Research article

Empowering Students: Transitioning to Self-Assessment of Written Exercises in Physics Courses

B. Irgens[1*], D. Micheron[1], and I.F. Pedersen[1]

[1] Faculty of Science and Technology, UiT the Arctic University of Norway

*Corresponding author. E-mail: borge.irgens@uit.no

Abstract: In Norwegian tertiary education, physics students typically spend considerable time on mandatory problem-solving assignments that they need to pass to qualify for the final exam. Frequently, the summative dimensions of these assessments are emphasized to a higher degree than the formative ones, which may limit the learning potential. In response, we modified these assignments by incorporating self-assessment, peer learning, and reflective practice, aiming to enhance formative feedback and student engagement.

This paper reports on the implementation of these modified assignments in two physics courses at UiT the Arctic University of Norway. Using student responses to an end-of-semester survey (N=64), we explore how the students participated in and perceived the modified assignments and their outcomes. The results indicate a predominantly positive response and a sense of improved learning, especially among first-semester students. Nevertheless, problem areas were also identified, such as a persistent focus on getting the correct answers rather than the learning process, and challenges with group dynamics. We discuss the implications of these findings for refining the assignments and suggest directions for future research.

Keywords: Self-Regulated Learning, Self-Assessment, Peer Learning, Feedback, mandatory assignments.

DOI: https://doi.org/10.5324/q94htp18

1 Introduction

In Norwegian tertiary physics courses, students are often required to complete and pass several qualifying tasks in order to gain access to an end-of-year exam. These tasks are frequently substantial mandatory written assignments that students solve individually and submit for evaluation by a teaching assistant (TA), who assigns a pass/fail grade. This process also serves formative purposes by both enabling TAs to correct errors and encouraging student engagement throughout the semester instead of cramming right before the exam. Student engagement – broadly understood as the behavioral, cognitive, and emotional involvement in the learning process (Fredricks et al., 2004) – is important for student learning (Lei et al., 2018). However, encouraging engagement with graded written assignments can also foster reliance on external validation and consume significant instructor resources (Boud & Molloy, 2013). Recently, Hellem and Lorås (2020) found that students exempted from mandatory assignments performed on the same level as their peers who followed a course regime with mandatory assignments, but they still argue that mandatory assignments are a way to ensure engagement with a wide variety of learning goals. Other authors advocate for their replacement with voluntary peer-assessment activities to maximize the formative learning potential (Haugan & Lysebo, 2018). Building on these insights, we modified the mandatory assignments to enhance their formative function while retaining their function as qualifying tasks for the exam. The modified assignment aims to build students' capacity to create their own feedback and use it to direct their learning by focusing instruction on peer learning, formative self-assessment, and self-regulated learning.

Self-Regulated Learning (SRL) is an umbrella term encompassing several theoretical models for how students can play a proactive role in their learning process. Zimmerman's cyclical model (1986) is one influential model of SRL, which incorporates forethought, performance, and self-reflection phases. In the forethought phase, the student analyses the task, sets goals and strategies, and self-motivates. During the performance phase, these strategies are executed while the student is self-monitoring. Finally, in the self-reflection phase, the student evaluates the learning outcomes and plans adjustments for future learning activities. Several studies have found a positive correlation between individual student SRL and achievement, though it is unclear what causes the effect (Jansen et al., 2019).

To support self-regulated learning through formative assessment, Nicol & Macfarlane-Dick (2006) highlight key principles, including providing clear criteria, developing self-assessment and reflection in learning, and encouraging dialogue with teachers and peers about learning. They also emphasize the need for feedback to be actionable, support positive motivation and self-esteem, and give high-quality information to the student to guide learning. The self-assessment process, which involves students analyzing the quality of their learning processes and outputs, can supplement or even replace feedback from the teacher. Implementing self-assessment in a group setting, involving peers and TAs, gives an excellent opportunity for rich dialogue about learning. However, effective group dynamics are crucial for the process to succeed. Social interdependence theory implies that successful group learning requires individual accountability, interdependence among group members, and a collective effort toward the group's success (Johnson et al., 2014). By making the students individually accountable for their work and dependent on the rest of the group

to succeed, we may enhance learning and prevent social loafing, where individual effort diminishes in a group context.

The first aim of this paper is to describe how we modified the mandatory assignments in two physics courses by adopting a three-step process comprising individual work, collaborative self-assessment, and reflection exercises (see section 2.2). The second aim is to investigate how students engaged with the modified assignments, by investigating the following research questions:

- How did the students participate in each phase of the modified assignments?
- How did the students perceive the modified assignments and their outcomes?

By exploring these questions, we aim to gain insights into the potential of the modified assignments for fostering independent and self-directed learning among our students. These insights will provide valuable guidance for refining this approach in future iterations.

2 Methods

2.1 Description of the courses

FYS-0100 General Physics is a first-semester course covering fundamental Newtonian mechanics, fluid mechanics, and thermodynamics. FYS-1001 Mechanics is a third-semester course on intermediate Newtonian mechanics, waves, and special relativity. Both courses are primarily intended for students of physics, mathematics, and related fields, as well as pre-service secondary school teachers. Instruction each week consisted of three hours of whole-class active learning activities. For FYS-0100 this consisted of Peer Instruction (Mazur, 1997) and for FYS-1001 it consisted of Team-Based Learning (Michaelsen, 2002). Both courses also offered a 90-minute seminar in smaller groups and TA-led help sessions.

