

Insights into Student Metacognition from Reflective Writing in an Introductory Studio Physics Course

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Learning is a process that involves mutual responsibility and practice adjustments. By mutual responsibility, we mean students' relying on their instructors and classmates for feedback as they proactively navigate new material. By practice adjustments, we mean changes in a student's approach to a course based on monitoring and evaluating their progress in the course. However, in introductory physics, many students struggle to adjust their practices in response to challenges encountered in the learning process. We studied these difficulties in an introductory studio physics course by assigning a weekly reflection journal with questions about the students' experience in the course, including the challenges they encountered and the study habits they practiced. These reflection assignments prompted the students to describe the roles fulfilled (or unfulfilled) by members of the course community, to identify practice adjustments (or lack thereof), and to self-assess their progress toward positive learning outcomes. We reviewed these students' final reflection assignment and recorded themes that emerged: These students talked about collaboration (interacting with a classmate in the learning process), course difficulty (degrees or progression of difficulty), responsibility (Who is responsible for the student's learning?), self-managed growth (the learner making adjustments or taking actions to maintain or assert agency over their learning), and a lack of change in their practices, capabilities, or success. These insights into the student learning experience will be used to further classify student responses and generate course improvements.

I. INTRODUCTION

Learning physics is known to pose difficulties for students. To meet these difficulties, students must monitor their learning and make adjustments to retain a trajectory toward success [1], but accurate monitoring and effective adjustments often require a measure of subject-matter familiarity [2]. We study this process by considering the metacognitive processes of framing and regulation of cognition.

Framing refers to the internal structure of expectations that learners use to understand their learning experience [3–5]. The frame with which a student approaches learning physics helps them identify activities as appropriate or productive toward that goal [6–8], an answer to the question, “What is going on here?” For example, one student might frame learning physics as a solitary endeavor (silently reading the textbook and working problems alone). Another student might frame learning physics as a collaborative effort (asking questions of classmates, offering nuggets of information to a group solving a problem). These different frames likely influence how each of these students responds to a given course structure (oriented around passive lecture or active small-group work) based on how they expect to position themselves within a course. This positional framing “refer[s] to the way in which participants understand themselves and one another to be related to one another in the interaction, especially regarding the kinds of contributions each of them is entitled, expected, and perhaps obligated to make” ([4], page 2).

Regulation of cognition refers to learners’ making adjustments or taking actions to maintain or assert agency over their learning [9, 10]. Such adjustments require planning, monitoring, evaluation, information management strategies, and debugging strategies [11, 12]. These skills can be taught directly to students [13–16] to maximize learning, reflectively learn from their mistakes, and develop independence as learners [9, 17, 18]. One means of delivering this training is “to create a learning environment where students are required to explain and discuss their thought processes” ([9], page 1), such as in a studio physics environment [19]. While regulation of cognition is often applied in Physics Education Research to the specific activity of problem solving [20–22], we apply this concept to a larger grain of an entire course, where students must plan, monitor, evaluate, strategize, and debug how they navigate the course as a whole.

Based on this framework, we conceive of learning as a process that involves progressive practice adjustments: a change in behaviors, expectations, and self-management with a goal of improving the student’s odds of succeeding in the course. We view these changes as “progressive” in the sense that they build upon one another, ultimately producing the student’s trajectory within the course. The trajectory that results from these practice adjustments might produce a positive outcome (such as a student’s homework scores improving) or negative outcome (such as a student withdrawing from the course). Therefore, it is critical that instructors and students explicitly attend to this process. We pose the research

question: What challenging experiences prompt students to change their study practices in a studio physics course?

II. COURSE CONTEXT

We explore this question using course materials collected in a first-semester calculus-based introductory physics course during spring 2021 at a mid-sized regional state university. This 104-student course was team-taught using a studio physics format [19]. The typical week in this course required students to watch a 25-minute pre-lecture video before each of two 50-minute lectures to introduce new material, and participate in two two-hour studio sessions to collaboratively explore course material. A Friday session was dedicated to homework review or conducting biweekly exams. Assessments included quizzes about the pre-lecture videos, Letters Home [23] about studio activities, problem sets, and a weekly reflective writing assignment. To support this heavily structured format and provide students with metacognitive training [13–16], the instructors invested a studio session at the beginning of the semester to discussing research-demonstrated benefits of active learning and guiding each student in creating a weekly schedule to complete coursework.

