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WIP: Effectiveness of Different Reflection Approaches for Improving Mastery in an Engineering Laboratory Course

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Work-in-Progress: Effectiveness of different reflection approaches for improving mastery in an engineering laboratory course

Introduction

Providing students with detailed, descriptive feedback and having them reflect on what they have learned can foster self-directed learning [1], a critical ability for future engineers who need to be able to translate their skills and knowledge to novel situations [2]. Standards-based grading (SBG) has been slowly emerging in the engineering education field as a way to provide students with feedback on how well they are meeting course standards [3]. This grading approach contrasts traditional summative based grading which only shows students their performance on the assignment and fails to provide assessment of the learning standards with which they struggle. The use of SBG can help students transform their grade-centric mentality to a focus on learning. Our previous research investigated SBG implementation to evaluate lab reports in engineering lab-based courses and identified student weaknesses in two problem-solving standards: problem identification and interpretation [4].

Recent work demonstrating improved SBG value with structured reflection [5] motivates us to leverage reflection to develop students' metacognition with the ultimate goal of improving mastery in their weaknesses. For scientists and engineers, laboratory and design notebooks record a project from its start to completion. When done well, these notebooks are an inherently reflective practice on one's own learning, understanding, and decision-making process [6]. We hypothesize that reflection, especially if done while learning (e.g., lab notebooks) in addition to reflection after receiving SBG feedback, will improve student mastery in "problem identification" and "interpretation".

This work-in-progress aims to determine if there are differences in mastery (quantified by standards-based grading of lab reports) across different reflection implementations (post-assignment reflections, post-assignment reflections + reflection while doing with laboratory notebook). In addition, we plan to evaluate secondary outcomes such as student attitude and engagement with both the process of reflection and SBG, as well as the quality of reflections across offerings of a course with different reflection requirements.

Methods

Course and student population

This ongoing study is being performed in an introductory experimental design laboratory course that is required for sophomore undergraduate Biomedical Engineering students at Northwestern University. This course is offered twice a year with the same instructors and enrolls 20-40 students per offering. Students are grouped depending on the quarter in which they enrolled in the course (Quarter A "QA" or Quarter B "QB") and there are nominal differences between groups. Northwestern's Institutional Review Board has reviewed and approved the procedures of this study.

Reflection

As part of the course, students are assigned a draft lab report and a formal lab report for each 5-week course module [module 1 (M1) and module 2 (M2)] (Figure 1). These reports are submitted as a group and assessed using SBG of seven problem solving skills [4] (Appendix A).

Feedback on the draft lab report is only provided for standards 1–3. Participants enrolled in QA and QB, complete formal reflections similar to [7, 8] at three time points for each course module: 1) at the time they submit their draft reports, 2) after receiving their SBG on their draft report, and 3) after receiving their SBG on their final report (Figure 1). Students enrolled in QB will be asked to maintain a laboratory notebook as an additional reflective activity. Prior to assignment of the first reflection, all students are given some instruction on what a quality reflection may contain using students' examples from a previous course offering. All students are asked to complete an end-of-course questionnaire about their perceived value of reflection and their engagement with SBG.

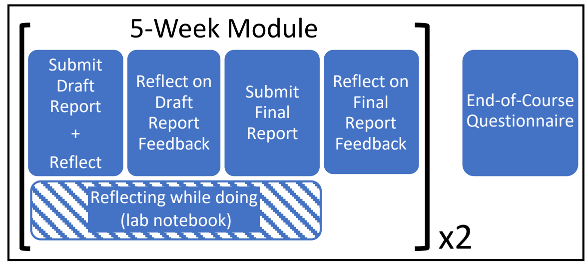

Figure 1: Schematic of the order of course reflection activities assigned to both QA and QB students (solid) and those assigned only to QB students (diagonal stripes).

Assessment of mastery, reflection quality, and student attitude and engagement

Student mastery is assessed using SBG of the draft (three problem-solving skills) and final lab reports (seven problem-solving skills). Quality of student reflections are evaluated using a 10-point scale (Table 1). This quality evaluation was developed after reviewing other studies that evaluated reflection quality [8, 9] and reviewing student reflections from a previous offering of this course. This quality scale assesses whether the student reflection responds to what is being asked for in the reflection question, is relevant to the learning objectives, and is specific. Because reflection prior to receiving SBG only asks students to respond to question 1, the quality of that reflection is based on a 4-point scale (Table 1).

Student attitude and engagement are evaluated through an end-of-course questionnaire. This questionnaire was adapted from Carberry, *et. al.*, 2013 [10] and Diefes-Dux & Castro, 2019 [11].

Table 1: Reflections Questions and Quality Scale

Reflecting **before** SBG feedback is returned	Reflecting **after** SBG feedback is returned	Quality of reflections each ❑ = 1 point.
1. What do you believe you **have** and **have not** learned and achieved in this assignment?	1. What do you believe you **have** and **have not** learned and achieved in this assignment?	❑ Includes statements about course content ❑ Evaluates what the student (individually) **has** learned ❑ Evaluates what the student (individually) **has not** learned ❑ Makes a connection between the student's learning and the course content
N/A	2. How well do you think the evaluation of your work (the points-based grade) represents what you have/have not learned and achieved?	❑ Makes a connection between the student learning and the course standards
	3. What learning objectives/standards are high priority for you to focus on developing going forward?	❑ Includes statements about course objectives/standards as specified in the course syllabus. ❑ Makes a connection between what the student **has not** learned and the course objectives
	4. What specific **actions** do you plan to take based on our evaluation of your work?	❑ Addresses a weakness in the learning objective identified in 3 ❑ The action to be taken is specifically described ❑ The action is realistic and achievable

The students are asked to choose to what extent they "agree" with various statements about SBG, reflection, their use of lab notebooks, and their learning in the course (Appendix B). A 4-point Likert scale (strongly agree, agree, disagree, strongly disagree) is utilized.