To be eligible for the final written exam, which accounted for 100% of the course grade, students were required to achieve a passing grade on at least four qualifying tasks throughout the semester, including some of the modified assignments described in this paper. These assignments comprised four out of six tasks in FYS-0100 and two out of five in FYS-1001. The number of assignments each student completed could vary because of this flexibility, but most students opted to participate in all of them.

The first and second authors taught FYS-1001 and FYS-0100, respectively. This dual role could influence data collection and interpretation, leading to potential biases. Measures to address this are described in sections 2.3 and 2.4.

2.2 The modified assignments

Motivated by what we perceived as a limited effectiveness of the traditional assignments in promoting deep learning and engagement, we modified them to be more formative and supportive of SRL. This redesign incorporated self-assessment, reflective practice, and peer learning to engage the students actively in the feedback process, based on the method of Mota et al. (2019). The modified assignments comprised individual, group, and reflection phases with corresponding student deliverables, jointly determining an overall pass/fail grade. Each phase is described in detail in the following subsections.

2.2.1 Phase 1 – Individual assignment

In the first phase, students were assigned three to four relatively challenging problems to work on individually. The students submitted their solution drafts to promote independent accountability for preparation, an essential factor for fostering effective group dynamics in the subsequent group phase. Additionally, the students could test their ability to solve complex physics problems independently, which we considered beneficial because of the final individual exam. However, we encouraged students to seek instructor guidance if they needed help to get started.

We wanted students to practice getting started on a problem by themselves, so to reduce stress and collaboration in this phase, we assessed the deliverable on effort rather than correctness. To help the students work productively on the problem, while also making their reasoning visible for feedback, we encouraged them to use a four-step problem-solving strategy:

1) **Understanding the problem:** Students focus on understanding the problem statement by rephrasing it, drawing relevant diagrams, and identifying known and unknown parameters.
2) **Formulating a plan:** Students make appropriate assumptions and select applicable principles and equations while providing justifications for their use.
3) **Executing the plan:** Students solve equations and perform other calculations to arrive at an answer.
4) **Evaluate the answer:** Students evaluate their answers critically by performing unit checks and considering limiting cases to ensure the consistency and reasonableness of their answers.

This strategy, similar to others used in physics education literature on problem-solving (Burkholder et al., 2020; Heller & Reif, 1984), aimed to help students work on a new problem and make their thought process transparent and structured. The strategy was modeled for the students through examples and in-class problem-solving. In FYS-0100, students were strongly encouraged to use a provided template.

We hoped this structured problem-solving strategy would foster the forethought phase of self-regulated learning, where the focus is on analyzing the task and setting goals, while also reminding students to self-monitor their work (Zimmermann, 1986).

2.2.2 Phase 2 – Collaborative Self-Assessment

After submitting their solutions, the students attended a seminar where they self-assessed them in small groups. Their instructions were to find, annotate, and comment or propose corrections on any conceptual and procedural errors in their work. A TA was available to answer questions and facilitate discussions throughout this process.

During the first half of the seminar, the students shared and compared their solutions, providing and receiving feedback from their peers. This allowed them to explain their solutions, find some errors, and gain new perspectives on the problems. In the second half, or if the discussion was winding down, the TA handed out the instructor's solution for comparison with their own.

After self-assessing, the students resubmitted their annotated solutions, which showed the insights gained from the group discussions. The TA assessed the annotations based on the degree to which students identified their errors and showed they

understood what they could have done instead, and could give additional feedback if significant errors were overlooked. This allowed the TAs to spend much less time grading and providing feedback on simple errors the students can identify, freeing up time for other activities—for example, giving feedback that focuses on the bigger picture of the student's understanding rather than looking deeply into problem-specific details. To summarize, this phase not only encourages students to self-assess and engage in dialogue with peers and teachers about learning, but also provides the students with high-quality feedback from the TAs, both key principles for promoting self-regulated learning through formative assessment (Nicol & Macfarlane-Dick, 2006).

2.2.3 Phase 3 – Self-reflection phase

Following the seminar where they self-assessed their solutions, the students completed an online reflection exercise. We hoped that reflecting on their learning processes in the context of the specific assignment and their broader coursework, and planning strategies for improvement, would feed into a new cycle of SRL. The exercise included:

- evaluating their overall understanding of the content included in the assignment.
- describing what they had learned through the activity and what they still found challenging.
- making plans to address these difficulties in the coming weeks.
- evaluating their learning process in the course as a whole[1].

Completing the reflection exercise was required, but the content was not graded to encourage honest reflections without the pressure of assessment.

