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Rule-based access to learning materials in a Flipped class in embedded programming

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ABSTRACT

This empirical study explores the effectiveness of the Flipped Classroom (FC) model combined with blended learning in the context of Electrotechnical Bachelor of Engineering education in a digital electronics and programming course on 2nd semester. It particularly focuses on the use of a Learning Management System (LMS) to facilitate pre-class, in-class, and post-class activities, emphasizing the role of quizzes, video materials, and slide presentations in enhancing student engagement and preparation. The research was conducted over several semesters, comparing student engagement metrics and assignment quality before and after the implementation of rule-based access to learning materials. Data were gathered from the LMS, including quiz participation rates and access to pre-class slide presentations and correlated with the quality of students' assignment submissions.

The findings indicate a mixed impact of rule-based access on student preparation, with some improvement in quiz participation and slide access but less engagement with video materials. However, the quality of assignment submissions did not significantly correlate with the enforced pre-class activities, suggesting that motivation and engagement might be influenced by factors beyond the structured access to learning materials. The study also highlights the challenges of encouraging consistent student preparation and the potential of LMS tools to tailor the learning experience to individual needs.

The research contributes to the ongoing discussion about the flipped classroom (FC) model's effectiveness, offering insights into how digital tools and structured access rules can enhance or hinder student learning in programming courses. It calls for

further investigation into the motivational factors driving student engagement in blended learning environments.

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1 INTRODUCTION

In this empirical work, we will study and analyze if students uses of materials reflects the quality of assignment and if a rule based setup in the learning management system improves the uses of material compared to year without any rule set. The rule-based access to the lesson slide presentations was introduced in fall 2023 and also used in spring 2024. The rule is: The quiz must be scored before getting access to the in-class slide presentations. The paper introduces the concept of the flipped class, drawing from relevant literature and providing motivation for the research questions. The course used is introduced. Details about data collection and results are presented. The paper concludes with a discussion and conclusion.

1.1 Introduction flipped classroom

Programming involves various skills to learn. The Flipped Classroom (FC) creates a new learning environment with practical programming sessions and enhances

students' learning experiences (Siripongdee, Pimdee, & Tuntiwongwanich, 2020).

The main advantages of FC are providing students with knowledge before class and preparing them to spend extra time in class for active and collaborative learning (Eusoff, Salleh, Mohd, 2021). The FC principle typically covers 3 parts of activity: pre-class, in-class, and post-class. Our course Digital electronics and Programming (62734) on 2nd semester electro technology Bachelor of Engineering used for research here uses pre-class activity: video, slides, quiz and in class activity use slides and assignment programming as well as post-class work on the assignment and report for documentation.

This paper written by Eusoff, Zin, Salleh(2022) shows literature review and it reveals in-class activity hands-on experiences are most used, whereas only 21% use assignments. Moreover, they find mostly pre-class videos to convey knowledge and quizzes. When using FC, learning is individualized, and students must be able to learn at their own pace and ask questions to the facilitators in the class. (Rasheed A. et al. 2020). The teacher's role is changed to support, guide, and facilitate the students towards learning from different perspectives.

The teacher is responsible for materials available online due to the FC being a 24/7 classroom. The FC model also effectively enhances students' engagement, interaction, self-efficacy, and attitudes (Eusoff, Zin, Salleh, 2022), But in practice, one of the challenges educators face is ensuring students' participation in learning activities in pre-class (Eusoff, Salleh, Zin, 2021). Our previous work (Schultz, & Blaszczyk, 2023).) reveals that 25 – 30% percent of the students don’t use the pre-class materials.

