can be quickly accessed on the web, people do not need to have a lot of knowledge.
Post-phase	Week 5	Knowledge and understanding	In education, punishment is more effective than rewards.
	Week 6	Learning theories	For children who are not motivated to study, offering rewards (e.g., giving 1000 yen for getting a perfect score) can be effective in increasing their motivation.
	Week 7	Motivation	People cannot change the talents with which they are born.

* The preparatory topics were designed for the upcoming lecture, and students were required to select "for" or "against" each topic, providing reasons for their stance on the PPB.

2.2.4 Design of the PPB in the LMS

PPBs were established using the bulletin board function of each university's LMS. After setting the publicly displayed names, the instructor presented a theme related to the upcoming lecture (Table 1) and asked students to articulate their positions and provide reasons. Students recorded their opinions in response to the instructor's posts. While students were able to reference other students' opinions, the activity was designed for sharing rather than direct discussion among them; therefore, they were instructed to submit their posts to the instructor. Preparatory tasks had to be completed within three days of the lecture video having been uploaded, after which further postings were not allowed. The posted opinions remained accessible for viewing. Under the full condition, engagement with the PPB began from the first session. Under the delayed condition, it was announced that the PPB would be implemented after the instructor confirmed students' course registration. Until the third session, students were instructed to contemplate the preparatory topics presented on the slides at the end of each lecture and to formulate their own perspectives prior to the subsequent lecture.

2.2.5 Design of the OMP in the LMS

Following the lecture, students were instructed to submit an OMP with the following guidelines: "Did your thoughts change before and after the lecture? Please indicate whether your opinion has changed and provide a rationale in relation to the lecture content. Your evaluations will not be affected by whether your opinion has changed. Please document your thoughts as they are." The OMP had to be submitted via the LMS within three days of the video upload. The OMP was not accessible to students and was reviewed solely by the instructor.

Using Onoda and Shinogaya's (2014) analytical framework, an analysis was conducted to explore how integrated understanding developed through the connection between prior knowledge and lecture content. Two aspects of students' post-class written reflections were assessed using distinct 4-point rating scales. The "knowledge change reflection score" measured how clearly students reflected on changes in their own understanding before and after the lecture. This score specifically captured the articulation of conceptual shifts and the reasoning behind these changes. The scoring criteria were as follows: 1) The student mentioned a change in knowledge, but the nature of the change was unclear or ambiguous. 2) The student clearly described what had changed in their knowledge, but the reason for the change was not sufficiently explained. 3) The student described what had changed and provided an explanation or reasoning for the change. 4) The student articulated a clear change in understanding and offered a personal interpretation or insight into why that change occurred, demonstrating a metacognitive awareness of how their knowledge evolved through the learning process. The lecture-based thinking score evaluated the extent to which students' reflections demonstrated cognitive engagement with the content presented in the lecture. This score reflected the depth of reasoning and generation of novel ideas or critical insights. The scoring criteria were as follows: 1) The response contained no or minimal reference to the lecture content. 2) The student referred to lecture content but merely reproduced terminology or concepts without interpretation. 3) The student examined lecture content with some degree of analytical thinking. 4) The student engaged with the lecture content and presented original insights, extended reasoning, or creative perspectives beyond what was explicitly covered in class. Examples of the scoring for each level are presented in Table 2. The highest level of the lecture-based thinking score corresponds to the "extended description" that Onoda and Shinogaya (2014) identified as particularly difficult to elicit from students.

As a scoring trial, 300 descriptions were randomly selected from the OMPs from the eighth session onward that were excluded from the analysis. They were then scored by the author and a university instructor specializing in educational psychology using the said criteria. As no significant discrepancies were evident in the evaluations between the raters, the OMPs were independently evaluated by each rater. The intraclass correlation coefficient between raters was .84 (95% CI [.82, .85]) for the knowledge change reflection score and .78 (95% CI [.76, .80]) for the lecture-based thinking score, indicating sufficient inter-rater reliability. Therefore, the average of the evaluators' scores was used for the analysis.

Table 2. Examples of scoring for one-minute papers (OMPs) in the motivation class (Week 7)

Examples of descriptions in OMPs	Scoring	
	Knowledge change reflection	Lecture-based thinking
・My perspective changed after doing the pre-class preparation.	1	1
・Before the lecture, I supported giving money as an incentive, but after learning, I began to have second thoughts.	2	1
・During the preparatory writing, I had a negative impression of using money to encourage learning and chose to oppose it, so I understood and agreed with the theory of extrinsic motivation. In that sense, my stance has not changed. However, I have come to believe that using money to motivate people who lack motivation is not necessarily a bad idea.	3	2
・I chose to oppose using money to motivate learning during the preparatory task because I believed it would cause students to lose sight of the true value of learning. My opinion did not change after the lecture, but I realized that I had assumed that learners motivated by extrinsic rewards would always remain extrinsically motivated and never understand the intrinsic value of learning. If there are gradients in extrinsic motivation, I now believe it might be a good approach to initially use money to motivate and then gradually encourage learners to identify intrinsic value in their studies.	4	3
・When I was preparing, I thought that motivating people with money was a good idea, and I still believe this currently. In motivation theory, I understand that extrinsic motivation is realistic and in line with the real-world salary system, and that its value gradually becomes internalized, but I believe intrinsic motivation is unrealistic. This may be because I do not remember ever feeling intrinsically motivated.	2	3
・My opinion changed after the class. A theory that includes a gradation solely for extrinsic motivation but only a single state for intrinsic motivation is unbalanced and feels strange. There are experiences that make you forget about time, experiences that are highly valuable and make you really feel because of the immersion, and experiences that are fun but meaningless. If we assume a difference between these types of experiences, would the theory of intrinsic motivation not become easier to understand?	1	4

2.2.6 Ethical Approval and Informed Consent

All practices and surveys in this study were conducted in compliance with local legislation and research institution requirements and approved by the ethics review committee of the author's institution. Students were informed during the first session of both conditions that participation in the PPB and submission of the OMP would be part of the evaluation. They were advised that their preparatory postings, OMP descriptions, and questionnaire responses might be published in academic conferences and papers in a form that concealed their personal information. They were assured that they could refuse this at their discretion, and that this decision would not affect their evaluation. It was decided that the data used in this study would exclude formative assessment tests or end-of-term examinations. After these explanations were presented orally and on the LMS, the students were asked to provide their consent, and only the data of those who consented were included in the analysis.