The reflective writing assignment, released each Friday and due Monday, posed free-response questions about the students’ experience in the course, including their study habits. On average, each student completed 11.5 ± 3.9 of the 14 reflection assignments. The instructors discussed these reflections each week and used students’ comments to adjust course pacing, identify topics for review, and offer recommendations to students. Many reflection questions prompted the students to reflect on the roles fulfilled (or unfulfilled) by themselves, their instructors, and their classmates; to identify practice adjustments; and to self-assess their progress toward positive learning outcomes. Here, we examine responses to the final reflection assignment, found in Appendix A.

During the students’ final reflection assignment, we asked if they would consent to participate in this study by allowing us to review their reflection assignments. Since we designed this study half-way through the semester, we presented them the option to allow all of their reflection assignments to be reviewed or just their final reflection assignment. The materials collected represent a time-evolving self-assessment of the students’ progress during the course and we are currently reviewing these submissions. Of the 104 students in the course, 15 consented to having only their final reflection assignment reviewed and 47 consented to having all their reflection assignments reviewed. Here, we examine themes we identified in the $N = 62$ students’ final reflection assignments.

III. THEMES IN STUDENT REFLECTIONS

Three authors independently reviewed the students’ final reflection assignment. During this review, they recorded pre-

liminary themes that emerged across multiple students' reflection assignments. We met to discuss themes, finding that the authors had identified many overlapping themes with common example instances. We spent two rounds of discussion revising our theme descriptions, combining the preliminary themes into common ideas. With these descriptions agreed upon, we returned to the reflection assignments to collect example instances of each theme. In this review, our unit of analysis was each student's response to each prompt in the final reflection assignment. A given response could be coded with more than one theme, but the excerpts that follow were chosen to clearly highlight a single theme rather than a combination of themes. These themes center around the students' descriptions of their practice adjustments (or lack thereof) and their sense of mutual responsibility between themselves, their instructors, and their classmates. We then discussed these themes and developed agreed-upon descriptions for identifying instances of each, as follows:

1. Collaboration: The response mentions the learner interacting with a classmate in the learning process.
2. Difficulty: The response comments on degrees of difficulty or progression of difficulty in the course.
3. Inauthentic: The response does little more than repeat the question as a statement.
4. Responsibility: The response discusses the degree to which a member of the class community (individual student, instructor, or classmates) bears responsibility for a student's learning.
5. Self-Managed Growth: The response mentions the learner making adjustments or taking actions to maintain or assert agency over their learning.
6. Static: The response mentions a lack of change in practices, academic ability, or success in the course.

In the subsections that follow, we illustrate each of these themes with excerpts from the students' final reflections. Future work will examine the frequency with which each of these themes arose across all reflection assignments.

A. Collaboration

The theme of *collaboration* means a response that mentions the learner interacting with a classmate in the learning process. The studio format of this course required students to work in groups for 6-8 hours per week, so instances of this theme help illuminate ways in which students found this group work a help or a hindrance. This theme helps address our research question by giving insight into how students made use of their groups as a learning resource. This theme can be subdivided into *positive experiences* and *negative experiences* with collaboration.

Positive Experiences: For example, one student found the group work in this course to be a more positive experience than previous group work: "I've always been independent in my classwork and never really liked working in groups. This was one of the first classes I've had difficulty in and I'm

so glad I had amazing classmates that provided help when needed." We note that this positive perception is framed by the perceived difficulty of the course (their first time facing a significant challenge) and determined by the classmates' support ("help when needed"). Another student made a similar comment: "I never really thought about the roles I would like my peers to play in my learning, however, after having multiple sessions that caused me to have to figure things out with only my peers, I understood what roles I would like them to fulfill." This student's expectations for collaboration were previously unformed, giving them no framework for the experience, but now they have a clearer framework for such expectations as they continue in their coursework.

Negative Experiences: One female student commented, "In the beginning of the semester, I had higher expectations for collaborating with classmates. After I was ignored by a couple boys I worked with, my perspective may have changed. I am the one who usually tutored people in physics." This describes a shift to a more negative framing of collaboration. Another student thought the group-oriented design of the studio format was a significant challenge: "The amount of times I heard students saying they had no idea what was going on in the class [was] too many. It was blind leading the blind."

B. Difficulty

The theme of *difficulty* means a response that comments on degrees of course difficulty or the progression of difficulty throughout the semester. Instances of this theme can include statements of course difficulty overall, difficulty of particular topics or assignments, or the progression of course difficulty (becoming more or less difficult) over the semester. This theme is relevant to our research question since it helps us identify challenges that students faced, and then examine whether those challenges prompted a practice adjustment. Statements in this theme talked about the *impact of course difficulty*, the *pacing of topics*, and *encouragement*.

