Enhancing Pre-Class Content Learning in a Flipped Classroom: An Experimental Study of the Benefits of Note-taking

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***Abstract*—This research-to-practice full paper describes an experimental study investigating the benefits of note-taking to enhance pre-class content learning in a flipped classroom (FC) environment applied to an Engineering Physics course. In an FC, fundamental content learning occurs before the class (targeting low cognitive levels on Bloom's taxonomy), allowing in-class time to reinforce and apply concepts (addressing high cognitive levels on Bloom's taxonomy). However, there is a lack of empirical and controlled research studies investigating optimal strategies for obtaining high-value pre-class content learning. This study aims to contribute to this matter.**

Four groups are considered, each comprising an average of 40 students, following the FC instructional methodology. Pre-class activities precede the class, including reading prepared documents and watching prepared videos. In-class assessments consist of a brief multiple-choice test (maximum of 5 questions) related to the pre-class activities, aiming to evaluate low cognitive levels on Bloom's taxonomy. To enhance note-taking practices, students are encouraged to take notes, and at the beginning of the course, a video showcasing five note-taking strategies is provided. The experiment carried out along one of the chapters revised in the Engineering Physics course includes one control group and one experimental group. In the control group, students are encouraged to take notes without additional guidance, whereas in the experimental group, students receive a fill-in-the-blank style note-taking guide.

The results indicate that students who engage in note-taking, irrespective of the strategy used, outperform those who do not take notes. It is well-documented that note-taking produces an improvement in the in-class learning process. Here, we show how this benefit can be translated to activities before class, enhancing self-regulation learning and reducing the cognitive load during in-class note-taking. Regarding the note-taking guide, there is no significant evidence to support the improvement of student performance. This lack of progress may be attributed to the nature of the guide, using a linear note-taking strategy that ends with non-generative notes. This study shows the benefits of note-taking in enhancing pre-class content learning in an FC environment applied to an Engineering Physics course and invites us to rethink how the note-taking guide structure could encourage the production of generative notes.

***Index Terms*—note-taking, flipped classroom, linear note-taking strategy, Bloom's taxonomy**

I. Introduction

Flipped classroom (FC) is a methodology that has gained significant attention and popularity in higher education, particularly in STEM fields, such as mathematics, statistics, chemistry, and engineering, where it is reported to improve students' learning outcomes, attendance, attitude, motivation, and subsequent performance [1]–[5]. However, for the FC methodology to be effective, students must engage in the completion of a pre-class learning assignment, which should cover the lower levels of cognition, according to Bloom's revised taxonomy. Students' comprehension of the content of the pre-class materials significantly affects the in-class activities designed to go for higher-order cognition [6]. Reading texts and watching videos have been the preferred pre-class activities [7]–[10], but whether or not students effectively read the texts or watched the videos is a question that remains open.

Note-taking is a valuable strategy that can significantly enhance the learning process and improve the retention of content in memory. Students who effectively take notes can interpret, organize, and store content [11], resulting in better comprehension and memorization. However, effective note-taking requires a high cognitive effort since it involves selecting relevant information, organizing it into coherent structures, and integrating it with prior knowledge to facilitate learning and memory [12]. Moreover, some studies recommend the longhand over digital note-taking to achieve the benefits mentioned [13], [14].

Guiding students to take effective notes while reducing cognitive effort can be achieved by providing them with guided notes, which are traditionally defined as instructor-generated handouts with blanks that are filled in during class [15]. While numerous studies have investigated the effects of guided notes on learning during class [16]–[18], the application of guided notes during pre-class activities has received less attention. Recent studies [19], [20] have adopted strategies modified from the Watch-Summary-Question (WSQ) learning mode to enhance pre-class content learning. Although these strategies may not strictly fit the traditional definition of guided notes, they involve instructor-prepared guide material and underscore the need to redefine guided notes to include modern technology and methodologies.

The present study aimed to analyze the effect of free-styling longhand note-taking on students' comprehension of pre-class materials in a flipped classroom environment. The impact of the traditional definition of guided note-taking was also analyzed.