2.3 Results

Table 3 presents the descriptive statistics for the OMP scores in the pre-phase (second to fourth sessions) and post-phase (fifth to seventh sessions), and Figure 1 illustrates these trends. In addition, to clarify the relationship between the two OMP scores, supplementary analyses examined their associations at both the between-student and within-student levels. First, a naïve correlation computed across all observations indicated a modest positive association between the knowledge change reflection score and the lecture-based thinking score ($r = .32$). When the analysis focused on between-student differences by correlating participants' mean scores across sessions, a stronger association was observed ($r = .64$), suggesting that students who tended to score higher on one dimension also tended

to score higher on the other overall. In contrast, analyses targeting within-student associations revealed much weaker relationships. The average within-student correlation, calculated by estimating correlations separately for each participant and then averaging them, was small (mean r = .13, median r = .14). A similar result was obtained using person-mean-centered scores, which isolated within-student covariation by removing between-student differences (r = .15). Taken together, these results indicate that although the two OMP scores are moderately related at the level of individual differences, their moment-to-moment fluctuations within students across sessions are only weakly coupled, suggesting that they capture partially distinct aspects of students' reflective processes.

Table 3. Descriptive statistics for the OMP scores (Study 1)

	Full condition (n = 124)		Delayed condition (n = 162)	
	Mean	SD	Mean	SD
Knowledge change reflection score				
Pre-phase	3.01	0.70	2.40	0.72
Post-phase	2.94	0.76	2.89	0.73
Lecture-based thinking score				
Pre-phase	2.43	0.69	2.37	0.71
Post-phase	2.44	0.71	2.41	0.69

Note. SD = Standard Deviation.

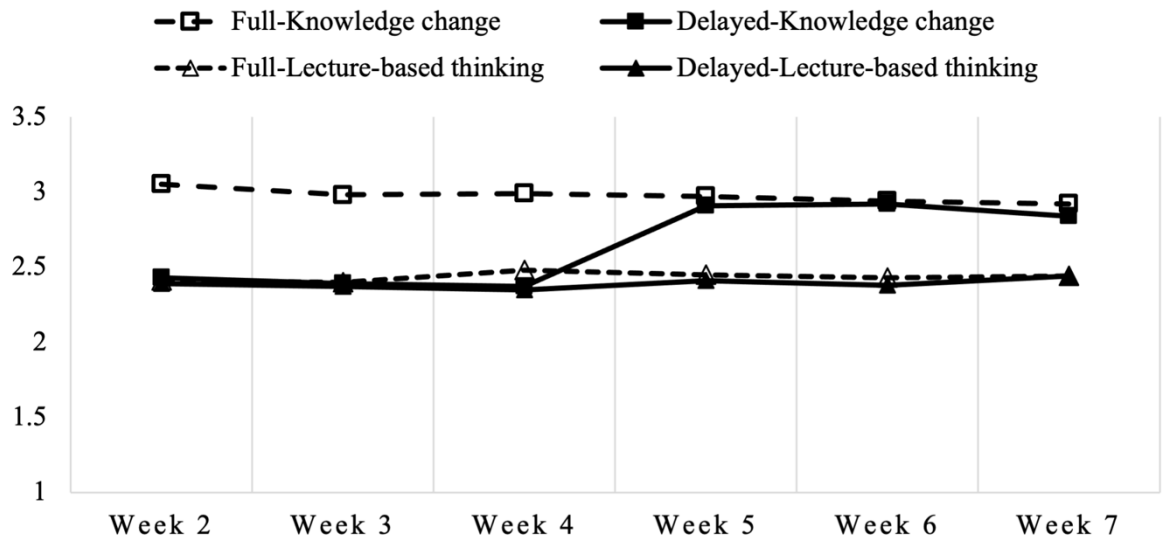

Figure 1. Trends of OMP scores (Study 1)

Note. "Full" and "Delayed" indicate experimental conditions. "Knowledge change" represents the knowledge change reflection score, and "Lecture-based thinking" represents the lecture-based thinking score.

To examine the differences in OMP scores between the pre- and post-phases, a mixed-effects model was employed, with the OMP scores as the dependent variable and participant-level random effects included. The conditions (0: full condition, 1: delayed condition), phase (0: pre, 1: post), and interaction term between the conditions and phases were included as independent variables. Gender (0: women, 1: men), grade, and dummy variables for each week's lectures were included as control variables. Dummy variables for lectures were included in the model except for the second week, which served as the reference category, and the seventh week, which was excluded because of redundancy. The analysis, with the knowledge change reflection score as the dependent variable, revealed a significant interaction (Table 4). Consequently, a post-hoc test with Sidak correction was conducted using the emmeans package. The results indicated that in the pre-phase, the scores for the delayed condition were significantly lower than those for the full condition ($t = 5.44$, $p < .001$). However, in the post-phase, no significant difference was observed between the two conditions ($t = -0.08$, $p = 1.00$). The scores for the full condition did not change from pre-phase to post-phase ($t = 1.49$, $p = .589$), whereas the scores for the delayed condition increased significantly from pre-phase to post-phase (t

= -3.43, p = .004). The analysis results, with the lecture-based thinking score as the dependent variable, showed no significant estimates for the condition, phases, or interaction terms.

Table 4. Summary of the linear mixed-effects model predicting OMP scores (Study 1)

	Knowledge change reflection score			Lecture-based thinking score		
Fixed effects	Est.	SE	p	Est.	SE	p
Intercept	3.14	0.10	< .001	2.49	0.09	< .001
Condition	-0.55	0.10	< .001	-0.04	0.10	.716
Phase	-0.14	0.09	.138	0.03	0.09	.766
Gender	-0.11	0.07	.128	-0.15	0.07	.038
Grade	-0.04	0.05	.376	-0.00	0.05	.991
Condition: Phase	0.56	0.09	< .001	0.03	0.08	.755
Week 3	-0.06	0.08	.476	-0.02	0.07	.807
Week 4	-0.06	0.08	.435	0.01	0.07	.922
Week 5	0.06	0.08	.435	-0.01	0.07	.845
Week 6	0.05	0.08	.518	-0.04	0.07	.607
Random effects	Var.	SD		Var.	SD	
Participant	0.23	0.48		0.24	0.49	
Residual	0.88	0.94		0.73	0.85	

Note. Est. = Estimate; SE = Standard Error; Var. = Variance; SD = Standard Deviation; Week = lecture dummy.

2.4 Discussion

The knowledge change reflection score for the delayed condition increased from the pre- to post-phase, reaching the full condition level in the post-phase. Introducing a PPB for on-demand lectures is expected to encourage high-quality reflection by connecting prior knowledge with new knowledge acquired during lectures. It is assumed that prior knowledge is activated by writing one's own opinions on the PPB with an awareness of other students as the audience. Reading others' opinions and attending lectures while being aware of the differences between one's prior knowledge and that of others likely promotes reflection, thereby deepening understanding by linking prior knowledge with the lecture content. These results suggest that the PPB effectively facilitates the link between prior knowledge and lecture content. However, no significant differences were observed between conditions in lecture-based thinking scores. Engaging in spontaneous reasoning about lecture content is likely more challenging than reasoning about prior knowledge, as occurs in preparatory tasks. This finding aligns with Onoda and Shinogaya (2014), who highlighted the difficulty students face in reasoning independently and expanding their interpretation of lecture content.