2.3 Data collection

As part of the course evaluation, an online survey was administered at the end of the semester. The survey was organized around the different phases of the assignments, with questions addressing student participation, experiences, and perceptions related to each phase and the overall assignments. Quantitative data was collected through numerical response questions (e.g., time spent on assignments), rating scale questions (e.g., frequency of collaboration), and Likert-style questions (e.g., agreement with sufficiency of feedback). Consistent with a convergent mixed methods design (Creswell & Plano Clark, 2018), we collected complementary qualitative data to validate and illustrate the quantitative data and to give the students an opportunity to express their concerns. Free-response questions were used to elicit students' thoughts on specific aspects we were concerned about, on each phase, and the activity as a whole. English translations of the survey questions used in this study are available in an appendix.

Before participating in the survey, the students were informed about the research project. It was emphasized that participation was voluntary and that they could withdraw from the study and have their data deleted at any time without affecting their course experience or outcomes. The survey was conducted at the end of the semester to reduce

[1] For FYS-0100 students new to the university, additional questions on learning goals and participation in the offered learning activities were included to better highlight the connection between them.

the risk of students feeling pressured to participate or afraid to respond truthfully. It should also be noted that the survey was administered before the final exam, but that the exam was anonymous (blind grading). The Norwegian Centre for Research Data (NSD) approved the research protocol.

In total, 94 students took the exam in the two courses. Of these 29 of 52 students (56%) from FYS-0100 and 35 of 42 students (83%) from FYS-1001 completed the survey and provided informed consent for their data to be included in this study.

2.4 Analysis

Our analysis aimed to explore students' participation, experiences and perceptions related to the modified assignments by combining the quantitative and qualitative approaches.

Quantitative data analysis involved calculating descriptive statistics and creating graphical representations to facilitate interpretations. This approach gives us an overview of how the student population participated in, experienced, and perceived the outcomes of the assignments on quantitative measures. Data from the two courses are presented separately to show potential differences between the two student groups, though their responses did not differ substantially in most aspects.

Qualitative data analysis was based on a general inductive approach (Thomas, 2006). The purpose of the qualitative analysis was to elaborate on the overall quantitative findings by identifying themes that more deeply illustrate how the students engaged with the modified assignments. Therefore, we analyzed the qualitative data from both student groups together.

All three authors familiarized themselves with the data separately, noting first impressions and tentative codes. Subsequently, we met to discuss our findings and formulate themes based on our initial coding. In this phase, we observed that codes connected to participation were explicitly connected to concrete activities like the use of problem-solving strategies. For participation, the inductive analysis thus mainly led to a data reduction, resulting in a condensed description of students' participation patterns.

The codes connected to student experiences and perceptions, however, emerged from student responses across several different questionnaire items: There were some items designed to probe the students' perceptions of the assignments as a whole (e.g., What are the drawbacks/benefits of the new form of mandatory assignments), but students' experiences and perceptions would also shine through when they were asked to comment freely on different phases of the assignments, and sometimes even when they explained how they participated in the different activities. For student experiences and perceptions, we therefore found that identifying some overarching themes would best reflect what we saw in the data.

After discussing the qualitative data, the first author combined the qualitative and quantitative findings, and all three authors subsequently contributed to revising and refining the description of the themes. The resulting description of student participation was organized around the activities in the three phases, as the data concerning participation were directly connected to these phases. The description of student

experiences and perceptions, however, was organized according to the overarching themes that emerged from the qualitative analysis, as the qualitative findings here were less tied to specific activities and the quantitative data could also be linked to these overarching themes.

3 Findings

This section presents the results in two subsections: one focuses on how students participated in the different phases, and the other explores students' experiences and perceptions. The subsections will, however, overlap as each of these aspects inherently shapes the others, and we are interpreting the students' understanding of events.

3.1 Student participation

3.1.1 Individual assignment

The initial phase required students to engage in individual problem-solving tasks outside the classroom. We expected that students would spend some time attempting (but not necessarily succeeding) to solve the problems using the previously outlined problem-solving strategy. This section presents data on how students completed this task, focusing on time-on-task, collaboration, and problem-solving strategy use.

Time on task

In both the courses, students on average reported spending about ten hours per assignment and attempting all the problems in each problem set. It should be noted that we do not know how much time students used to spend on traditional assignments. Nevertheless, this was substantially more than we expected, given that they did not need to arrive at correct answers to pass. This substantial time investment suggests a significant effort on average. However, when asked to elaborate on how they worked on the assignments responses varied in distribution: while many reported spreading the work over several days, for instance "2 hours per day until I was done", others would do "long hours in the evening" right before the deadline. Notably, some students indicated that this was affected by mandatory coursework in other courses.

Collaboration

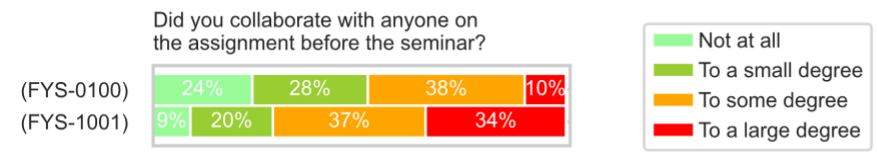

Figure 1. *The degree to which students reported collaborating with peers in the individual assignment phase.*

We suspected that some collaboration between students would occur despite instructions that students work individually in this phase. To investigate this, the survey included rating scale items where students indicated the extent and reasons for such

collaboration. As shown in Figure 1, most students, especially in the advanced course, collaborated at least a little in this phase. Figure 2 further reveals that the most common reported reasons for collaborating were difficulty understanding the questions, seeking help when stuck, comparing solutions, and a desire to learn more.