II. Related work

A. Flipped classroom

The flipped classroom is an effective active learning methodology because it has the potential to enhance learning by fostering higher-order thinking skills. Here, students engage with educational content at home before class, focusing on activities, projects, and discussions. FC aims to optimize in-person class time to achieve more interactive and collaborative learning experiences, improving participation and understanding by correlating with student confidence, motivation, and engagement [21].

Pre-class activities are those that students do before attending class. They are designed to prepare students with the content that will be worked on in class. These activities can be assigned readings, educational videos, practice exercises, and previous questionnaires. The goal is to maximize class time by allowing students to arrive prepared and ready to participate in meaningful discussions and collaborative learning activities. These activities are essential when using the flipped classroom methodology because they promote student responsibility, classroom time optimization, active learning facilitation, and class participation preparation. There is a lack of empirical and controlled research work where the best strategies are determined to introduce the contents before class. As mentioned in [8], three methods for learning content before class (interactive online tutorials, video lectures, and textbook-style readings) were tested in two identical, non-specialized introductory biology courses. These researchers found that video lectures present a slight advantage in overall student learning compared to interactive tutorials or traditional textbook readings. It is also mentioned that, despite the differences in the ability of the two groups to learn effectively through autonomous pre-class activities using the flipped classroom methodology, students from both groups showed similar learning gains in the final evaluation.

Another example of an effective FC application is one from the medical field, where textbook readings were the only activity for developing pre-class learning in a medical anatomy course. In this study, researchers demonstrated that they effectively transmitted fundamental knowledge to the students and prepared them for Project Learning sessions [9]. On the other hand, some research has explored the avoidance of textbook readings. This is the case of a study in an undergraduate introductory biology course, where instructors developed texts and provided their students with reading guides as preparatory learning materials. Students in this study were highly motivated by the materials of the pre-class activities; they completed the assigned readings and showed higher performance in examinations [22].

Video is another way of delivering content in pre-class activities for FC. The study of [23] focused on online videos with two processing modes: visual and auditory, and online PowerPoint slides providing students with short, direct, and easy-to-understand low-level content which is consistent with the lower elements of Bloom's taxonomy. This study included 160 university students from computer science who preferred online videos to online PowerPoint slides [23].

When implementing FC, it is crucial to designate specific content for pre-class activities. For instance, FC was integrated into a Research Methodology course, where pre-established content and autonomous tasks were crafted to enhance students' skills and competencies. Utilizing open-access videos containing the exact content intended for review proved to be effective in engaging students. Furthermore, employing appropriate strategies to ensure students adequately prepared for these activities before class was found to be essential [24]

B. Note-taking and guided note-taking

In general, note-taking, as a fundamental learning strategy, involves students' active engagement in summarizing, synthesizing, and organizing information presented in instructional materials [25]. Two main functions are attribute to note-taking [26]: the encoding and the storage function. The first involves the act of taking notes itself, which helps students interpret, organize, and store information, leading to improved memorization and comprehension [11]. On the other hand, the storage function emphasizes the usefulness of notes for review, aiding in the retention of key concepts and details [27]. Additionally, research indicates that taking notes effectively improves comprehension, retention, and content recall [28].

When the FC methodology is applied, note-taking is particularly crucial in STEM fields, where complex concepts and technical information abound. Studies conducted at the City College of New York emphasize note-taking as a fundamental aspect of effective learning in STEM disciplines, enabling students to interact with content outside traditional lectures and deepen their comprehension [29]. Furthermore, note-taking promotes self-regulated learning and enhances metacognitive awareness among STEM students, facilitating the development of effective study strategies and cognitive processing skills [30]. Trevors et al. [31] highlight the role of note-taking in fostering critical thinking and analytical skills essential for success in STEM fields. Through strategic note-taking practices, students in STEM disciplines can optimize their learning experience, enhance problem-solving abilities, and excel academically.

Note-taking imposes a high cognitive load due to the complex interplay of cognitive processes involved in the task. When individuals actively listen to spoken information, they must simultaneously comprehend the content, select key points for transcription, and engage in the physical act of writing or typing [25]. This study proposes integrating the free-style longhand note-taking approach into pre-class activities within a flipped classroom environment to mitigate the substantial cognitive demand. By doing so, it is anticipated that students will be more engaged in effectively completing the pre-class activities.