To address this limitation, Study 2 aimed to elucidate the characteristics of students who engaged in spontaneous reasoning about lecture content. Whereas Study 1 focused on on-demand lectures, Study 2 targeted face-to-face lectures and used the same design to confirm the effects of introducing PPBs, considering the generalizability of the findings.

3. Study 2

3.1 Purpose

Study 2 examined whether the effects of the PPBs observed in Study 1 could be replicated in face-to-face lectures. It also explored learner characteristics associated with enhanced benefits, particularly focusing on students' engagement with the PPBs, as reflected in their lecture-based thinking on the OMP.

3.2 Method

3.2.1 Participants and Analysis Targets

Of the 143 students (aged 18–22) who attended lectures on educational psychology taught by the same instructor as in Study 1 at two Japanese universities, only those who agreed to participate in the research and attended all seven sequential lectures were selected for analysis. A total of 141 students were analyzed: 37 from University E (12

women, 24 men, 1 unspecified) and 104 from University F (56 women, 48 men).

3.2.2 Conditions

The same design as in Study 1 was employed, with University E assigned to the full condition, using PPBs in all lectures from the first session, and University F assigned to the delayed condition, introducing PPBs from the fourth session onward.

3.2.3 Lectures to be Analyzed

The content and structure of all lectures analyzed were identical to those in Study 1 (Table 1). All lectures were conducted face-to-face, utilizing PowerPoint slides. As in Study 1, the opinions posted on the PPB were introduced during the first 10 minutes of the lectures.

3.2.4 Design of the PPB in the LMS

A PPB was established under the same conditions as in Study 1 (Table 1), with postings to be completed within three days of the lecture. Under both conditions, the teaching content remained identical to that in Study 1.

3.2.5 Design of the OMP in the LMS

The OMP task was set under the same conditions as in Study 1, with a submission deadline of three days after the lecture. The author and the same specialist used in Study 1 independently evaluated the OMP texts. The intraclass correlation coefficients between raters were .81 for the knowledge change reflection score (95% CI [.78, .83]) and .86 for the lecture-based thinking score (95% CI [.84, .86]). Given sufficient inter-rater reliability, the mean of the inter-rater scores was used in the analysis.

3.2.6 Questionnaire About Engagement in PPBs

To examine the relationship between the approach to the PPB and reflection by OMP, the following items were surveyed using Google Forms. The survey was conducted from the end of the seventh lecture until immediately before the eighth lecture.

(1) Time Spent on Preparation

The question was, “How much time do you spend on preparation? Please indicate the average time you spent on preparation for the last three lectures rather than for a specific lecture.” Responses were recorded on a 5-point scale (1: 1–5 minutes, 2: 5–10 minutes, 3: 10–15 minutes, 4: 15–20 minutes, 5: 20 minutes or more).

(2) Information Referenced During Preparation

The question was, “When writing on the PPB, do you reference the following information sources? Please indicate the extent to which you referenced these sources, on average, over the last three lectures, not for a specific lecture.” The items included “Academic books/papers,” “Internet,” and “Social media.” Responses were recorded on a 4-point scale (1: never, 2: rarely, 3: occasionally, and 4: frequently).

(3) Tendency to Read Other Students’ Posts

The question was, “How many other students’ opinions on the PPB do you read? Please indicate the extent to which you read these posts, on average, over the last three lectures, not for a specific lecture.” Responses were recorded on a 4-point scale (1: not at all, 2: some [less than half], 3: a considerable amount [more than half], 4: almost all).

3.2.7 Ethical Approval and Informed Consent

The same as in Study 1.

3.3 Results

3.3.1 Changes in OMP Scores

Table 5 presents the descriptive statistics for the OMP scores in the pre-phase (second to fourth sessions) and post-phase (fifth to seventh sessions), and Figure 2 illustrates these trends. As in Study 1, supplementary analyses were conducted to examine the association between the OMP scores at the between-student and within-student levels. A naïve correlation across all observations indicated a moderate positive association ($r = .43$). When focusing on between-student differences by correlating participants’ mean scores, a strong association was observed ($r = .81$). In contrast, within-student associations were weak: the average within-student correlation was small (mean $r = .07$, median $r = .10$), and a similarly modest association was obtained using person-mean-centered scores ($r = .11$). These results replicate the pattern observed in Study 1, indicating that while the two scores are strongly related at the level of individual differences, their within-student covariation across sessions remains limited.

Table 5. Descriptive statistics for the OMP scores (Study 2)

	Full condition (n = 37)		Delayed condition (n = 104)	
	Mean	SD	Mean	SD
Knowledge change reflection score				
Pre-phase	2.91	0.71	2.29	0.79
Post-phase	2.72	0.61	2.82	0.82
Lecture-based thinking score				
Pre-phase	2.59	0.90	2.27	0.69
Post-phase	2.65	0.86	2.54	1.04

Note. SD = Standard Deviation.

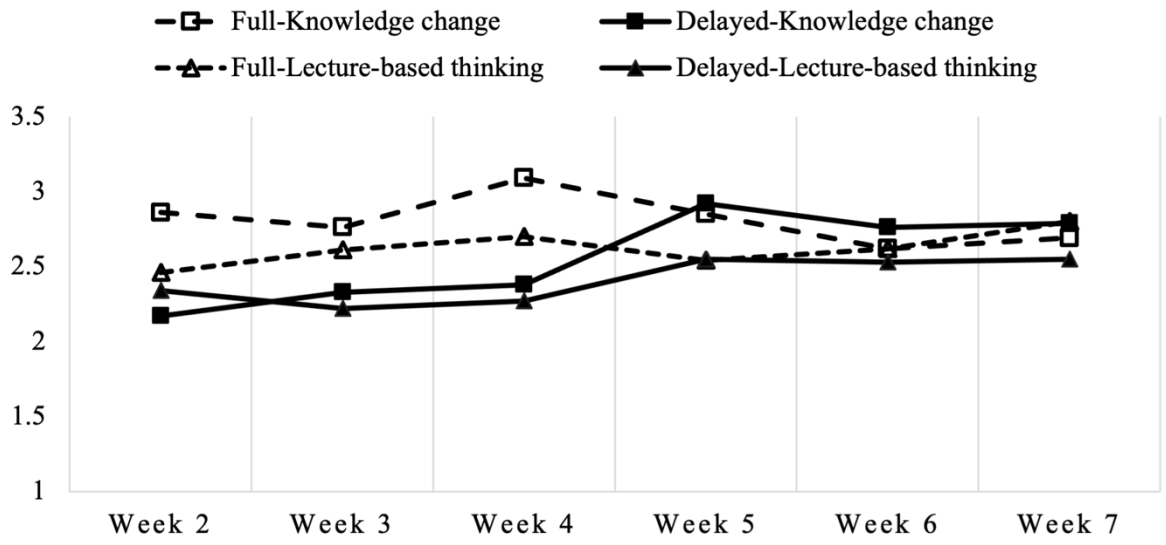

Figure 2. Trends of OMP scores (Study 2)

Note. "Full" and "Delayed" indicate experimental conditions. "Knowledge change" represents the knowledge change reflection score, and "Lecture-based thinking" represents the lecture-based thinking score.