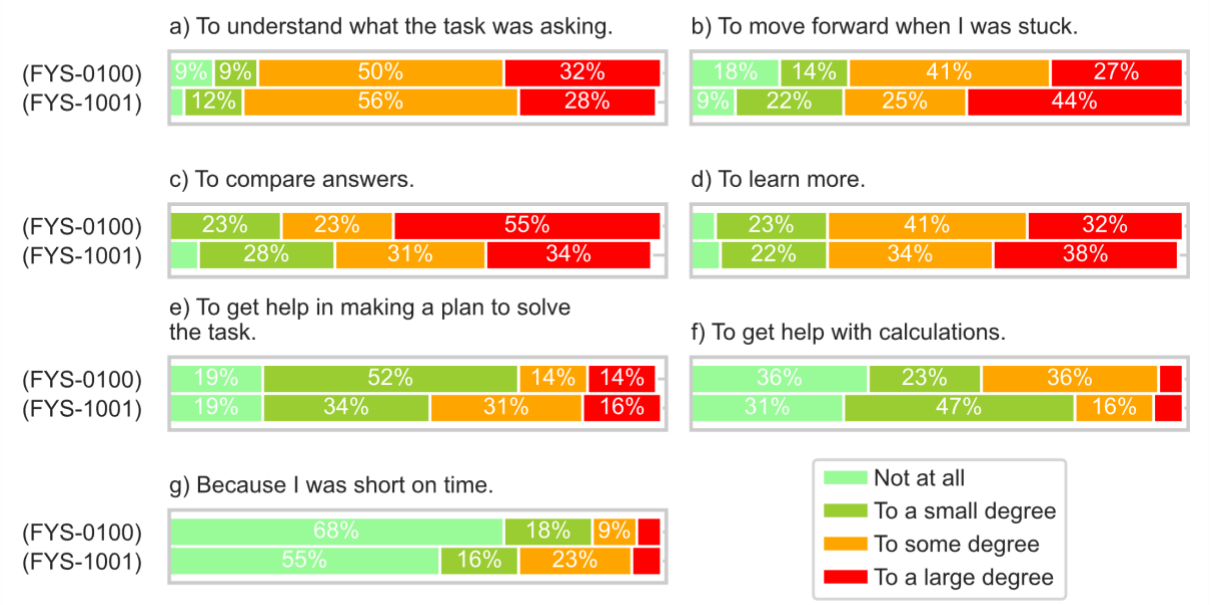

Figure 2. *Students' self-reported reasons to collaborate.*

In free-response items, students were asked to describe any additional reasons or ways of collaborating, and a few wrote about collaboration with peers when they described how they worked on the individual assignment. Their responses mirrored the quantitative results in Figure 2: Many explained that they collaborated when they got stuck in some way. For some, this collaboration aimed to get started on the problems, like the student who explained: "Before the seminar, I worked on my own and only asked others how they interpreted the task". Others attempted to solve the problems individually but sought help from peers when faced with difficulties (e.g., "I mainly work on the individual part alone, maybe discussing solution methods with others if I am struggling with the solution"). Additionally, some students explain how they primarily collaborated by comparing their solutions, and as one student put it, this made them "a little more confident that what I did was right".

Problem-solving strategy

To gain an understanding of whether students approached the problems as we intended, we asked them to indicate how often they used the recommended problem-solving strategy. As shown in Figure 3, the vast majority of students reported using this strategy either sometimes or all the time.

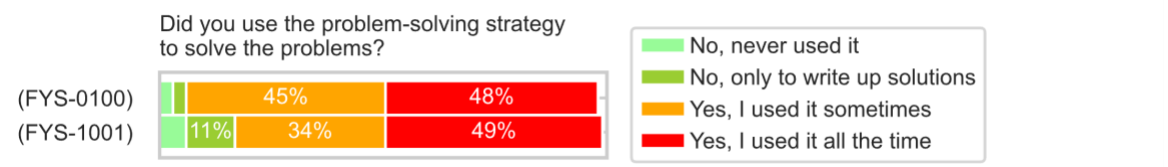

***Figure 3**. Students' self-reported use of the recommended problem-solving strategy.*

To better understand their approach, we asked the students to elaborate on how and why they utilized the strategy or chose not to. Their responses indicate a range of applications, from structuring solutions for clarity to using the strategy as a comprehensive guide to problem-solving. Statements such as "I used it to get a better overview of what I know, which theories I can use, and what the problem really is about," and "I followed the strategy religiously because I understood that it made me think in the right directions before doing calculations," illustrate how these students saw the strategy as a helpful way to approach understanding complex problems.