Motivation is the most important element when using the FC method. In addition, Lopes et al. (2019) have analyzed data regarding students' affective perception of flipped classrooms and write that the statistical analysis indicates, especially in the 3rd and 4th semesters, semesters in e-learning and classroom classes present a significantly higher affective perception. A motivation factor for the students could be quizzes - a kind of gamification, a competition. Many research articles ex (Eusoff, Zin, Salleh, 2022)(Baig, Yadegaridehkordi 2023)(Sobral, 2021) present data from research and literature reviews. The course (62734) activity in-class programming could also motivate the students as the program can do specific tasks in a microcontroller with a visible result. Lio (2024) has done an evaluation of the flipped

classroom used in programming and one of the findings is “the motivated students aggressively accessed the course materials and obtained a better score”. Founded on above studies and own experiences it is relevant to raise these two research questions: **1st research question:** Does a rule-based setup in the LMS system for access to in class slide-materials improve the amount of students answering the quizzes before class as well as uses of the pre class video and pre-class slides?

2nd research question: Is the solution to assignments dependent on the students' engagement with the in-class materials in the LMS?

In the next section the course in the LMS delivering data is described

1.2 The course Digital Electronics and Programming for research

As in general, programming learning software-development for embedded platforms (microcontroller) is pretty much the same. The main difference is the program runs in a small processor (microcontroller), not a PC. The course has been taught, during the last 8 years, as FC or semi-flipped. The course content is both about understanding the hardware and in parallel programming/configuring the controller to perform different tasks on the input-output, serial ports, etc. We use a Learning Management System (LMS), Learn, developed by Brightspace. At Learn the materials are sorted in different folders.

Preparation materials are available in a subfolder to the specific lesson folder and contain a slide series, a video presentation of the slide series, and a quiz and sometimes a demo to exemplify how to write a small program. The quiz questions are questions in the digital electronic, but there are also programming questions ex. true/false or select a correct program-statement among four opportunities about a program statement ex. read a signal level on a physical port or turn on a Light Emitting Diode (LED).

The quiz(es) results are used as an introduction to the lesson where we go through some of the answers at the beginning of the lesson. The video length is between 10 and 15 minutes as suggested in the literature (Baig, Yadegaridehkordi, 2023). Due to the time limitation, there are sometimes 2 or 3 videos for preparation.

We use Discord as a 24/7 online communication tool therefore students can always reach out for help or use it for internal discussion.

Students work in pairs-groups up to three students on four different assignments. The groups hand in a small report documentation for the program and a program. The teacher/supervisor correct each assignment report and the program. Moreover, an example solution will be available for students who have handed in the assignment. The course is evaluated through an oral individual exam. Students answer six general questions related to the curriculum, with 5 minutes to explain a randomly drawn topic. Afterward, additional questions assess program knowledge and understanding. The grade reflects documentation quality, program proficiency, and demonstrated understanding during the exam

2 METHOD AND DATA

For answering the questions raised above, we use empirical data from the LMS system and evaluation of two assignments. We extract a record of data for each student enrolled in the course. The record includes access/clicks on all topics, encompassing access/clicks to the lesson slides, pre-class slides, quiz scores, hand-

ins of assignments.

The Table 1, next page, shows year, semester and number of students enrolled and groups in spring semesters. In principle, all enrolled students should access all materials. From the LMS we use the records of data for answering the first question: Does a rule-based setup in the LMS system for access to in class slide-materials improve the amount of students answering the quizzes before Class, as well as uses of the pre class video and pre-class slides? The students in the fall semester are from a winter intake by February and are more diverse, and not everyone is just coming from high school but have been in work before the study started.

Table 1: Data size 2nd semester students enrolled into course 62734

Year	Fall - enrolled	Spring - enrolled	Groups of students
2022	28 students		
2023	29 students	48 students	21 with 43 stud.
2024		68 students	25 with 63 stud.

Whereas the spring semester students are from a fall intake by September and most students are continuing from their high school. In spring 2024, there are 68 students (IT-electronics students together with electro technology students).