To examine the differences in OMP scores between the pre- and post-phases, a mixed-effects model was employed, with the OMP scores as the dependent variable and participant-level random effects included. The conditions (0: full condition, 1: delayed condition), phase (0: pre, 1: post), and the interaction term between the conditions and phases were included as independent variables. Gender (0: women, 1: men), grade, and dummy variables for each week's lectures were included as control variables. Dummy variables for lectures were included in the model except for the second week, which served as the reference category, and the seventh week, which was excluded because of redundancy. The analysis, with the knowledge change reflection score as the dependent variable, showed a significant interaction (Table 6). Consequently, a post-hoc test with Sidak correction was conducted using the emmeans package. The results indicated that in the pre-phase, the scores for the delayed condition were significantly lower than those for the full condition ($t = 4.23$, $p < .001$). In the post-phase, no significant difference was observed between the two conditions ($t = 0.01$, $p = 1.00$). The scores for the full condition did not change from pre- to post-phase ($t = 0.84$, $p = .953$), whereas the scores for the delayed condition increased significantly from pre- to post-phase ($t = -5.51$, $p < .001$). However, the analysis results, with the lecture-based thinking score as the dependent variable, showed a significant estimate in this condition, and there was no interaction with the phase. Although the full condition had a higher lecture-based thinking score, there was no tendency for the lecture-based thinking score to increase after introducing the PPBs in the delayed condition. These findings indicate that the results of Study 1 were replicated in the delayed condition of Study 2 and no improvement in lecture-based thinking scores was observed.

Table 6. Summary of the linear mixed-effects model predicting OMP scores (Study 2)

	Knowledge change reflection score			Lecture-based thinking score		
Fixed effects	Est.	SE	p	Est.	SE	p
Intercept	2.54	0.20	< .001	2.39	0.23	< .001
Condition	-0.72	0.17	< .001	-0.45	0.20	.024
Phase	-0.12	0.14	.400	0.09	0.14	.518
Gender	0.08	0.11	.449	-0.01	0.13	.953
Grade	0.13	0.08	.108	0.13	0.09	.153
Condition: Phase	0.72	0.13	< .001	0.21	0.14	.127
Week 3	0.09	0.10	.405	-0.05	0.10	.630
Week 4	0.21	0.10	.038	0.01	0.10	.890
Week 5	0.14	0.10	.165	-0.07	0.10	.513
Week 6	-0.04	0.10	.703	-0.06	0.10	.582
Random effects	Var.	SD		Var.	SD	
Participant	0.33	0.58		0.53	0.73	
Residual	0.74	0.86		0.75	0.86	

Note. Est. = Estimate; SE = Standard Error; Var. = Variance; SD = Standard Deviation; Week = lecture dummy.

3.3.2 Engagement in PPBs and OMP Scores

To examine the relationship between the questionnaire survey results on the engagement in the PPB and OMP, the correlation coefficients between each variable and the OMP scores were calculated. The correlation matrix, calculated by pooling the conditions, is presented in Table 7. The only variable positively correlated with both knowledge change reflection and lecture-based thinking scores was the extent to which students read other students' posts. This suggests that students who read more of their peers' opinions tend to engage in higher-quality learning, including reasoning about lecture content.

Table 7. Correlation matrix of variables related to PPB engagement and OMP Scores

	1	2	3	4	5	6	7
1. Post-knowledge change reflection score							
2. Post-lecture-based thinking score	.72***						
3. Time spent on preparation	-.13	-.16					
4. Information reference – Books/papers	-.05	-.09	.18**				
5. Information reference – Internet	-.08	-.09	.01	.57***			
6. Information reference – Social media	-.09	-.13	.07	.56***	.30***		
7. Read other students' posts	.29***	.38***	-.21**	.22**	.16	.16	

Note. Values are Pearson correlations. *p < .05, **p < .01, ***p < .001.

3.4 Discussion

Introducing a PPB for face-to-face lectures encouraged high-quality reflection by connecting prior knowledge with new knowledge acquired during the lecture. This result is consistent with that of Study 1, suggesting that PPBs may facilitate high-quality reflection, whether the setting is online or face-to-face. In face-to-face lectures, the PPB, as a tool for learning outside the classroom, may have played a significant role in bridging prior knowledge with lecture content. However, as in Study 1, there was no increase in lecture-based thinking scores in the delayed condition. Although the results indicate that lecture-based thinking scores were higher in the full condition than in the delayed condition, the lack of an increase in the delayed condition suggests that this effect cannot be attributed to the introduction of the PPB after the first lecture. The absence of similar results in the full condition of Study 1 suggests that the positive effect of introducing a PPB from the beginning of the lecture cannot be conclusively determined.

In face-to-face lectures, more direct interaction is possible than in on-demand lectures. They allow students to share opinions posted on the PPB and their connection to the lecture to be discussed interactively while obtaining students' reactions. Nonetheless, it was difficult for students to add reasoning to the lecture content. In the OMP, students were required to write their thoughts both before and after the lecture, which likely enhanced their knowledge change reflection scores. They were also asked to refer to the lecture content, which encouraged their reasoning and interpretation of lecture content in relation to their prior knowledge. Nevertheless, the absence of an increase in lecture-based thinking scores in both Studies 1 and 2 suggests the need for new interventions to promote reasoning regarding lecture content.

The positive associations between the two OMP scores and students' tendency to read others' posts provide important implications for intervention design. On the PPB, diverse opinions were presented from both sides of the argument. The more opinions students refer to, the more likely they are to recognize the validity of perspectives other than their own. Naturally, they will also encounter opinions they find questionable or difficult to accept. Therefore, it is assumed that students participated in the lectures to understand the validity of their own and others' opinions as well as the academic basis for these opinions. This engagement probably encouraged them to think deeply about the lecture content and to develop their own reasoning. It would be beneficial to support students who do not refer to the PPB by providing them with opportunities to learn about their peers' opinions during lectures. Because the PPB is designed for out-of-class learning and is not monitored by the instructor, ensuring full participation of all students is challenging. For students who are unable to share their opinions in out-of-class settings, offering them the opportunity to do so during lectures would be effective. Providing students who do refer to the PPB with opportunities to reiterate their opinions and listen to others' perspectives during the lecture could stimulate their engagement. In Study 3, the integration of opinion-sharing discussions during preparation was introduced in face-to-face lectures that utilized PPBs, and the impact on the quality of post-lecture reviews was examined.