Salame and Thompson [32] underscore the importance of strategic note-taking practices in improving student performance and achievement. By providing guided notes that scaffold learning and focus on key concepts, instructors support students in processing information effectively and engaging with the material meaningfully. This aligns with active learning principles in STEM education, where students take ownership of their learning process and participate actively in knowledge construction under the guidance and support of their teacher. Moreover, note-taking interventions in flipped STEM classrooms can be tailored to meet the specific needs of students, incorporating elements such as partially completed proofs, diagrams, and examples to deepen understanding and encourage higher-order thinking skills [33]. To date, guided notes have evolved from their traditional linear definition [15] to encompass various forms such as graphic organizers, concept maps, flow charts, and the WSQ model, among others. Research has demonstrated their positive effects on learning outcomes [34]–[36], including pre-class content learning [19], [20]. Since the traditional linear guided note predates the flipped classroom methodology, research on its impact on pre-class activities is lacking. Given its low cognitive load, traditional guided notes may benefit pre-class content learning. Therefore, this study aims to analyze this aspect.

III. Research Questions

This study investigated the impact of free-styling longhand note-taking during pre-class activities on content comprehension at the start of class sessions within a flipped classroom setting. We also examined the effects of a guided note-taking approach in its traditional definition on comprehension scores at the beginning of class sessions in the same setting. As such, the following research questions are posed:

- RQ1: What is the effect of note-taking before class, specifically on assigned pre-class activities, on students' content comprehension at the beginning of a Physics class?
- RQ2: What is the effect of guided note-taking before class, specifically on assigned pre-class activities, on students' content comprehension at the beginning of a Physics class?

IV. Methodology

A. Context

This study was conducted during the second semester (16 weeks) of the 2023 academic year at an engineering-oriented Ecuadorian University. Specifically, 153 engineering students self-enrolled in four first-year Engineering Physics course sections. Throughout the semester, the course adopted a flipped-classroom approach, where students access information posted by instructors on the Learning Management System (LMS) before class and engage in concept application, problem-solving, laboratories, and complex activities during class time with instructor support [37], [38]. Instructors also assessed students' comprehension after reviewing pre-class materials, a common and necessary practice in flipped classroom courses [9]. Figure 1 exemplifies typical activities conducted before and during a flipped classroom setting. The present study occurred during the first half of the semester, beginning in the fourth week of classes. The intervention affected three sessions of the course.

B. Pre-class materials

The Engineering Physics course utilized a flipped-classroom approach, with instructors dedicating significant effort to designing pre-class materials for a chapter on *Work and Energy*, spanning three class sessions. To prevent information overload, instructors tailored readings and videos for student review based on the textbook assigned to the course. The videos offered solutions to typical basic and simple problems related to the topics of the readings. Research suggests that students in flipped-classroom courses prefer materials curated by their teachers over direct textbook readings [9]. This approach allowed instructors to choose content that focused on the development of Bloom's low-cognitive levels. Additionally, note-taking guides structured in a fill-in-the-blank format were designed. Figure 2 shows a sample of (a) a section of instructor-curated reading material, (b) a section of a reading note-taking guide, (c) a snapshot from a tutorial video demonstrating how to solve a physics problem related to the pre-class activities, and (d) a section of a video tutorial note-taking guide.

C. The note-taking emphasis

At the beginning of the semester, all students were introduced to the course's flipped classroom approach, emphasizing the importance of completing pre-class activities supported by note-taking for every session to enhance learning outcomes. Following the initial session, instructors directed all students to