Impact of Course Difficulty: These students' comments illustrate how that perception impacted their engagement over time. For example, one student reported that they started out "very active in this class and I engaged and was participative. [Later], not so much. As concepts became more out of my grasp, my mental state when in class or even thinking about this class just completely shut down. It became more difficult to convince myself to get started on work. Even though I attended class, I didn't feel like I was actually present." This student found difficulty with engagement stemming from difficulty in conceptual understanding.

Pacing of Topics: Another student found difficulty with the timing of course events: "I felt lost almost from the beginning of this class and I am ending it feeling just as lost. There is not a moment's rest in this class because as soon as I somewhat understand a concept, we are thrown into another." We note the contrast between "somewhat understand[ing] a concept" (which one might take as a positive comment on its own) with

concurrently feeling “just as lost” throughout the semester.

Encouragement: Not all student comments about course difficulty were entirely negative. The student who commented about the “blind leading the blind” also described feeling encouragement in the midst of this difficulty: “Hear[ing] students saying they had no idea what was going on in the class made me feel slightly better because I was one of those students for like all of the semester.” We will see more of this need for emotional support when we discuss the theme of Responsibility.

C. Inauthentic

This theme is used to identify responses that do little more than repeat the question as a statement. For example, in response to the prompt, “What roles do you think your instructors should ideally play in your learning process in this course?” one student wrote, “I think the instructors play major role in students’ learning process in this course.” Another student answered this question with, “My instructors should take on the role of instructors,” and in response to the similar question about their classmates, they wrote, “My classmates should play the part of classmates/groupmates.” We take instances of this theme as a sign of student disengagement, at least with the individual question being answered. We expect such responses to be associated with a lack of progress in the course, and plan to examine how instances of this theme correlate with themes found in more complete responses made by the same student to other questions.

D. Responsibility

This *a priori* theme is based on the concept of positional framing described in Section I [4] and indicates that the response discusses the degree to which a member of the class community (individual student, instructor, or classmates) bears responsibility for a student’s learning. Reflection questions 1-9 were specifically designed to elicit students’ perspectives about this aspect of learning. This theme helps address our research question by giving insight into students’ sense of ownership over their success in the course: Do they see success primarily residing within their own autonomy, or as dependent on the actions of their instructors or classmates?

Student Responsibility: One student described their personal responsibility in terms of time management: “I needed to be active in coming to class and participating in activities. I needed to be on top of my work and constantly sticking with my study [plan].” In contrast, another student focused their comments about responsibility on achieving final conceptual understanding: “[Group work] may be helpful if the classmates understand and help you when you’re struggling, but it’s ultimately up to you to understand topics.”

Classmate Responsibility: The female student we previously heard from about “usually tutor[ing] people in physics”

also commented, “Some of my classmates were helpful when we worked in groups during studio and breakout sessions, but I don’t depend on my classmates to learn.” She seems to have adopted a disproportionate responsibility toward her classmates to tutor them with no reciprocal support.

Instructor Responsibility: Students’ comments about instructor responsibility spanned a spectrum of their instructors bearing little direct responsibility to total responsibility for student learning. For example, one student wrote, “An instructor can bring a student to the waters of understanding, but cannot force them to drink from it,” while another reported an increased reliance on their instructors during the semester: “I was not aware of how essential professors are to how well a student does on a subject, but now I know that it plays a large role in not only our perspective of the material but also our willingness to learn.” One student felt that instructor responsibility should greatly outweigh classmate responsibility: “My instructors should play the role of expert teaching on the subject. Expert teaching [this student’s term for direct instruction] should make up 75% of all courses.” This student’s responses to other prompts indicates that they were contrasting direct instruction in other courses with the studio format in this course.

Many students framed their instructors’ roles in terms of responsiveness to students’ needs. For example, one student said, “Instructors should be patient with their students, and figure out the best way to teach their students.” In several students’ reflections, this idea of responsiveness included emotional support: “[Instructors] are not meant to be distant and should be able to make students feel comfortable with the material. There were times when they were too distant with us as a whole and this created some anxiety from the students.”