The second question: Is the solution to assignments dependent on the students' engagement with the in-class materials in the LMS? This question is answered using two assignments (Assignment 2 and Assignment 3) handed in in week 4 and 6 respectively in spring 2023 and spring 2024. Fulfillment of an assignment requires having a program running on the microcontroller and acceptable quality of documentation. Evaluation data is created as: The quality of documentation is given a rating from 2 for good, 1 for poor, and 0 for not handed in. The program is rated -1 for not running, 0 for not handed in, and 1 for running. As data is not Gaussian distributed, Spearman's correlation coefficient (named for Charles Spearman) summarizes the strength between the two data samples. For kind of falsification of correlation, data used in this analysis is only from students in groups either lacking a working program or adequate documentation, and those with satisfactory documentation but no working program, as well as groups that have not handed in a program, documentation, or both. Nevertheless, all students access data to in-class slide presentations is correlated with completed hand-in of report and program.

In the following result section, we conduct the data analyses and later in the discussion section we discuss the results.

3 RESULTS

Here, data records extracted from the LMS and data from correcting the tasks are analyzed.

3.1 Preparation by pre-class activity

For answering the first question, we use plots of students' completeness to pre-class materials in histograms for the first 8 lessons.

Figure 1 on next page shows students' pre-class activity during week 1 to week 8.

On the X-axis, the Module is the lesson in week 1 to 8. The Y scale is the percentage of students who have completeness/accessed the materials listed in the categories

shown by the legends.

The legends shown by color for each bar. The color changes for each legend and the first two colored bars are the video, the next two are the quiz, and the last two are the pre-class slide presentation.

- The figure to the left is for fall 2022 (F22) and fall 2023 (F23) covering: video_F23, quiz_F23, and sl_pr_F23 (pre-class slide presentation).
- The figure to the right is for the years: spring 2023 (S23) and spring 2024 (S24).