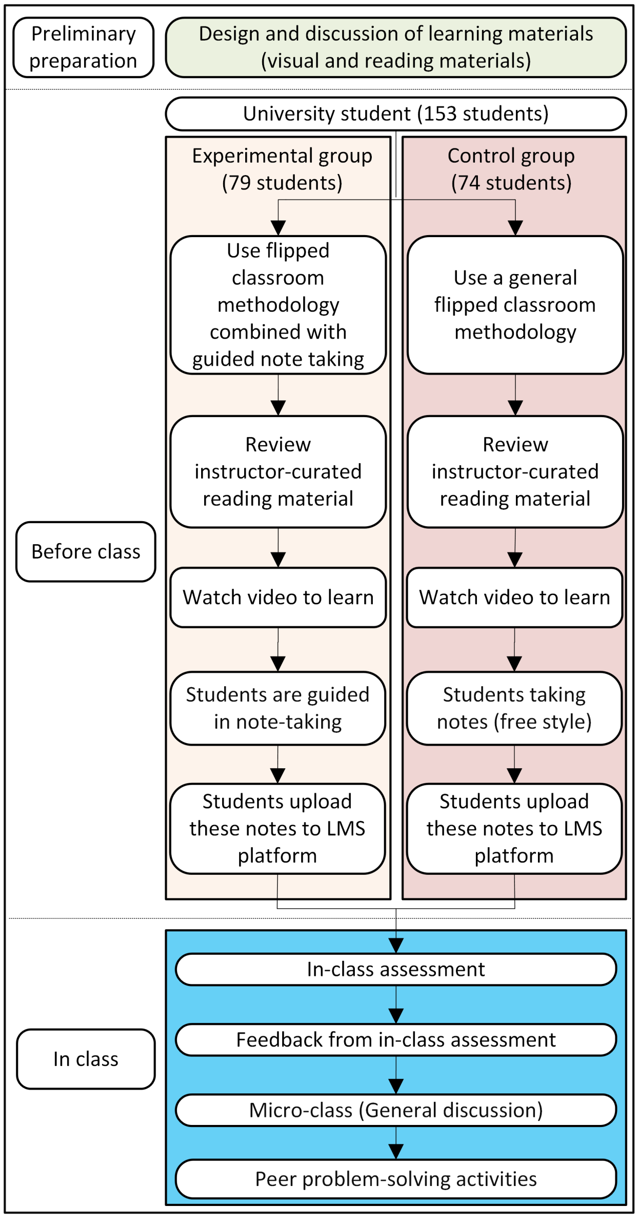

Fig. 1. Experimental Process

review a brief video outlining five note-taking strategies: short sentences, hierarchy, tables and schemes, conceptual maps, and the Cornell method. The objective was to offer diverse approaches that align with individual learning styles. However, instructors did not verify whether students watched the video, and no grading was assigned to this task. Throughout the semester, instructors consistently reminded students in each session to accompany pre-class activities with note-taking.

D. Participants

In this study, 153 first-year engineering students, with an average age of 19, participated. They were distributed across four sections, comprising 35 and 40 students (section 1 = 40, section 2 = 9, section 3 = 39, section 4 = 35). Female students accounted for 19% of the total participants, aligning with the typical gender distribution in engineering classes at the university. Three instructors across the four sections taught the course.

E. Experimental design

This study employed a quasi-experimental repeated measures design with control (74 participants) and experimental (79 participants) groups. Two-course sections were allocated to each group to ensure balance, given that sections were self-enrolled and the random assignment was not feasible. Notably, one section designated as part of the experimental group and another designated as part of the control group shared the same instructor. In contrast, the remaining two sections each had a different instructor.

The experiment involved directing students to take notes while reviewing videos or readings before classes. The experimental group utilized a structured note-taking guide (the same guide for both experimental sections) provided by their instructors, whereas the control group engaged in freestyle note-taking. Subsequently, students uploaded their notes to the Learning Management System (LMS). In-class assessments followed, comprising brief multiple-choice tests (maximum of 5 questions) aligned with pre-class activities, designed to evaluate lower cognitive levels according to Bloom's taxonomy. Instructors graded these tests on a scale of 0 to 100. This process was repeated three times, covering content related to the chapter on *Work and Energy*. Additionally, for these three sessions, instructors verified whether students uploaded evidence of their pre-class note-taking. Figure 1 illustrates the experimental process.

F. Instruments and Analyses

In-class assessments were conducted and designed collaboratively by the three instructors to measure students' progress and ensure consistency in content and complexity across tests. It was not possible to apply the same test per session due to differences in the sections' schedules. Each test comprised five multiple-choice questions and was administered in three sessions at the beginning of week three of the semester. The grading scale of the tests was zero to 100.

