Board #440: Effect of Reflection Exercises on Preparation for Exams: A Case Study in an ECE Machine Learning Class

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Abstract

Self-reflection can improve one's understanding and processing of complex concepts. It stimulates deep-learning and professional development. In this work, we introduced self-reflection assignments as an instrument to aid students, in the machine learning course under investigation, to prepare for the course conceptual-oriented exams since the programming homework assignments mainly focus on the practical aspects and applications of the studied algorithms. ANCOVA analysis was conducted to statistically study the effect of self-reflection assignments on exam scores. The analysis was conducted on two exam scores from two different cohorts, one of which did not use the self-reflection assignments while the other used reflection assignments to review the course contents before the exams. The results suggest that there is insufficient evidence to substantiate the claim that student performance in exams has shown improvement as a direct consequence of utilizing self-reflection assignments. In addition, an anonymous student survey was used to study how the students perceived the self-reflection assignments and how it helped deepen their understanding of the course materials and prepare them for taking the exam. The majority of the students who completed the survey had a positive perception of the reflection assignments. They found that the assignments helped solidify their high-level understanding of the different algorithms taught in class and aided in recalling the materials as they prepared for the exams. In future iterations of the course, we plan to revise the language and frequency of the assignments to more effectively assess students' understanding of the theoretical concepts.

1. Introduction

Machine learning courses are gaining more popularity in electrical and computer engineering (ECE) programs. They offer the students an opportunity to practice multiple concepts related to algorithms and software programming while learning an important topic. A typical machine-learning course focusses on the theory of different machine learning algorithms during class time while focusing on programming and application in the homework assignments and class projects. However, since the homework mainly focus on programming, the students do not get enough chances to practice their understanding of the theoretical concepts of the studied algorithms before the exams. To address this issue at the ECE department of the University of Pittsburgh, we recently used reflection assignments to help students prepare for their machine learning exams. In these assignments, the students were give a list of conceptual questions related to the covered algorithms, and the students were asked to reflect on these questions, and provide answers to them as well as provide a map that links the concepts among those questions.

Self-reflection is a process of introspection and self-evaluation that allows individuals to gain insight into their own thoughts, behaviors, and experiences. In the context of learning, Boud et al. defined self-reflection as engaging intellectual and affective activities that, along with their experience, lead to new understanding and appreciations [1]. In addition, the definition of self-reflection was further extended to include the processing of the relatively complex or unstructured ideas for which there is not an obvious solution [2].

Pedagogical reflection and its theory has become a significant instrument in educational practice. The focus of reflection can vary depending on individual needs, context, and desired learning outcomes. Content reflection focuses on understanding and applying the gained knowledge. On the other hand, process reflection emphases on analyzing learning strategies and metacognition skills. On a personal and character development scale, affective reflection pays attention to exploring emotions and personal values related to learning experiences [3], [4]. The reflection assignment can take different forms too. In journaling reflections, students writes down their thoughts and feeling towards a structured exploration and processing of their learning experience [5]. If multiple reflection activities are assigned for different topics throughout the semester, students can create a portfolio that provides them with a holistic view of their learning process [6].

In the field of engineering education, self-reflection has gained recognition as a valuable tool for promoting deep learning, critical thinking, and professional development among engineering students. By engaging in self-reflection, students can enhance their metacognitive skills, become more self-aware that they can identify their strengths and weaknesses, set goals, develop strategies to improve their learning approaches, and develop a deeper understanding of their learning processes. Hence, self-reflection enables students to enhance their learning experiences and personal development [7], [8]. In addition, self-reflection provides the students with the opportunity to take a mental step back and analyze their learning process. It is not just about reviewing flashcards or re-reading notes; it is about actively assessing one's strengths and weaknesses, identifying areas of confusion, and tailoring study strategies accordingly. Therefore, it can aid students preparing for their exams effectively. Previous studies, e.g., [9], found that self-reflection has improved academic performance. However, it was only to a limited extent. This motivated the authors to study the effect of self-reflection in preparation for machine-learning exams. The research questions that the author investigated are as follows: 1) How students perceived the effect of reflection assignments on their understanding and preparation for exams? 2) To what extent do reflection assignments enhance exam scores, if at all?