4. Study 3

4.1 Purpose

Given the limited support for higher-order reflection identified in Studies 1 and 2, Study 3 examined whether the incorporation of peer discussion could enhance this aspect of learning. This study utilized a PPB as an out-of-class learning tool for face-to-face lectures, and in-class discussions were conducted to enable students to share opinions formed during preparation. Expanding upon the findings of Study 2, which indicated that students who considered others' opinions generally attained higher scores on lecture-based thinking, Study 3 explored whether providing opportunities to share opinions during lecture preparation was associated with enhanced reflection and spontaneous reasoning regarding lecture content.

4.2 Method

4.2.1 Participants and Analysis Targets

Of the 234 students (aged 18–22) who attended lectures on educational psychology taught by the same instructor as in Studies 1 and 2 at four Japanese universities, those who agreed to participate in the research and had attended all seven sequential lectures were selected for analysis. A total of 211 students were analyzed: 50 from University G (38 women, 12 men), 45 from University H (20 women, 24 men, 1 unspecified), 57 from University I (29 women, 26 men, 2 unspecified), and 56 from University J (35 women, 21 men).

4.2.2 Conditions

In Study 3, two conditions were established; in both, the PPB was used from the first session, comparable to the full conditions in Studies 1 and 2. J University was assigned to the preparation-only condition, with no discussion held. In contrast, G, H, and I Universities were assigned to the "preparation–discussion" condition, according to which discussions were conducted during the lecture to share opinions formed during the first minutes of each class, starting from the fourth session onwards.

4.2.3 Lectures to be Analyzed

The structure of the lectures analyzed was consistent with that of Studies 1 and 2 (Table 1). However, in the preparation–discussion condition, a discussion was introduced at the onset of the lecture and opinions expressed during preparation were shared in groups. These groups consisted of approximately 3–5 students in close proximity, who gathered freely and discussed their opinions for approximately five minutes. Because the students were free to choose their seats, some formed groups with the same members each time, whereas others formed groups with different members, resulting in varying group sizes. Following the discussion, similar to the preparation-only

condition, the instructor provided a five-minute introduction to the overall content of the preparation before proceeding to the lecture content.

4.2.4 Design of the PPB in the LMS

A PPB was established under the same conditions as in Studies 1 and 2 (Table 1).

4.2.5 Design of the OMP in the LMS

The OMP task was set under the same conditions as those in Studies 1 and 2. The author and the same specialist used in Studies 1 and 2 independently evaluated the OMP texts. The intraclass correlation coefficients between raters were .85 for the knowledge change reflection score (95% CI [.83, .86]) and .78 for the lecture-based thinking score (95% CI [.75, .85]). Given the satisfactory inter-rater reliability, the mean of the inter-rater scores was used in the analysis.

4.2.6 Questionnaire About PPBs

To examine whether the introduction of the discussion affected students' engagement with the PPB, the survey was conducted twice using the same Google Forms procedure as in Study 2, once prior to the introduction of the discussion and once after its implementation. The pre-intervention survey was completed between the end of the fourth class and the beginning of the fifth class, and the post-intervention survey was completed between the end of the seventh class and the beginning of the eighth class. The questions were identical to those used in Study 2.

4.2.7 Ethical Approval and Informed Consent

The same as in Studies 1 and 2.

4.3 Results

4.3.1 Changes in OMP Scores

Table 8 presents the descriptive statistics for the OMP scores from the second to seventh sessions, and Figure 3 illustrates the trends. As in Studies 1 and 2, supplementary analyses examined the association between the OMP scores at the between-student and within-student levels. A naïve correlation across all observations indicated a small-to-moderate positive association (r = .25). When focusing on between-student differences by correlating participants' mean scores, the association was stronger (r = .63). In contrast, within-student associations were minimal: the average within-student correlation was small (mean r = .06, median r = .09), and a comparable result was obtained using person-mean-centered scores (r = .06). Overall, Study 3 revealed the same general pattern as Studies 1 and 2, suggesting that the two scoring dimensions are more strongly aligned as stable individual differences than as coupled within-student fluctuations over time.

Table 8. Descriptive statistics for the OMP scores (Study 3)

	Preparation-only condition (n = 56)		Preparation–discussion condition (n = 155)	
	Mean	SD	Mean	SD
Knowledge change reflection score				
Pre-phase	2.96	0.85	2.81	0.68
Post-phase	2.94	0.86	3.20	0.75
Lecture-based thinking score				
Pre-phase	2.37	0.72	2.26	0.65
Post-phase	2.50	0.73	2.77	0.65

Note. SD = Standard Deviation.

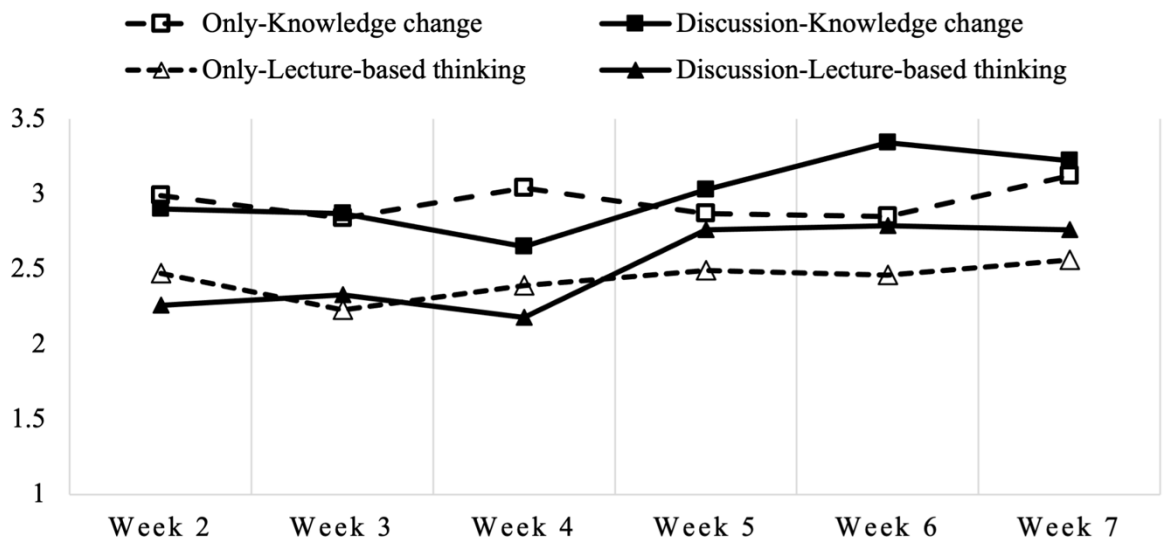

Figure 3. Trends of OMP scores (Study 3)

Note. "Only" and "Discussion" indicate experimental conditions. "Knowledge change" represents the knowledge change reflection score, and "Lecture-based thinking" represents the lecture-based thinking score.