The primary objective of these assessments was to evaluate students' comprehension of topics covered in preceding self-contained activities, enabling educators to dynamically tailor their teaching to meet student needs and reinforce any concepts or processes that may have posed challenges.

Descriptive statistics were computed for students' scores, categorized by experimental condition and note-taking status. To address RQ1, one-way ANOVA tests were employed to detect variations between note-taking groups for each session. Additionally, a repeated measures ANOVA test was utilized to examine scores across the three sessions and experimental conditions to address RQ2.

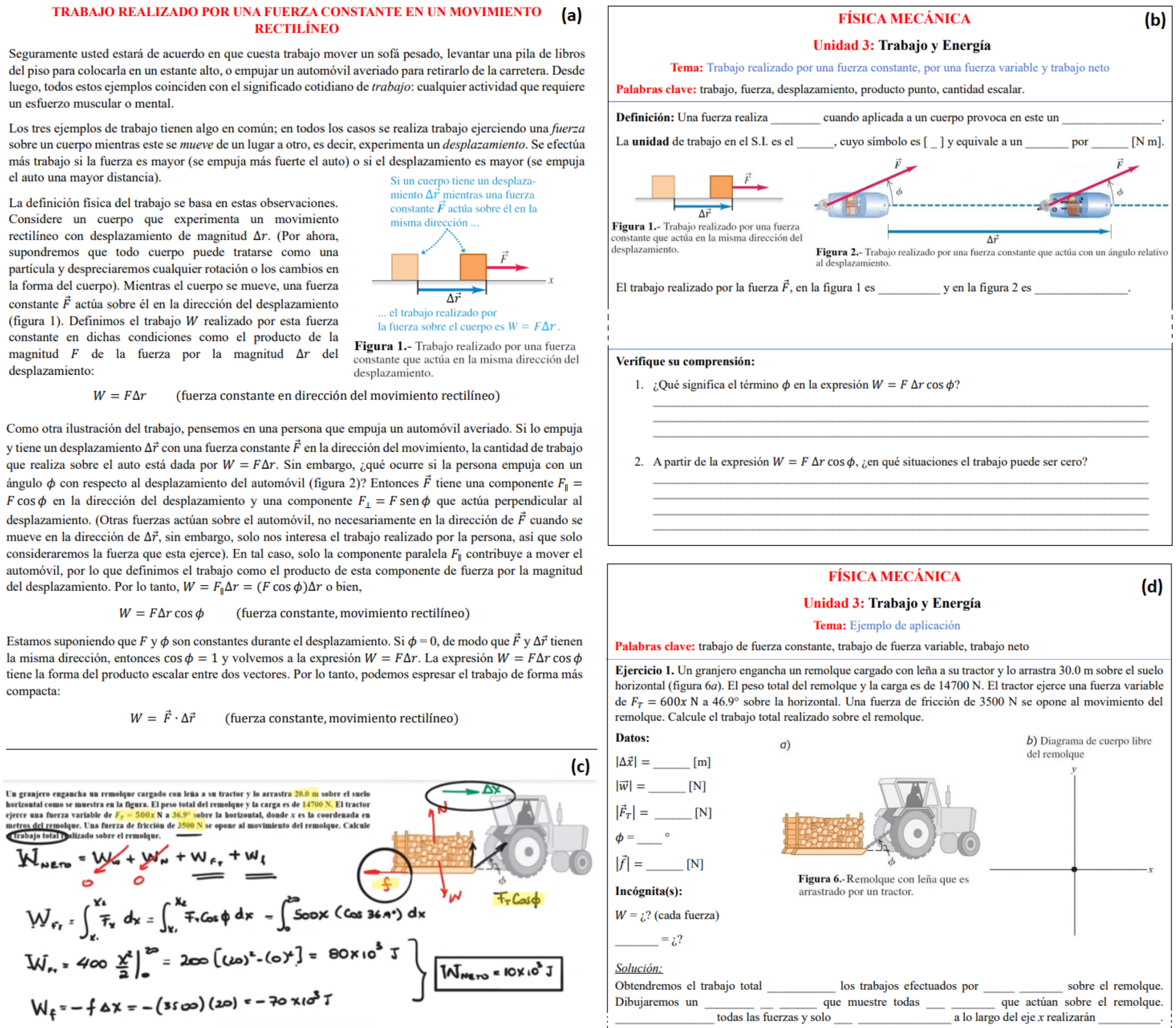

Fig. 2. (a) Instructor-curated reading material, (b) Note-taking guide, (c) Physics problem-solving video tutorial, and (d) Note-taking guide associated with the video tutorial in (c).

V. Results

A. Descriptive Statistics

Before presenting the results related to the research questions, Table I shows descriptive statistics, grouped by note-taking condition, of the students' comprehension scores before starting each class session. Students who engaged in note-taking reached higher scores than those who did not engage in note-taking for all the sessions. As shown in Table I, students who used note-taking reached zero in sessions 2 and 3, and those who did not use notes obtained zero only in session 3. The maximum score reached by the students in both note-taking conditions was 100.

Table II includes descriptives of the scores under the note-taking guide usage conditions. The maximum score reached by students under both conditions was 100. Note that students under the control condition (no guide use) reached higher mean scores in the comprehension assessment before starting sessions 2 and 3; however, those in the experimental condition had a smaller Standard Deviation (SD) and did not obtain zero in all the sessions.

B. RQ1: What is the effect of note-taking before class, specifically on assigned pre-class activities, on students' content comprehension at the beginning of a Physics class?