Statistical Analysis

A lower-tailed Mann-Whitney-Wilcoxon Rank sum test will be implemented to assess if there is a statistically significant difference in mastery of course standards and in quality of student reflections between quarters (QA and QB), modules (M1 and M2), and draft and final assessments. Student engagement with, and attitude toward, SBG and reflection will be compared between quarters. Across all analysis, $p < 0.05$ will be considered statistically significant. Hake's gain (HG = (post – pre)/(max score – pre)) will be calculated and presented to show a normalized improvement in student mastery or reflection quality between quarters (QA and QB), modules (M1 and M2), or draft and final assessments [12].

Initial Findings

To date, we have enrolled 18 students in QA and they have completed M1. There was significant improvement in student mastery between the draft and the final report of M1 for all three problem solving skills evaluated (problem identification: HG = 0.8, $p = 0.039$; knowledge processing: HG = 0.6, $p = 0.019$; approach/experimental design: HG = 0.6, $p = 0.012$).

Student reflection quality prior to receiving SBG feedback on the draft was on average 3.31 ± 0.6, out of 4. Quality of student reflection after receiving SBG feedback on the draft and after receiving SBG on the final report were, 7.69 ± 2.10 and 7.94 ± 2.14, respectively (on a scale of 10). There was a significant improvement in quality of student reflection between student reflection on standards-based feedback of the draft and standards-based feedback of the final report (HG = 0.11; $p < 0.001$).

Conclusion and Future Work

This study will provide insight into how the integration of reflection (i.e. reflecting post-assessment vs reflection post assessment + reflection while doing) affects mastery of standards, quality of student reflections, and student attitude toward SBG. Our preliminary data collection has found improvement in student mastery and the quality of student reflections between the draft report and final report of module 1 in this course. Though it is early in the data collection stage, this may suggest that the act of students receiving feedback and reflecting on their feedback aids in student mastery of course standards. It is notable that the greatest improvement we saw in student mastery was in problem identification; this is a problem-solving skill we have previously identified as being weak in students in our department. Through the completion of this study, we aim to gain understanding of how different reflection types may benefit the use of SBG as feedback for student learning. We expect that providing engineering students' optimized opportunities to reflect on their learning will aid their development as self-directed learners.

Though we have focused on implementing reflective practices in a laboratory-based course, we believe the use of reflection can be integrated and valuable to a variety of courses (e.g., traditional, project-based, etc.). To see the value of combining SBG and reflection the course would need to allow for multiple assessments of each learning objective; students need the opportunity to identify learning objectives in which they are weak, make a plan to improve, time to execute that plan, and ultimately see if they have improved upon or mastered that learning objective as the course progresses.

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APPENDIX

A. Standards Based Grading

Table 1: Course Standards

	Problem Solving standard (PSS)	Description
1	Problem Identification	Identifies problem and construct a hypothesis. Show a strong connection to the literature.
2	Knowledge Processing	Locates, evaluates, integrates, and applies knowledge to support hypothesis. Assesses the accuracy of conclusions in literature and generates original critique of third-party methods or assertions.
3	Approach/Experiment Design	Formulates the approach and appropriate experimental design.
4	Analysis	Analyzes and graphs appropriately data needed to test hypothesis
5	Interpretation	Interprets analysis to draw conclusions about hypothesis and ties to greater significance.
6	Communication	Demonstrates clarity, organization, appropriate format, good use of graphics, and correct scope (appropriate for audience). Presents credible information accurately. Uses citations appropriately.
7	Teamwork	Establishes goals, plans tasks and assigns responsibility to individual team members, meets deadlines, and communicates effectively

B. End-of-Course Questionnaire

This will be assigned with the final. On a Likert scale - 4 point (strongly agree, agree, disagree, strongly disagree).

<u>Value of SBG Reflection Activity</u>

1. The standards-based grading reflections used in this course…
   a. motivated me to do well in the course.
   b. required too much effort.
   c. was an effective way to increase my engagement in the course.
   d. helped me better understand my own personal learning.
   e. made me frustrated and anxious.
   f. required too much time.
   g. increased my level of responsibility for my own learning.
2. The material learned in this course…
   a. will be of value to me after graduation.
   b. was useful in my pursuit of my career and/or graduate school goals.
   c. helped me see the relevance of engineering to the real world.
   d. helped me learn the importance of experimental design to biomedical engineering.
3. I would like to see reflections used in other courses.
4. I would recommend this course to a friend.

<u>Engagement with SBG System Questionnaire</u>

Referring to the standards while completing work:

- While completing the written deliverable for Module 1, I referred to the standards listed on the grading rubric.
- While completing the written deliverable for Module 2, I referred to the standards listed on the grading rubric.
- While studying for the final exam, I referred to my progress towards meeting course standards in the learning outcomes tab of Canvas.

Metacognition:

- I believe that having access to the standards associated with the written deliverable makes me aware of what I need to learn.
- I believe that having access to the standards associated with the course guides my study habits.

Reflection on Assessment/Standards-based Grading:

- I reviewed my team's performance on the standards soon after feedback on a project milestone was released.
- I plan to review my performance on the standards associated with the final exam after feedback is released.

- I believe that having my work assessed based on the standards keeps me aware of what I have and have not learned.
- I used the assessment of my performance on Module 1 standards to guide my work on Module 2.
- I used the assessment of my performance on the standards to guide my preparations for the final exam.
- I believe that having my work assessed based on standards guides my study habits.
- I believe that all courses should use standards as the basis for assessment of my work.