To examine the differences in OMP scores between the pre- and post-phases, a mixed-effects model was used, with the OMP scores as the dependent variable and participant-level random effects included. The conditions (0: preparation-only condition, 1: preparation–discussion condition), phase (0: pre, 1: post), and interaction term between conditions and phases were included as independent variables. Gender (0: women, 1: men), grade, and dummy variables for each week's lectures were included as control variables. Dummy variables for lectures were included in the model except for the second week, which served as the reference category, and the seventh week, which was excluded because of redundancy. The analysis, using the knowledge change reflection score as the dependent variable, revealed a significant interaction (Table 9). Consequently, a post-hoc test with Sidak correction was conducted using the emmeans package. The results indicated that in both phases, no significant difference was observed between the two conditions (pre: $t = 0.68$, $p = .984$, post: $t = -2.56$, $p = .063$). The scores for the preparation-only condition did not change from pre- to post-phase ($t = 0.11$, $p = 1.00$), whereas the scores for the preparation–discussion condition increased significantly from pre- to post-phase ($t = -3.73$, $p = .001$). The results of the analysis using the lecture-based thinking score as the dependent variable showed a significant interaction. A post-hoc test with Sidak correction indicated that in the pre-phase, no significant difference was observed between the two conditions ($t = 0.68$, $p = .983$). However, in the post-phase, the scores for the preparation–discussion condition were significantly higher than those for the preparation-only condition ($t = -3.17$, $p = .010$). The scores for the preparation-only condition did not change from pre- to post-phase ($t = -1.31$, $p = .719$), while the scores for the preparation–discussion condition increased significantly from pre- to post-phase ($t = -6.60$, $p < .001$).

Table 9. Summary of the linear mixed-effects model predicting OMP scores (Study 3)

	Knowledge change reflection score			Lecture-based thinking score		
Fixed effects	Est.	SE	p	Est.	SE	p
Intercept	2.81	0.16	< .001	2.37	0.14	< .001
Condition	-0.08	0.12	.498	-0.07	0.10	.495
Phase	-0.01	0.13	.912	0.14	0.11	.191
Gender	-0.04	0.08	.624	-0.15	0.07	.036
Grade	0.12	0.06	.050	0.03	0.05	.550
Condition: Phase	0.39	0.12	.002	0.40	0.10	< .001
Week 3	-0.06	0.09	.536	-0.00	0.08	.992
Week 4	-0.17	0.09	.073	-0.06	0.08	.408
Week 5	-0.20	0.09	.034	-0.03	0.08	.662
Week 6	0.02	0.09	.838	-0.01	0.08	.875
Random effects	Var.	SD		Var.	SD	
Participant	0.26	0.51		0.22	0.47	
Residual	0.95	0.98		0.64	0.80	

Note. Est. = Estimate; SE = Standard Error; Var. = Variance; SD = Standard Deviation; Week = lecture dummy.

4.3.2 Changes in Engagement in PPBs

To examine the differences in engagement with PPBs between the pre- and post-phases, a mixed-effects model was used, with the engagement score as the dependent variable, incorporating participant-level random effects. The conditions (0: preparation-only condition, 1: preparation–discussion condition), phase (0: pre, 1: post), and interaction term between conditions and phases were included as independent variables. Gender (0: women, 1: men) and grade were included as control variables. The analysis with the time spent score as the dependent variable showed a significant interaction (Table 10). Consequently, a post-hoc test with Sidak correction was conducted using the emmeans package. The results indicated that no significant difference was observed in time spent on preparation, in both phases, between the two conditions (pre: $t = 0.25$, $p = 1.00$, post: $t = -2.64$, $p = .052$). The scores for the preparation-only condition did not change from pre- to post-phase ($t = 0.21$, $p = 1.00$), whereas the scores for the preparation–discussion condition increased significantly from pre- to post-phase ($t = -7.58$, $p < .001$). When the tendency to refer to other students' opinions was used as the dependent variable, a significant interaction effect was observed. A post-hoc test with Sidak correction indicated that, in the pre-phase, no significant difference was observed between the two conditions ($t = -0.62$, $p = .990$). In the post-phase, the scores for the preparation–discussion condition were significantly higher than those for the preparation-only condition ($t = -4.24$, $p < .001$). The scores for the preparation-only condition did not change from pre- to post-phase ($t = 1.60$, $p = .507$), whereas the scores for the preparation–discussion condition increased significantly from pre- to post-phase ($t = -7.33$, $p < .001$).

Table 10. Summary of the linear mixed-effects model predicting engagement scores (Study 3)

	Time spent			Reference – Books/papers			Reference – Internet		
Fixed effects	Est.	SE	p	Est.	SE	p	Est.	SE	p
Intercept	2.15	0.24	< .001	1.22	0.15	< .001	2.05	0.37	< .001
Condition	-0.42	0.21	.048	0.27	0.13	.133	0.28	0.23	.217
Phase	-0.02	0.09	.838	0.04	0.05	.473	0.05	0.08	.511
Gender	0.01	0.12	.909	0.09	0.07	.210	0.06	0.14	.666
Grade	0.09	0.09	.289	-0.10	0.06	.061	-0.02	0.10	.822
Condition: Phase	0.42	0.10	< .001	-0.08	0.06	.162	-0.08	0.10	.403
Random effects	Var.	SD		Var.	SD		Var.	SD	
Participant	0.75	0.87		0.31	0.55		1.12	1.06	
Residual	0.21	0.46		0.07	0.26		0.19	0.43	

Table 10. Continued

	Reference – Social media			Read other students' posts		
Fixed effects	Est.	SE	p	Est.	SE	p
Intercept	1.84	0.21	< .001	2.34	0.20	< .001
Condition	0.07	0.17	.669	-0.39	0.18	.033
Phase	-0.07	0.06	.218	-0.13	0.08	.111
Gender	-0.07	0.11	.545	-0.09	0.10	.340
Grade	-0.16	0.08	.059	-0.00	0.07	.972
Condition: Phase	0.05	0.07	.444	0.47	0.09	< .001
Random effects	Var.	SD		Var.	SD	
Participant	0.71	0.84		0.50	0.70	
Residual	0.09	0.31		0.17	0.41	

Note. Est. = Estimate; SE = Standard Error; Var. = Variance; SD = Standard Deviation.