To answer RQ1, we ran a set of one-way ANOVA tests per session, using the scores obtained by students in pre-class assessment at the beginning of each of the three sessions as the dependent variables and engagement in note-taking as the independent variable. The significance level was set to α = 0.05.

TABLE I
SCORE STATISTICS PER NOTE-TAKING CONDITION PER SESSION

Session 1	X	S.D.	Min
No Note Taking (23)	53.9	23.7	20
Note-Taking (116)	69.0	21.5	20
Session 2	X	S.D.	Min
No Note Taking (23)	60.9	22.9	20
Note-Taking (118)	68.4	24.4	0
Session 3	X	S.D.	Min
No Note Taking (26)	47.7	25.3	0
Note-Taking (114)	65.8	26.2	0

TABLE II
SCORE STASTISTICS PER EXPERIMENTAL CONDITION PER SESSION

Session 1	X	S.D.	Min
Control (n1=69)	66.4	22.9	20
Experimental (n2=70)	66.6	22.3	20
Session 2	X	S.D.	Min
Control (n1=66)	69.4	27.2	0
Experimental (n2=75)	65.3	21.4	20
Session 3	X	S.D.	Min
Control (n1=66)	66.1	27.6	0
Experimental (n2=74)	59.2	25.9	20

In sessions 1 and 3, there were statistical differences in the mean scores reached by students who engaged in note-taking (session 1, F(1,137) = 9.1 p = 0.003; session 3 F(1,138) = 10.2, p = 0.002), while there was no statistical difference for the scores obtained by the students in session 2 (F(1,139) = 1.9, p = 0.170). Nevertheless, as stated in the descriptive subsection, students who engaged in note-taking always achieved higher mean scores in all the sessions.

C. RQ2: What is the effect of guided note-taking before class, specifically on assigned pre-class activities, on students' content comprehension at the beginning of a Physics class?

To answer RQ2, we ran a repeated measures ANOVA test, using the scores obtained by students in pre-class assessment at the beginning of each of the three sessions as the dependent variables and the usage of the note-taking guide as the independent variable. The significance level was set to α = 0.05. After running the test, no significant difference was found among the conditions along the time (F(2,943) = 1.02, p = 0.363), nor the conditions.