As part of this course’s assessment, we administered the Colorado Learning Attitudes about Science Survey (CLASS) [24] at the beginning and end of the semester, which quantitatively describes students’ attitudes toward physics. CLASS item 12 (“I cannot learn physics if the teacher does not explain things well in class.”) touches on this subject of instructor responsibility. Of the 83 students who completed the CLASS post-survey, 65 (78%) reported agreeing or strongly agreeing with this statement. This agreement confirms that many of these students place significant responsibility for learning on their instructors.

E. Self-Managed Growth

This theme includes responses that mention the learner making adjustments or taking actions to maintain or assert agency over their learning. This theme therefore represents the clearest examples of students making practice adjustments during the semester. For example, this student comments on specific tasks required to manage their learning: “I should put in the time and pay attention to what is being taught and doing the assignment in order to understand the topic.” This sounds similar to the previously quoted stu-

dent who talked about “be[ing] on top of my work and constantly sticking with my study [plan].” As we expand our analysis to include the students’ reflections from the entire semester, we will attend to how these perspectives evolved.

F. Static

This theme indicates that the response mentions a lack of change in the student’s practices, academic ability, or success in the course. As we identify examples of this theme throughout the students’ reflections, we are interested to see whether this theme correlates with a lack of practice adjustments or unsuccessful practice adjustments. For example, one student touched on all aspects of this theme when they said, “I guess I could’ve gone for a higher grade [success], but nothing really sticks out to me as extremely lacking [academic ability] and it just would’ve required more time input for diminishing returns [practices], something I wasn’t on board for.” This student’s lack of progress seems rooted in a sense of futility.

IV. DISCUSSION AND CONCLUSIONS

This initial analysis offers insights for instructors. Particularly, we see that this implementation of studio physics left some students feeling behind, even with instructors’ attending to course pacing and helping students establish reasonable expectations for an engaged-learning course. We think that the initial class period dedicated to teaching students about engaged-learning strategies seems to have helped frame their discussion of the course. For example, the student who commented that they became less “engaged and participative” still seems to value these elements of the learning process. The student who commented that instructors should play the role of instructors and students should play the role of students is not drawing on vocabulary introduced in this discussion. Still others seemed to maintain a preference for direct instruction (“expert teaching”) despite this discussion. We suggest that a more sustained discussion of this topic would be helpful.

We have described learning as a process that involves progressive practice adjustments, in which students change their behaviors, expectations, and self-management with a goal of improving their odds of succeeding in a course. This study asked students to reflect on this process in an end-of-semester writing assignment. We present excerpts describing students’ perceptions of how collaboration, course difficulty, responsibility, and self-managed growth impacted their progress through the course. We plan to trace these themes in further analysis of reflective assignments throughout the semester.

Appendix A: Final Reflection Assignment

These questions ask about the role of your instructors in your learning.

1. What roles do you think your instructors should ideally play in your learning in this course?
2. How well do you think they fulfilled those roles?
3. Do you think your perspective on Question 1 has changed over the semester? If so, how? Why?

These questions ask about the role of your classmates in your learning.

4. What roles do you think your classmates should ideally play in your learning in this course?
5. How well do you think they fulfilled those roles?
6. Do you think your perspective on Question 4 has changed over the semester? If so, how? Why?

These questions ask about your role in your learning.

7. What roles do you think you should ideally play in your learning in this course?
8. How well do you think you fulfilled those roles?
9. Do you think your perspective on Question 7 has changed over the semester? If so, how? Why?

These questions ask about the weekly reflections.

10. How many of the weekly reflections led you to adopt a new practice or make a change in your approach to this course? None - Some - About half - Most - All

If you answered “Some”, “About half”, “Most”, or “All”, please answer the following:

11. Describe an example of a new practice or change in your approach to this course that you adopted as a result of a weekly reflection.
12. What was your goal in adopting this new practice or change in your approach?
13. Did the new practice or change in your approach help you accomplish your goal? Why or why not?

Rate your agreement on each of the following.

14. The weekly reflections often included questions I was already thinking about. Strongly Disagree - Disagree - Neutral - Agree - Strongly Agree

If you agreed or strongly agreed, describe an example.

15. I often thought about questions from the weekly reflection after turning in my answers. Strongly Disagree - Disagree - Neutral - Agree - Strongly Agree

If you agreed or strongly agreed, describe an example.

16. Approximately how much time did you spend on the Reflection assignment each week?

These questions ask about your accomplishments in this course.

17. What are you proud of from this course? How did you accomplish what you’re proud of?
18. What do you wish you could have accomplished in this course but didn’t? What do you think prevented you from accomplishing it?

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