However, several students explained that they used only parts of the strategy or did not devise a plan before attempting a trial-and-error strategy. This is illustrated by students stating that "I start by analyzing the task and then draw figures and list what is known. Then I somewhat depart from the model, insofar as I do not devise a plan but use a trial-and-method, as this is what I am used to. I have started to try devising a plan first, but I haven't quite mastered it" or "At first, the plan is to try and err, therefore, I often go back and write a plan when I, after some trial and error, can see how to solve the problem". It seems some students expect (or think that we expect them) to follow the problem-solving strategy linearly, and indicate that this does not fit with how they often need to adjust their approach during the problem-solving.

Finally, we asked the students who indicated they did not use the problem-solving strategy why they chose not to. For most, it was related to time. Either just that it "takes a long time" or that "if you first make a plan and it turns out to be wrong you have wasted a lot of time". Others stated that "for me, this is an unnatural way to think", or that it was obvious how to solve the problem.

3.1.2 Collaborative Self-Assessment

The second phase was conducted during one of the 90-minute seminars. The students were instructed to find and discuss issues in their solutions and annotate them to demonstrate their improved understanding. A TA was present to answer questions and facilitate discussion.

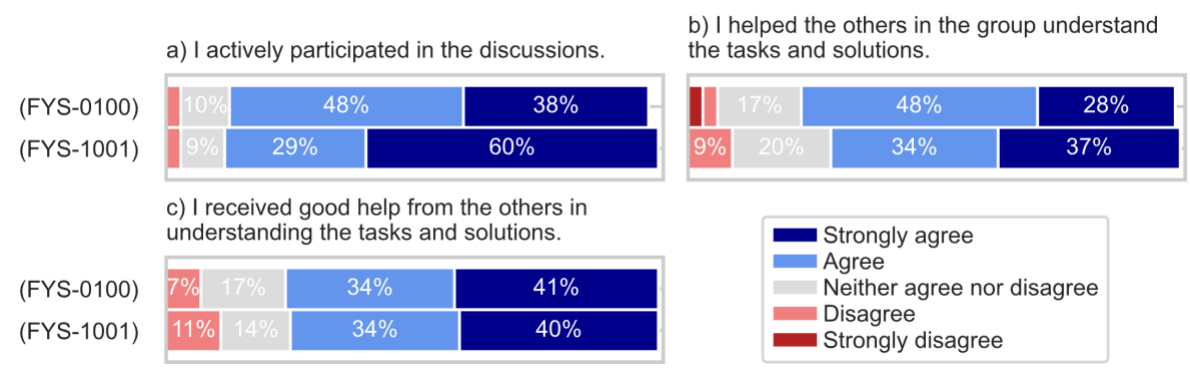

Figure 4. *Participation in group discussions.*

As Figure 4 shows, 70-80% of the students agreed or strongly agreed that they actively participated and gave and received help from their peers. However, this picture is somewhat nuanced by data from free-response questions asking the students to elaborate on how they experienced the collaborative self-assessment and on the perceived drawbacks of the modified assignments as a whole. From the student responses, it appears that some groups struggled with group dynamics, and the students presented different perspectives on why they had not worked well together. Many students highlighted challenges from group members they felt could have been better prepared or contributed more to the discussion, for instance stating that "there are several who participate little, and then we do not get a good discussion where everyone can learn". On the other hand, other students expressed that some dominant peers would "take control, and it feels more like we are sitting and listening to him/her learn the material than learning it ourselves."

3.1.3 Working with feedback

After self-assessing in the seminar, for the final organized phase of the activities, the students answered a reflection exercise with some questions encouraging them to reflect on how they did on the assignment and plan what they could do to improve. We were concerned with whether students were addressing the issues they identified, thereby engaging in the SRL-cycle.

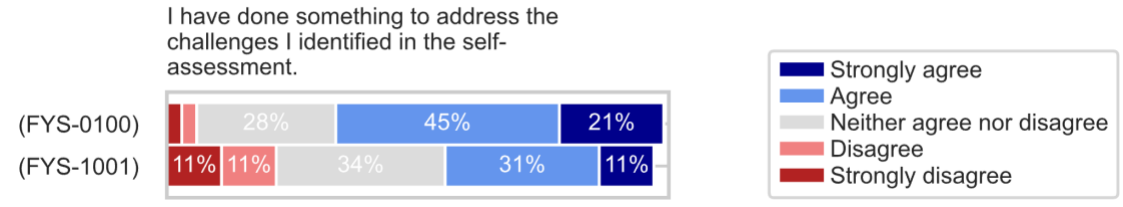

Figure 5. *Addressing self-assessed challenges.*

In total, a slim majority of students reported doing something about their identified challenges, as shown in Figure 5. We also included a free-response item asking the students to describe how they worked on the challenges they identified and whether they utilized the feedback they received from the TA. The most common theme involved taking

the identified challenges or TA feedback into account during the next mandatory assignment. At the same time, a few students describe how they utilized the feedback in their day-to-day studies, as two students put it: “I actively worked on the issues from the self-assessment when working on weekly homework sets, as well as subsequent mandatory assignments” and “I tried to do more exercises. Watch YouTube-videos on topics I struggle with.”

3.2 Students’ experiences and perceptions

This subsection focuses on students' experiences of the activity and their perceptions of the learning outcome. The findings are organized thematically to highlight overarching patterns and provide a more integrated understanding of the students’ experiences while avoiding redundancies. The findings are drawn from quantitative data from Likert-style questions and qualitative data from free-response questions.