5. General Discussion

5.1 Effects of PPBs

The present findings indicate that PPBs consistently facilitate high-quality reflection by integrating prior knowledge with newly acquired lecture content, irrespective of lecture format (on-demand or face-to-face). By generating and sharing opinions before lectures, students are prompted to externalize their existing knowledge and to reevaluate it from a metacognitive perspective. These processes are fundamental to meaningful learning, as understanding evolves through the integration of new information with prior knowledge structures (Alexander et al., 1997; Last et al., 2001; Moos & Azevedo, 2008). From this perspective, engagement with PPBs can be interpreted as effectively facilitating a comprehensive understanding of lecture content.

Simultaneously, Studies 1 and 2 revealed that the exclusive use of a PPB did not reliably facilitate spontaneous reasoning or elaboration beyond the lecture content. This finding indicates that, although PPBs facilitate integration, they may be insufficient for fostering higher-order reflection that necessitates independent inference generation by students. The relationship between students' engagement with the PPB and the content of their OMP reflections was analyzed to further examine this limitation. The results indicated that students who actively referenced and evaluated their peers' opinions were more inclined to engage in spontaneous reasoning regarding the lecture content.

These findings imply that the fundamental mechanism of higher-order reflection resides not only in articulating one's own ideas, but also in comparing and reconciling various perspectives on the same topic. When students seek to understand the validity of others' opinions in relation to lecture content, they are prompted to refine their own reasoning and to incorporate additional explanations or inferences. The results of Study 3 corroborate this interpretation, demonstrating that the incorporation of in-class discussions with PPBs significantly enhanced reflections that featured elaborated reasoning based on lecture content.

Collectively, the results indicate that fostering spontaneous reasoning in post-lecture reflection requires more than merely activating prior knowledge. Rather, it relies on learning environments that encourage comparative thinking and engagement with peers' perspectives. Although previous studies have highlighted the challenges of fostering higher-order reflection in OMPs in higher education, the current findings demonstrate that this issue can be addressed by strategically integrating preparatory posting activities with peer interaction opportunities.

5.2 Implications for Higher Education Practice

Comprehending one's prior knowledge through metacognitive processes and linking it to lecture content via reasoning are essential objectives in higher education learning. This study's findings demonstrate that PPBs effectively facilitate the externalization of prior knowledge and promote reflective engagement with lecture content among students. The extensive utilization of LMSs in higher education facilitates the implementation of PPBs with minimal supplementary resources, allowing for seamless integration into existing instructional practices.

Importantly, the current findings also underscore a crucial limitation of depending solely on PPBs. Although they facilitate integrative understanding, they do not inherently foster reasoning that expands or elaborates on lecture content. This challenge of fostering higher-order reasoning via post-lecture reflection has been documented in previous research (Onoda & Shinogaya, 2014) and was also apparent in Studies 1 and 2. The results of Study 2 indicate that this limitation may occur when students express their own opinions without actively considering others' perspectives, thereby reducing opportunities for comparative reasoning.

From a practical standpoint, Study 3 demonstrates a pragmatic method for overcoming this limitation by incorporating brief peer discussion at the start of the lecture. Students should ideally review and contemplate their peers' perspectives on the PPB before attending class; however, influencing students' out-of-class behaviors frequently proves to be difficult. Incorporating a brief discussion activity—approximately five minutes—into the lecture enables instructors to provide a structured opportunity for students to explore alternative perspectives, even with minimal prior engagement with the PPB. Notably, this discussion can occur without complex grouping or extensive instructor intervention, maintaining its practicality in large or time-constrained classes.

Collectively, these findings indicate that integrating PPBs with brief, low-cost peer discussion can effectively connect out-of-class preparation with in-class learning. This integration prompts students to link prior knowledge with lecture content and to engage in higher-order cognitive processes through comparison and reasoning. This approach provides a scalable and theoretically sound strategy in higher education, with educational benefits likely surpassing implementation costs.

5.3 Limitations and Future Prospects

Despite its significant implications, this study also has certain limitations. First, the assessment of students' understanding of lecture content and its relation to prior knowledge was based on qualitative analyses of OMP reflections. The primary aim of this study was to examine the quality of students' reflections, that is, how students articulated and integrated their understanding of prior knowledge and lecture content. Its aim was not to establish a causal relationship between reflective quality and objective learning outcomes such as test scores or course grades. In addition, informed consent restrictions prevented the use of official academic performance indicators in the analyses. For these reasons, objective achievement measures were not included in the present study. From this perspective, OMP-based text analysis was adopted as a theoretically appropriate approach for capturing students' reasoning processes and levels of reflection. Nevertheless, future research should incorporate objective learning outcome measures to examine how reflective quality relates to knowledge retention and academic achievement. Moreover, because experimental conditions were assigned at the university level rather than at the individual level, institutional characteristics may have been partially confounded with the intervention conditions. Although lecture content, instructional materials, and the instructor were standardized across institutions, unmeasured contextual differences cannot be entirely ruled out. Future studies employing randomized assignment within the same institution would further strengthen causal inference.

In addition, the study sample may have been biased toward students with relatively higher levels of engagement and self-regulated learning, as participation required informed consent and consistent attendance across sessions. This sampling characteristic may limit the generalizability of the findings to less engaged or more heterogeneous student populations and may lead to an overestimation of the magnitude of the observed effects. However, the primary aim of this study was to examine reflective processes and the conditions under which PPBs facilitate different levels of reflection, rather than to estimate population-level effect sizes. Thus, employing a stable and engaged sample provided an appropriate context for addressing these research questions. Future research should examine whether similar patterns emerge in more diverse student populations.

Second, the PPB implemented in this study primarily relied on basic LMS functions and was structured around instructor-initiated prompts, to which students responded individually. This design may have restricted opportunities for dialogic interaction among students during the preparatory phase. Considering that dialogue and reciprocal engagement are recognized as conducive to deeper understanding, future studies could examine whether modifying the structure of PPBs to facilitate peer-to-peer interaction—such as group-based posting or pre-lecture discussion within the board—would further enhance both preparation quality and post-lecture reflection.

Finally, although the present study demonstrated that integrating PPBs with brief in-class discussion can facilitate higher-order reflection, the specific conditions that optimize such interactions require further elucidation. For example, future research could explore how factors such as group composition, discussion timing, or the nature of preparatory prompts influence students' engagement and reasoning processes. As LMSs evolve and become more integrated into higher education, systematic studies on optimizing simple, scalable tools such as PPBs will be essential for advancing both theory and practice in lecture-based instruction.