To address the research questions mentioned earlier, we introduced reflection assignments for the first time in the Fall of 2023 as a tool to aid in exam preparation for the machine learning course offered by the Department of Electrical and Computer Engineering at the University of Pittsburgh. We conducted a survey among the students enrolled in that semester to gather their perceptions of the effectiveness of self-reflection. Additionally, we conducted a statistical analysis on exam scores between two student cohorts: Spring 2023, where no reflection assignments were used, and Fall 2023, where reflection assignments were first introduced in this course.

The Methods section of this paper introduces and references the various assessment and data analysis methods used to capture students' perception and performance in response to self-reflection assignments. These methods include techniques for statistical analysis and qualitative data analysis. In the Results section, we present and discuss the quantitative analysis of students' exam scores comparing those with reflection assignments to those without these assignments. Additionally, we analyze and discuss student perspectives on the effectiveness of self-reflection in this course.

2. Methods

2.1. Course Description and Instructional Pedagogy

This study centers around the machine learning course offered at the ECE department of the University of Pittsburgh. The course, an elective 3-credit class, typically attracts an average enrollment of 25 students per semester. It encompasses both theoretical concepts and practical considerations pertaining to a range of machine learning algorithms, including linear regression, logistic regression, support vector machines, and neural networks. To ensure equal rigor, the course is structured into modules, each of which focuses on a specific algorithm. The first half of the semester is taught synchronously in a traditional fashion, and the second half of the semester is flipped. Active learning exercises are used throughout the semester to ensure students' involvement with the material and to restore students' attention [10]. For the flipped modules, students were required to watch between three to seven video lectures, each ranging from 4 to 20 minutes in length, before attending class and attempt an accountability quiz at the beginning of the following class meeting. During class, the algorithms of the flipped modules were reinforced through discussions and demos. In all modules, programming homework assignments were utilized to further gauge students' learning and expose the student to the various practical considerations of the studied algorithms. The course features two exams, one at the middle of the semester and another during the final exams week. The exams cover the theoretical aspects of the taught algorithms. Each exam is composed of 40 multiple-choice questions and two open ended questions. Partial flipping has no significant effect on student performance in the exams of this course as we previously reported in [11]. The data utilized in this study were obtained from two iterations of the course, where in the first iteration, no reflection assignments were used, and in the second iteration, reflection assignments were introduced. Data collection took place during the spring semester of 2023 with 21 students enrolled and the fall semester of 2023 with 30 students enrolled. Both semesters were conducted in person, with all class activities held in the course's assigned classroom.

2.2. Reflection assignments

In Fall 2023, with the aim of assisting students in preparing for the course exams, we introduced a self-reflection assignment two weeks before each of the two exams. Each assignment included reflection prompts covering various aspects of the algorithms discussed in the course, as well as prompts to create a mind-map connecting different parts of the same algorithm and exploring how different algorithms approach the same problem. Sample questions can be found in Table 1. To encourage students to engage with these questions, these assignments were counted as bonus points towards their final grade. As a result, twenty-seven students (out of 30) completed the first reflection assignment before the first exam, whereas 25 students completed the second assignment.

2.2. Direct Assessment of Student Performance

To directly assess the impact of the reflection assignments on student performance, we analyzed the exam scores of two cohorts: the Spring 2023 cohort, where no reflection assignments were used, and the Fall 2023 cohort, where the reflection assignments were introduced for the first time in the course. In both semesters, the exams were kept the same, students had access to the exams only during the exam time, and the instructor used the same rubrics in both semesters.

Table 1. Sample Reflection Questions

How to map a vector from the original representation to a reduced Eigen-space? How is the Covariance matrix useful in that regard?
KNN does not learn an explicit hypothesis. Comment!
When is it guaranteed that gradient descent converge to local minima? How about global minima?
We can design linear regression, $y = \theta^T x$, to fit nonlinear functions. Describe how we can achieve that.
What is mutual information and how do you interpret it?
How does the loss affect the decision boundary?