3.2.1 Discomfort and the correct answer

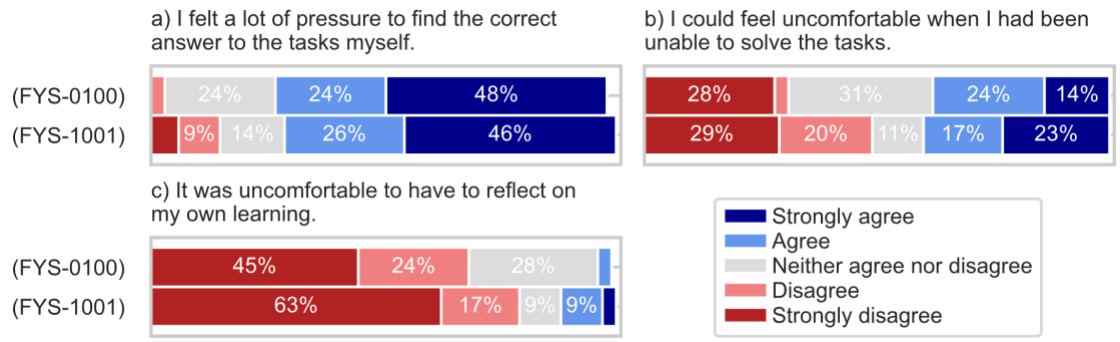

Figure 6*. Students’ perceptions of discomfort in unsolved tasks.*

We were concerned that some students might find parts of the activity stressful or uncomfortable, so the survey included a few Likert-style questions regarding aspects we thought could be stressful in the different phases. As shown in Figure 6a, most students felt pressured to find the correct answers during the individual phase despite our emphasis on the problem-solving process and effort over correctness in this phase. Afterward, Figure 6b shows that a notable proportion of students felt somewhat uncomfortable during the seminars if they could not solve some problems. On the other hand, Figure 6c shows that very few students found it uncomfortable to reflect on challenges in the self-reflection phase.

Preoccupation with finding the correct solutions was also a recurring theme in the qualitative data. The anxiety was expressed overtly in statements from some students – such as one that “felt a lot of pressure to get the right answer on all the problems" when commenting on the individual part, and another that explained that if “everyone else got [the task] right and I did not, it could be difficult to dare to say what I was thinking and ask if they could explain a bit more thoroughly” when commenting on the discussion phase. This also emerged implicitly through numerous statements about collaboration and comparing answers with peers. However, some students report that their perspective

changed over time. For example, one student said, “After a while, I understood that this is a learning process and not a test.”

3.2.2 Learning with peers

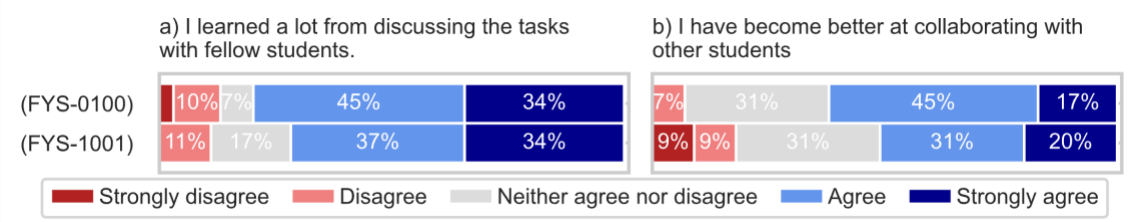

Figure 7. *Students’ perceptions of collaborating with peers.*

Most of the students felt their learning benefited from collaborating with peers. This was evident in both the students feeling that they learned a lot from the peer discussions during the seminars (Figure 7a) and from “learning more” being one of the primary reasons for collaboration during the individual phase (Figure 2d). Additionally, about half the students believed they had become better at collaborating with their peers (Figure 7b). The positive sides of collaboration were also a recurring theme in the free-response items wherein the students were asked to comment on the seminar phase and benefits of the new design. Generally, many students expressed appreciation for “better facilitation for discussion with peers.” A few students explained why they found this beneficial, for instance, that you “see and discuss different solution pathways” and “remember the content better when you explain to the others in the group.”