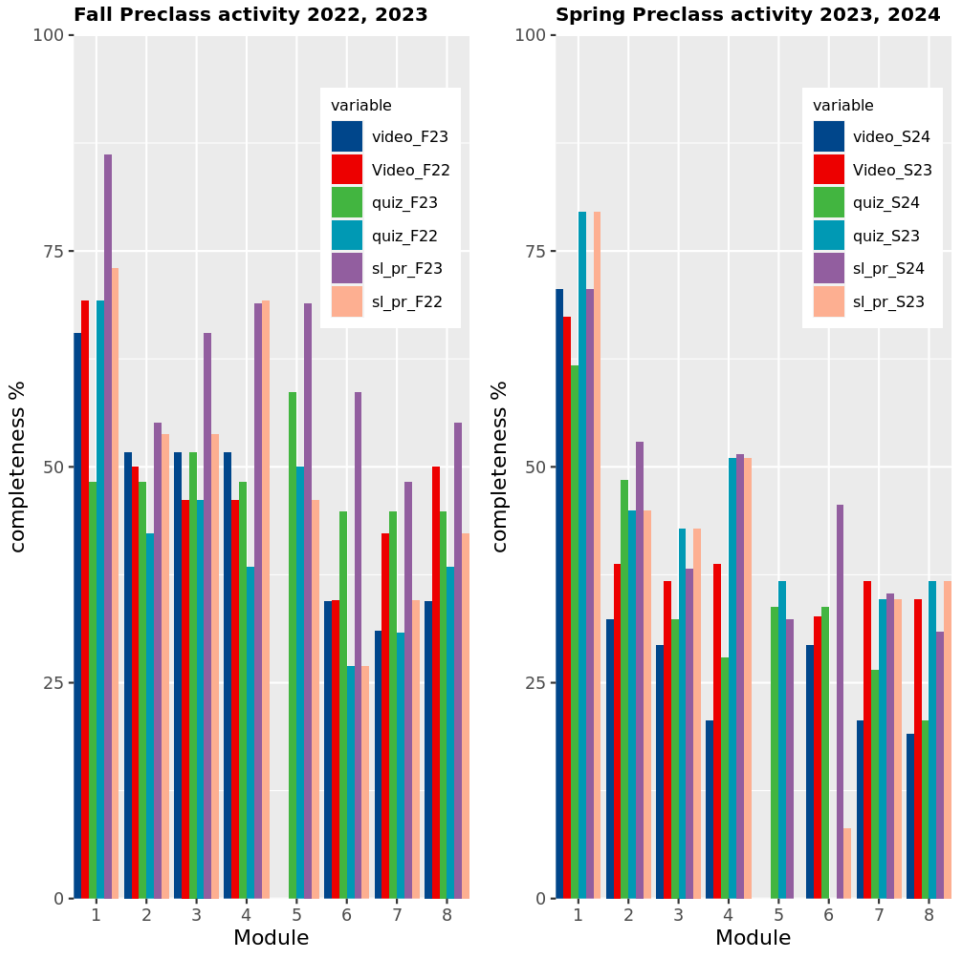

Figure 1: Pre-class activity in fall 2022, 2023, spring 2023, 2024.

The Average value for access for each kind of material is:

- **Video**: video_S24 2024: 29.14 % and for 2023: 38.78% so a decrease by 10%.
- **Quiz**: quiz_S24 2024: 31.25 % and for 2023: 36.36 % a decrease by 5%
- **Pre-class slide series**: sl_pr_S24 2024: 39.81% and for 2023 36.36% an increase by 3%.

Overall, students accessed the pre-class slide presentations improved from S23 to S24 except for lessons: 1,3,8. While video access and quiz scores for all semesters have mixed results depending on the module.

Looking at the left figure for fall 2023 compared to fall 2022; the same picture pre-class slides are used more in 2023 than the previous year. The pre class slide series is together with the video mend as the foundation for the quiz. This is also confirmed by the figure both quiz and pre class slides is accessed more in fall 2023. But in the

spring 2024, with some exceptions, it is the opposite picture. Students in 2024 are not complete the quizzes as much as in spring 2023. Looking on the video access, the students in spring 2024 use the video more for preparing than in spring 2023. That could of course be the reasons for not accessing the pre-class slides. Exactly opposite to spring 2023, where the students access the video less. The rule about the quiz to be completed seems not to motivate the students to do more quizzes in spring 2024 compared to spring 2023 where there was no rule. However, in fall 2023 the rule could have an impact on the uses of the materials compared to fall 2022, where there were no rules applied.

3.2 The Slide materials

The figure 2 shows how the students access the in class slides (sl_les22/23/24) and pre class slides (sl_pre22/23/24) in years: 2022, 2023, and 2024. Again, a pair of colors address the two types of slides and the related semesters. The semester term and year is headline for each sub-figure in figure 2. In addition, on the x-axes Module is the lesson from 1 to 8. The slides used in the lesson are used most which also is found by (O. Schultz and T. 2023).For Spring 2024 there is small difference between the slides for preparation (sl_pre24) and slide ls_les24 used in the lesson. Whereas in spring 2023 the difference between access in class and pre class slides, is more than 10%

On average, 42% have accessed the preparations slide presentations in spring 2024, and in spring 2023 only 31% accessed, so an increase of 11%, and for the slide presentations used in the lesson, the average access is 57% in spring 2024 and in spring 2023 78.6%, so a decrease of 21% - reflected in the outstanding purple bars in figure 2 to the right. So, with the rule use less access to the slide presentations and less quiz completed.

Therefore, the rule about the quiz must be done, does not in 2024 motivate students to take the quiz and watch the pre-class slide presentations nor the in-class slide presentations, but in Fall 2023 with the rule used, it results in higher completeness. It could be explained with rules that motivates students.