Analysis of covariance (ANCOVA) [12] was conducted for the comparisons of exam scores between the two cohorts, with GPA at the start of the semester used as the control variable to take historical academic performance into account. Additionally, Hedge's *g* effect sizes were calculated to determine the practical significance of the differences, with values below 0.50 considered small and values 0.80 or above large [13], [14]. The Hedge's *g* was used in this study because it is appropriate for small samples [15].

2.3. Assessment of Student Perspectives

Student perspectives on the use of self-reflection assignments to prepare for the course exams were obtained by conducting anonymous surveys at the end of the Fall 2023 semester, prior to posting the final grades. The survey consisted of two questions. The first question was a Likert scale question aimed at gathering students' opinions on how the reflection assignments aided in deepening their understanding of the course materials and preparing for the exams. The second question was an open-ended free form question that allowed students to discuss any specific aspects that helped them. The survey questions are shown in Table 2. Human subjects' IRB exemption was secured for this form of student assessment. Participation in the survey was voluntary and no incentives were given for participation. In total, twenty-two responses were collected and analyzed (73% response rate). Since the second questions' responses were in a free form, we content analyzed them using a coding scheme similar to those developed as part of previous studies [11], [16]–[18].

3. Results and Discussion

3.1. Direct Assessment of Student Performance

Table 3 presents a summary of the ANCOVA analysis results comparing exam scores before and after the introduction of self-reflection assignments in the machine learning course. There was no significant difference in students' scores pre- or post the introduction of the reflection assignments. In Fall 2023, when reflection assignments were used, the scores of the second exam were higher compared to Spring 2023, where no reflection assignments were used. However, the scores of the first exam in Fall 2023 were slightly lower than those in Spring 2023. Nevertheless, according to the Hedge's size effect, these differences are not practically significant. Based on the data presented in Table 3, there is no significant evidence to support the claim that student performance in exams has improved as a result of using self-reflection assignments. This result is to some degree in alignment with Lew and Schmidt's in health sciences were they concluded that the enhancement is students acadimic performance was limited to some extent [9].

Table 2. Survey Questions

This semester, you were asked to reflect on the materials studied and answer reflection review questions. How strongly do you agree with the following statement? (Likert scale) a. The reflection assignments helped me deepen my understanding of the topics covered b. The reflection assignments enhanced my preparation for machine learning exams.
Whenever applicable, please discuss how the reflection assignment helped you to enhance you understanding of the algorithms and prepare for the exam.

Table 3: Exam score comparisons before and after the introduction of self-reflection assignments.

	Mean Score (100)		***p-value***	**Effect Size**
	Cohorts 1, No reflection assignment (*n*=21)	Cohort 2, With reflection assignment (*n*=30)	ANCOVA test	Hedge's g
Exam 1	74.52	74.26	0.93	0.02
Exam 2	65.5	67.1	0.69	0.11

3.2. Assessment of Student Perspectives on Self-reflection

The first survey question in Table 2 gathered students' perspectives on the effect of the reflection assignment on their understanding of the studied algorithms and on their preparation for the exams. More than 80% of the students found that the reflection assignments were helpful in both regards. Twelve survey participants (55%) strongly agreed that the reflection assignments aided a deeper understanding of the course topics. Thus, despite not significantly impacting exam scores, reflection assignments provide students with increased confidence when taking exams. The results of this question are summarized in Figure 1.

The content analysis of the second survey question revealed that the main strength of the reflection assignment was its ability to allow students to revisit and systematically review the course materials with a fresh and focused mindset, as stated by fourteen participants. This process helped them recall and reinforce concepts as they prepared for the exams. Four students mentioned that these assignments helped them to learn how everything worked from a high level and the general outline of the topics in this course. We quote the following from one of the student's responses: "since oftentimes the homework was at a deeper level, but the review helped me zoom out and review all the content in a short period of time to help me consolidate and remember the main points of all the important and main topics before the exam, so it was tremendously helpful for sure as one of the steps to help me prepare for exams." On the other hand, four students found it challenging to correlate the reflection assignment questions with the multiple-choice questions to be expected on the exam. We quote the following statement from one of the responses: "it was difficult to conceptualize or practice what the short answer process would be. Topics seemed either too complex or too broad to ever be applicable on an exam." Thus, overall, the reflection