VI. DISCUSSION

A. Research Question 1

In session 1 and session 3, students who engaged in note-taking outperformed peers who did not show evidence of pre-class reading notes. We could not demonstrate the same for session 2. Overall, these findings are consistent with several studies that establish a clear connection between note-taking during reading and engaging in learning activities, resulting in score improvements (See [39], [40], [41], [29], among others). Specifically, the results corroborate a prevailing trend advocating for a return to fundamental practices, whereby students are encouraged to take notes to prepare for readings and activities before class sessions. This trend is supported by Gourley's work [42], which demonstrated that annotating during pre-reading activities enhanced economics students' quiz and examination grades compared to those who only engaged in reading activities. Furthermore, collaborative note-taking approaches have been associated with positive outcomes by other authors [43], although this aspect was not explored in our research.

In session 2, although students who participated in note-taking achieved higher scores than their peers in the alternate condition, this difference was not statistically significant. In the experimental group, students were tasked with uploading their notes, yet instructors did not assess the quality of these notes. Consequently, students may have merely produced notes to meet course requirements. Research suggests that well-crafted notes directly enhance quiz and exam grades [41]. Furthermore, we did not verify whether students reviewed their notes before the assessment. As noted by Gourley [42], students who openly review their notes during quizzes or examinations typically achieve higher scores than those whose notes are not reviewed.

B. Research Question 2

The students who used guided note-taking did not show better scores in their assessment than the ones who did not use this approach, contrary to previous reports [44], even within a comparable setting where active learning was integrated with guided note-taking in a physics course [45]. These results can be explained as follows:

Firstly, the structure of the guided notes leaves no room to personalize the note-taking procedure. Essentially, note-taking demands that students comprehend content write it down, and learn all at once [46], making it a highly personal endeavor. In other words, the structure of guided notes should allow students to align their note-taking with their individual writing styles and learning strategies (e.g., incorporating sketches, conceptual maps, etc.) while ensuring they do not overlook key elements of the process [23].

Secondly, the note-taking guided approach was implemented for three sessions within a single week. This brief timeframe may have prevented the substantial establishment of this learning practice and improved grades. D'Souza and Broeseker [47] suggest that the development of study skills and learning habits might require at least a year of training; moreover, other studies suggest that positive evidence could be observed over 5 years [45], surpassing the duration of our study.

VII. Limitations and further research

We acknowledge the following limitations of the study:

First, the study was a one-week intervention, which is a short time for establishing and developing note-taking skills. A longer period of experimentation is required to gain sound outcomes.

Second, instructors did not evaluate the quality of the notes uploaded by the students, potentially influencing their impact on comprehension assessment outcomes. Therefore, future research endeavors must include an assessment of students' note quality.

Third, the rigid structure of the guided note-taking approach may have restricted students' ability to reflect their understanding within their notes. Therefore, it is imperative to redesign the guided note-taking process, enabling students to imprint their understanding via generative note-taking and sense-making as they engage in note-taking activities. This approach would pave the way for comprehensive reviews as students prepare for quizzes or examinations.

Fourth, students' pre-existing knowledge regarding the topic addressed in the three sessions was not evaluated before the intervention. Thus, it remains to be seen whether participants had varying levels of expertise at the study's outset. Then, for future research, this assessment should take place previously.

Fifth, the outcomes of this study are particularly tailored to an Engineering Physics course, prompting the need for broader exploration beyond engineering disciplines. Additionally, considering the youthful demographics of the participants, it is advisable to ascertain whether the study's findings hold across various subject areas and age groups.

Sixth, from a methodological perspective, this study did not incorporate a qualitative approach, which could have provided valuable insights or complemented some of the findings.

Finally, on the positive side, this study was set up in a naturalistic environment, allowing for observations of authentic classroom behaviors potentially applicable to similar contexts. Nevertheless, we cannot generalize the present results. Further research is necessary, incorporating the insights gained from this study, to conduct new experiments and expand our understanding of note-taking approaches.

VIII. Conclusion

This study offers valuable practical insights into the pivotal role of note-taking and guided note-taking within pre-class activities in a flipped classroom environment, specifically examining their influence on understanding concepts and improvement of grades in an Engineering Physics course. Moving forward, it is essential for future research to tackle the limitations identified herein and integrate qualitative methodologies alongside quantitative analyses. This approach will further enrich our comprehension of effective note-taking strategies and their impact on educational outcomes.

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