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References

Abeysekera, L., & Dawson, P. (2015). Motivation and cognitive load in the flipped classroom: Definition, rationale and a call for research. *Higher Education Research & Development, 34*(1), 1-14. https://doi.org/10.1080/07294360.2014.934336

Agavekar, R., Bhore, P., Kadam, H., & Moharir, M. (2023). Effective application of one minute paper and muddiest point technique to enhance students' active engagement: A case study. *Journal of Engineering Education Transformations*, 01-10. https://journaleet.in/index.php/jeet/article/view/281

Alexander, P.A., Murphy, P.K., Woods, B.S., Duhon, K.E., & Parker, D. (1997). College instruction and concomitant changes in students' knowledge, interest, and strategy use: A study of domain learning. *Contemporary Educational Psychology, 22*(2), 125-146. https://doi.org/10.1006/ceps.1997.0927

Alleman, J., Brophy, J., Knighton, B., Ley, R., Botwinski, B., & Middlestead, S. (2010). *Homework done right: Powerful learning in real-life situations*. Thousand Oaks, CA: Corwin Press.

Bellhäuser, H., Dignath, C., & Theobald, M. (2023). Daily automated feedback enhances self-regulated learning: A longitudinal randomized field experiment. *Frontiers in Psychology, 14*, 1125873. https://doi.org/10.3389/fpsyg.2023.1125873

Benesse Educational Research and Development Institute. (2021). *Fact-finding survey on university student life and learning*. Retrieved from https://benesse.jp/berd/koutou/research/detail_5772.html

Cavalcanti, A.P., Barbosa, A., Carvalho, R., Freitas, F., Tsai, Y.-S., Gašević, D., & Mello, R.F. (2021). Automatic feedback in online learning environments: A systematic literature review. *Computers and Education: Artificial Intelligence, 2*, 100027. https://doi.org/10.1016/j.caeai.2021.100027

Hamilton, R.J. (1985). A framework for the evaluation of the effectiveness of adjunct questions and objectives. *Review of Educational Research, 55*(1), 47-85. https://doi.org/10.3102/00346543055001047

Holtzman, R. (2007). Adapting the one-minute paper for active learning. *Academic Exchange Quarterly, 11*(2), 97-101. https://wsac.wa.gov/sites/default/files/2014.ptw.%285%29.pdf

King, A. (1992). Facilitating elaborative learning through guided student-generated questioning. *Educational Psychologist, 27*(1), 111-126. https://doi.org/10.1207/s15326985ep2701_8

Last, D.A., O'Donnell, A.M., & Kelly, A.E. (2001). The effects of prior knowledge and goal strength on the use of hypertext. *Journal of Educational Multimedia and Hypermedia, 10*(1), 3-25. https://www.learntechlib.org/primary/p/8447/

Mayer, R.E. (1996). Learning strategies for making sense out of expository text: The SOI model for guiding three cognitive processes in knowledge construction. *Educational Psychology Review, 8*, 357-371. https://doi.org/10.1007/BF01463939

Midgette, E., Haria, P., & MacArthur, C. (2008). The effects of content and audience awareness goals for revision on

the persuasive essays of fifth- and eighth-grade students. *Reading and Writing, 21*(1), 131-151. https://doi.org/10.1007/s11145-007-9067-9

Moos, D.C., & Azevedo, R. (2008). Self-regulated learning with hypermedia: The role of prior domain knowledge. *Contemporary Educational Psychology, 33*(2), 270-298. https://doi.org/10.1016/j.cedpsych.2007.03.001

O'Flaherty, J., & Phillips, C. (2015). The use of flipped classrooms in higher education: A scoping review. *The Internet and Higher Education, 25*, 85-95. https://doi.org/10.1016/j.iheduc.2015.02.002

Omarchevska, Y., van Leeuwen, A., & Mainhard, T. (2025). The flipped classroom: First-time student preparatory activity patterns and their relation to course performance and self-regulation. *Journal of Computing in Higher Education, 37*, 1-23. https://doi.org/10.1007/s12528-024-09399-0

Onoda, R., & Shinogaya, K. (2014). Enhancing the quality of learners' reflection: Effects of the teacher's response and interaction with beliefs about reflection. *Japanese Journal of Educational Psychology, 62*(2), 115-128. https://doi.org/10.5926/jjep.62.115

Onodipe, G., Romanow, D., & Robbins, M. (2025). Enhancing students' academic success through reflective writing in an undergraduate flipped course. *International Journal for the Scholarship of Teaching and Learning, 19*(1), Article 5. https://doi.org/10.20429/ijsotl.2025.190105

Pressley, M., Tanenbaum, R., McDaniel, M.A., & Wood, E. (1990). What happens when university students try to answer prequestions that accompany textbook material? *Contemporary Educational Psychology, 15*(1), 27-35. https://doi.org/10.1016/0361-476X(90)90003-J

Roscoe, R.D., & Chi, M.T. (2007). Understanding tutor learning: Knowledge-building and knowledge-telling in peer tutors' explanations and questions. *Review of Educational Research, 77*(4), 534-574. https://doi.org/10.3102/0034654307309920

Samuelstuen, M.S., & Bråten, I. (2005). Decoding, knowledge, and strategies in comprehension of expository text. *Scandinavian Journal of Psychology, 46*, 107-117. https://doi.org/10.1111/j.1467-9450.2005.00441.x

Shinogaya, K. (2018). Motives, beliefs, and perceptions among learners affect preparatory learning strategies. *Journal of Educational Research, 111*(5), 612-619. https://doi.org/10.1080/00220671.2017.1349074

Shinogaya, K. (2021). Effective ways of enhancing the quality of question generating and spontaneous information search outside the classroom. *International Journal of Higher Education, 10*(3), 58-74. https://doi.org/10.5430/ijhe.v10n3p58

Shinogaya, K., & Onoda, R. (2021). Teachers' collaboration for enhancing the quality of preparatory learning and reflection. *Nihon University Journal of Faculty Development, 9*, 25-38.

Stead, D.R. (2005). A review of the one-minute paper. *Active Learning in Higher Education, 6*(2), 118-131. https://doi.org/10.1177/1469787405054237

Titsworth, B.S., & Kiewra, K.A. (2004). Spoken organizational lecture cues and student notetaking as facilitators of student learning. *Contemporary Educational Psychology, 29*(4), 447-461. https://doi.org/10.1016/j.cedpsych.2003.12.001

Van der Meij, H. (1990). Question asking: To know that you do not know is not enough. *Journal of Educational Psychology, 82*, 505-512. https://doi.org/10.1037/0022-0663.82.3.505

Zimmerman, B.J. (1989). A social cognitive view of self-regulated academic learning. *Journal of Educational Psychology, 81*(3), 329-339. https://doi.org/10.1037/0022-0663.81.3.329

Zimmerman, B.J., & Schunk, D. (2001). *Self-regulated learning and academic achievement: Theoretical perspectives*. Mahwah, NJ: Lawrence Erlbaum Associates.