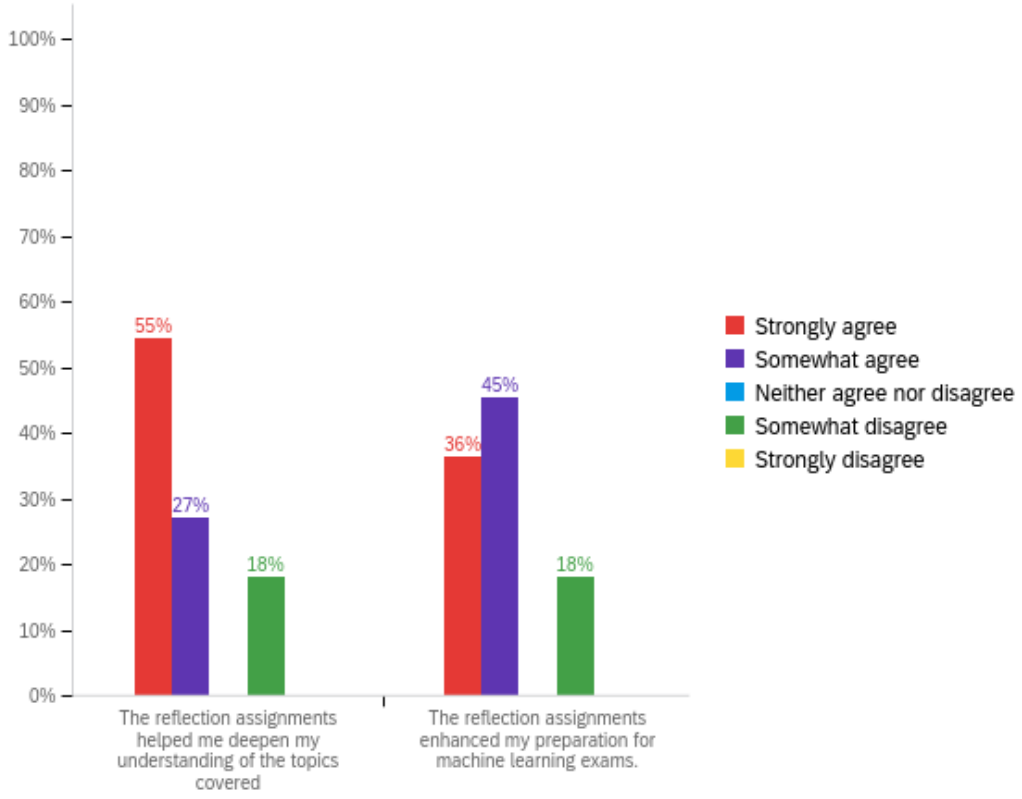

Figure 1. Students' responses to the first survey question.

assignments were a positive experience to the majority of the students to gain more perspectives and insights about the course topics. Clear instructions would be helpful to clarify that these assignments are not intended to serve as direct exam guides. Instead, students can utilize them to construct mind maps that aid in addressing the various aspects of each topic, ultimately enhancing their exam preparation. Additionally, modifying the format and frequency of the assignments might prove beneficial.

4. Conclusions

The machine learning course offered at the ECE department hosting this study covers several algorithms for regression and classification. The homework assignments focus on the practical aspects of implementing the covered algorithms and their applications on real data, while the exams concentrate on the theoretical aspects and conceptual understanding of the studied algorithms. In order to assist students in better preparing for their exams, we introduced self-reflection assignments before each of the course exams. Students were asked to reflect on the concepts and the connections between them. To assess the impact of these reflection assignments on students' exam performance, we conducted statistical analysis of variance between two cohorts of the course: one without reflection assignments from Spring 2023 and one with reflection assignments from Fall 2023. The scores of the cohort with reflection assignments were not

significantly different from those of the cohort without reflection assignments. However, when surveyed about their perspective on the use of reflective assignments, the majority of students indicated that these assignments had helped them recall and reinforce their conceptual understanding of the studied materials. Additionally, the assignments enabled them to see the bigger picture of how the different components of each algorithm are linked together. Future directions for this work include refining the assignment language and format, as well as collecting data from more cohorts to strengthen the statistical assessment conclusions regarding the impact of reflection on students' academic performance.

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