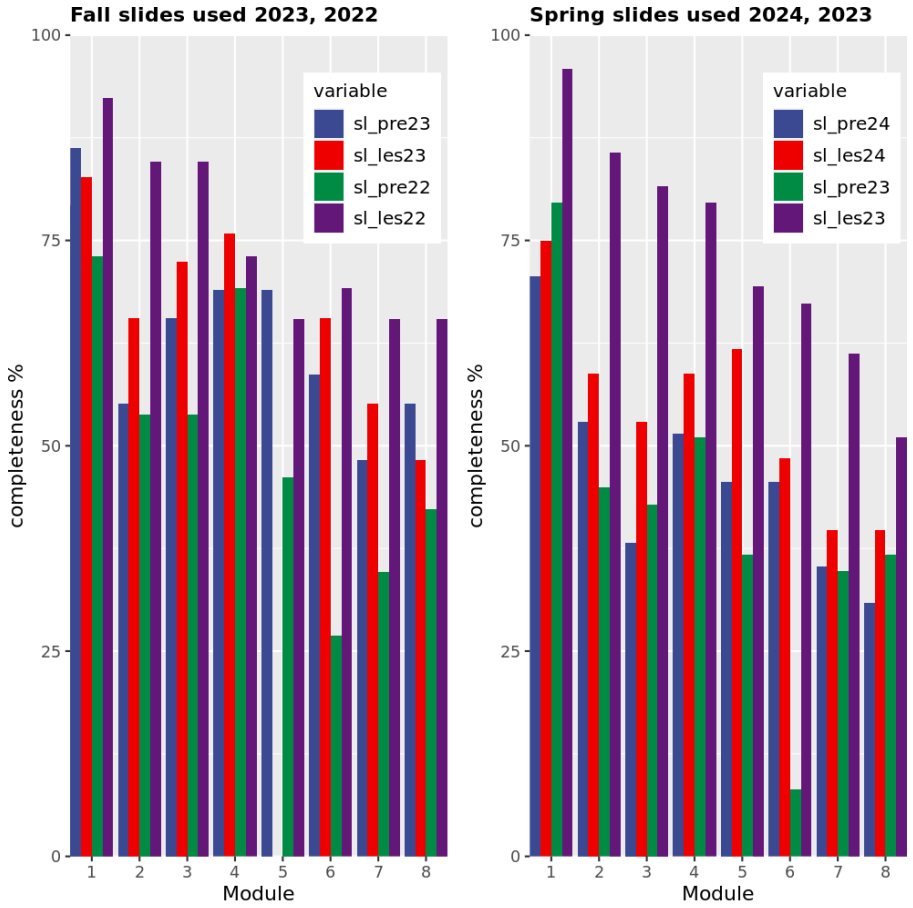

Figure 2: In-class and pre-class slide activity in fall 2022, 2023, spring 2023, 2024.

3.3 Quality of assignment work

Table 2 shows the documentation evaluation data correlated to slide presentations (doc_sl) for lessons, and slide presentations for preparation (doc_psl) and quizzes before class (doc_q). And the program evaluation-data correlation to slides used in class (pro_sl) and slide presentations for preparation (pro_psl). Data is from students not completely full fill assignments as explained in section 2. Spring 2023 no rule for getting access to in class slide presentations. Spring 2024 we use the rule: quiz must be scored before access to in class slide presentations.

Table 2. Correlation coefficients scoring assignments in relation to activity

year	assign	doc_sl	doc_psl	doc_q	pro_sl	pro_psl
Spring 2023	2	0.58	0.51	0.23	-0.27	-0.26
Spring 2024	2	-0.47	-0.16	0.12	0.33	0,21
Spring 2023	3	0.44	0,22	0,36	0,19	-0,36
Spring 2024	3	-0,22	0,073	-0,045	0,015	-0.13

Assign column is referring to assignment 2 and 3 by number.

- Rows spring 2023 -in blue:, there seems to be a weak correlation between the use of slides (doc_sl for lessons, doc_psl slides for pre-class) and the quality of documentation. But the program and slides (columns: pr_sl, pro_psl) does correlate weak negative – confirming programs quality is poor due to not using the hints in the slides.

- Rows spring 2024 – in black, with the rule for accessing slides introduced, there is a weak to none and negative correlation for the quality of documentation. Whereas for the program quality there is a weak correlation 0.33 to the slides for assignment 3 and for assignment 2 correlation of 0.33, which contradicts with the results in spring 2023.In spring 2024 Quality of documentation for assignments has a weak negative correlation to the slide presentations, that can be explained by less uses of the slides confirmed by figure1 and 2.