3.2.3 Working with feedback

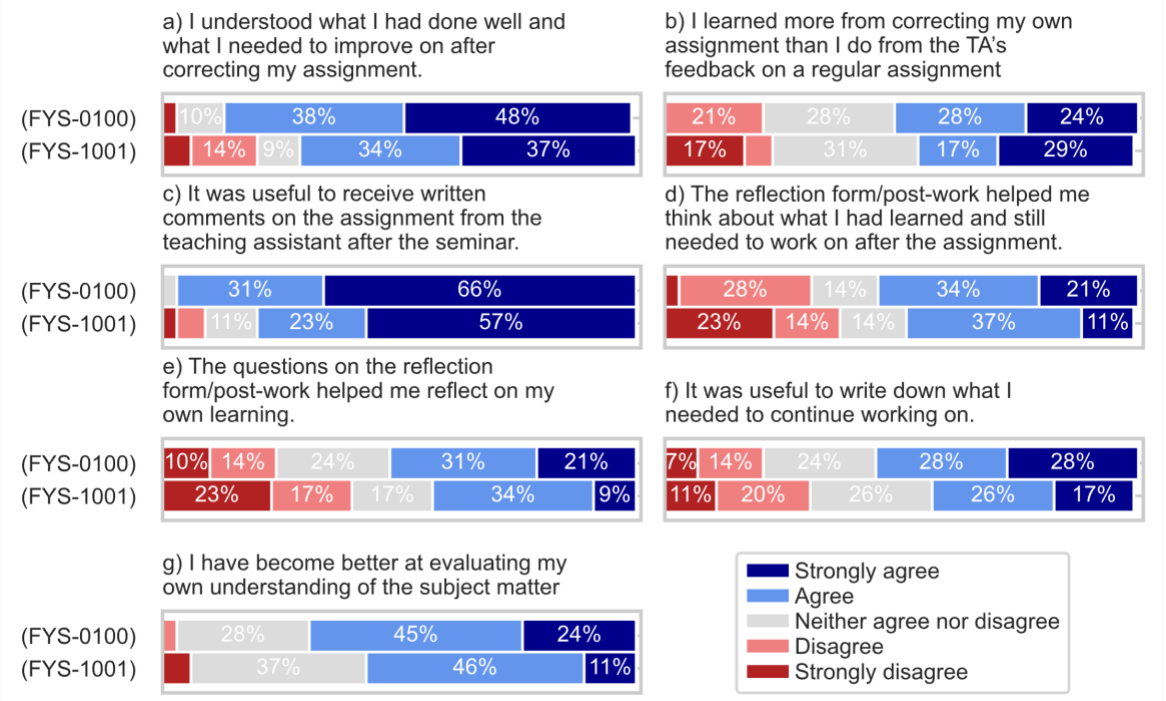

Figure 8. *Students’ perceptions of Self-Assessment, feedback, and the reflection - exercise.*

When we implemented the new assignments, an important goal was to have students take more responsibility for assessing their own learning and actively working on the challenges they identified. The first step would be for students to identify what must be worked on. As Figure 8a-b shows, most students felt that self-assessment enabled them to identify what they could improve, and many agreed that they learned more from self-correcting than from the feedback they usually get on traditional assignments. In the free-response answers, several students highlighted that being forced to look at their mistakes was beneficial. As one student puts it: “I often tend to skim the feedback from the TA. It is easier to notice what you must improve if you go through it yourself.”

After self-assessing, the students submitted their annotated solutions, and a TA reviewed them to ensure they had found most of the issues. The TAs would also give some feedback but were encouraged not to go into too much detail. Despite the positive perceptions of the self-assessment process, Figure 8c shows that almost all students appreciated the feedback from the TA. When we elicited the students’ comments on the self-assessment and what they had done with the feedback from the TA, we found that students had different experiences with the role the TA can play. For some students, feedback from the TA appeared to be more influential than their self-assessment, as. As one person noted: “I worked on some of the issues I identified in the self-assessment, but for the most part, I worked on the feedback from the TA”. Others perceived the TA feedback to be lacking in detail or difficult to understand, for instance, stating that “the TA did not provide sufficiently detailed feedback on what I needed to work on, so I did not take it into consideration”.

As the final part of the assignment, students were required to submit a reflection log with a few questions that prompted them to self-reflect on how the assignment had gone, what challenges they should still work on, and what plans they had to work on them. Figure 8d-f shows that about half of the students found these questions helpful in reflecting on their learning and found it useful to write reflections down.

3.2.4 Demanding but worth it

Responses from students across several different free-response questions show that many students found these assignments relatively challenging. Some students felt that “it takes more time,” while others shared specific factors that they felt were demanding. For some, this was due to the perceived demands of the assessment, as one student explained: "I interpreted the requirements for passing as much higher than other courses, with regards to how much I have to write.” For other students, it was the additional requirements of attending the seminar and preparing the extra deliverables that made the process more time-consuming, reflected by “it takes longer because of the seminar and reflection log.”

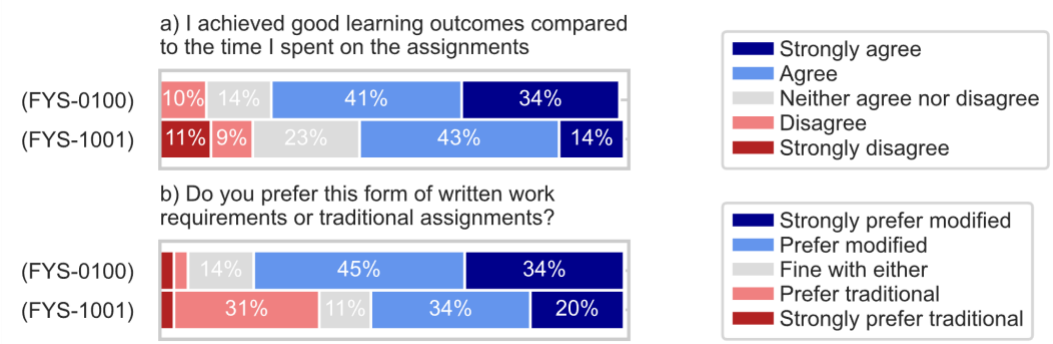

***Figure 9**. Students' perceptions of the activity overall.*

The students' perspectives on this extra time varied. Some expressed that the required effort was disproportionate to the learning outcomes, reflecting the view that it was "time you may instead have used for review or solving problems". At the same time, others believed it led to a deeper understanding. On the quantitative questions, a majority of students indicated that they achieved good learning outcomes compared to the time commitment and preferred the reformed over traditional assignments, as seen in Figure 9.