When using all students' **access data (slide presentations in-class and preparation slide presentation) for spring 2024** correlated to the hand-in of program and journal (for assignment 2) in correlation to the slides used in class it shows correlation by 0.40 and for assignment 3 hand-in correlated to in class slides by 0.28. In addition, **data for spring 2023** for assignment 2 close to zero correlation 0.060 whereas assignment 3 has a correlation to slides in class by 0.35. This confirms using the materials helps students to fulfill hand-in of assignments.

4 Discussion

The results shown in Figures 1 and 2, where we compare two different semesters in fall 2023 and 2022, and spring 2023 and 2024, indicate that, in general, there is less activity in 2024 compared to 2023, particularly for pre-class material in Figure

1. The rule setting, where a quiz must be scored before access to the lesson slides, does not seem to have any significant effect on activity in the Spring semester.

However, in the fall, there are up to 20% more students scoring on quizzes, and the pre-class slides series is more frequently visited. However, in spring 2024, where the rule is active, even the quiz scores are less than in spring 2023, except for lesson 2.

Figure 2 illustrates the difference between slides used for preparation and those used in the lesson. The rule for accessing the lesson slide series in spring 2024 does not motivate the students to do the quiz before class. However, opposite in the fall 2023 where activity was 10 to 20% higher compared to fall 2022 without any rule. Therefore, perhaps there is a motivation factor by the rule. That could lead to the conclusion on first question: "Does a rule-based setup in the LMS system for access to in class slide-materials improve the amount of students answering the quizzes before class as well as uses of the pre class video and pre-class slides". For the fall 2023, rule-based access improves the access to quizzes and materials, whereas in 2024 it seems not to have much influence. Conclusion on the points to the rule based assess can have an impact for some kind of students.

The other question: "Is the solution to assignments dependent on the students' engagement with the in-class materials in the LMS?". From table 2 we find there is in the positive correlation between the documentation quality and slides used in class for the spring 2023 and for spring 2024 a negative correlation between documentation quality and access to the slides used in class. In addition, the program quality has a positive correlation to the slides used in class for spring 2024 and opposite for the spring 2023.

When we look at completeness of assignment 2, 3 spring 2024, and correlated with completeness/access for slide presentations used in class there is a positive correlation between hand-in of the assignment and access to slide presentations.

When relate that to the first question then we must conclude the rule does not help all

students, but the more students use the slide presentations, the better quality of the assignments and completeness.

Regarding these results, one challenge with the pre-class activity and the programming assignment is that students are evaluated on the assignment report and the program running in the microcontroller, and there is not any tight coupling with the content on Learn. Ex. the material mainly for pre-class activity is about the digital electronics part and the general concept of the microcontroller not about programming. The assignment can be completed using resources like ChatGPT, which are accessible without login. This allows students to get immediate assistance with their tasks. The quizzes mirror the oral exam's theoretical questions, making them good practice. However, Schultz & Blaszczyk (2023) found no link between quiz performance and final grades. Similarly, quiz usage did not correlate with the quality of programming or documentation in the evaluated tasks (see table 2).

5. CONCLUSIONS

The research questions regarding whether a rule setup can motivate students to be more prepared by doing quizzes and thereby using the supplied materials are addressed in the work presented here, drawing on data from the LMS system. There is a tendency to suggest that the rule could motivate to do the quiz before class; however, it also presents challenges for students who haven't scored on the quiz and are thereby unable to access the slides for hints, consequently affecting their ability to fulfill the assignment. A correlation analysis between individual students' data from the LMS and the scores of assignments shows a weak correlation between the program running in the microcontroller and the use of slide presentation in the lesson. Students can complete the quiz by using the pre-class slide presentations, but the videos are not utilized as much. Nonetheless, the changes observed are minor. Therefore, other ways to motivate the students should in the future be tried in this course.

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chatGBT4 has been used for spelling and grammar correction.