4 Discussion

The new assignments were generally well received. However, we also see that students experienced some difficulties and engaged with the activity differently than we had intended, highlighting the need to reevaluate some aspects of our approach. In the following, we will discuss the contrast between our intentions and the students' engagement with problem-solving, self-assessment, and feedback.

4.1 Problem-Solving Outcomes: Stress, Correctness Focus, and Additional Collaboration

In the first phase, we intended for students to solve problems strategically, providing a problem-solving template as suggested by Burkholder et al. (2020), which we demonstrated in class. However, many students reported only partially using the suggested strategy. Notably, several students used parts of the strategy but skipped the planning step, preferring a trial-and-error approach. This approach is recognizable from the literature on novice problem-solving; for instance, Schoenfeld (1992) discusses how students working on unfamiliar problems often attempt to solve problems without analyzing and planning. Conversely, the expert will spend time on structured exploration, analysis, and planning before trying to implement a strategy and will monitor the progress toward a solution. The students' piecemeal approach suggests that they may need more sustained exposure to internalize the expert problem-solving process. Schoenfeld suggests that posing scaffolding questions during small-group and class discussions could help students acquire a process more like an expert problem solver. Another approach could be replacing recitation in seminars with more comparison

exercises (Mason & Singh, 2010) or using the modified assignments more frequently, as in Mota et al. (2019).

To allow students to explore different approaches and generate diverse ideas for the second phase, we assessed their solutions based on effort and the use of problem-solving strategies over correctness. We emphasized that this was a part of a learning process, encouraging students to engage with each problem, make mistakes, and learn from them. However, many students felt considerable pressure to arrive at correct solutions or experienced discomfort if they did not. This suggests we could do more to alleviate assessment-related anxiety.

Their focus on correctness and associated stress may have contributed to students' engagement in the first phase. For one thing, many students reported spending substantially more time than we intended on the individual phase. For another, many students collaborated during the first phase, possibly due to students feeling pressure to find the correct answers and being more inclined to seek peer assistance.

In addition to practicing problem-solving and producing something to assess during the seminar, the first phase was intended to ensure individual accountability, an essential factor for fostering effective group dynamics in the subsequent collaborative phase (Johnson et al., 2014; Michaelsen et al., 1997). As such, some pressure may serve a purpose in ensuring that students allocate adequate effort to their individual problem-solving, thereby fostering a positive learning outcome and – as argued by Michaelsen et al. (1997) – increasing the chances of constructive group discussions in the seminars. However, excessive pressure to perform can lead to undesirable outcomes, like disengagement, collaboration beyond acceptable limits, or copying from other students.

These negative effects could be reduced (see e.g. Krou et al., 2021; Miller et al., 2021) by striving to foster a classroom culture where students are more oriented toward mastery goals (focusing on learning and developing an understanding of the content) than performance goals (focusing on demonstrating aptitude compared to peers). Though we have already made efforts in this direction, we may improve the new assignments further by more careful messaging around mastery, more reflection prompts, emphasizing learning over performance, or modifying the way deliverables are assessed.

4.2 Collaborative Self-Assessment and the SRL-cycle

The second phase was intended to further students' learning through peer discussions by allowing the students to review and discuss their solutions and exchange explanations and feedback. Our findings suggest that this phase effectively fulfilled that purpose, as most students felt they received the help and feedback they needed and gave generally positive feedback on collaboration and self-assessment.

However, some students reported issues with group dynamics, such as peers not contributing, or lack of opportunity for input as the rest of the group rushed through problems. A factor hindering student participation could be their focus on the correctness of solutions, as students who were uncertain or unable to solve the problems may hesitate to participate fully or seek help, fearing negative judgments from

peers. Similarly, if confident students mainly focus on correctness, they may not be interested in what struggling students have to offer.

Several strategies could be implemented to mitigate these issues. For instance, more specific collaboration guidelines (e.g., assigning roles or talking points) or formal anonymous feedback mechanisms to allow for honest assessments and timely interventions from the instructor team. It may also be possible to further devalue the correct answer in the students' eyes.

Many students felt they learned at least as much from self-assessment as from the feedback traditionally provided by the TA. However, almost all of them also found subsequently receiving written feedback from the TA helpful, which raises the question of what good quality feedback to the students is when they have already self-assessed their submission and reflected on their learning. Nicol and Macfarlane-Dick (2006) propose that good quality feedback is information that helps students troubleshoot their performance and helps them close the gap between the goal and where they are currently. Some of the teacher resources freed up by having the students self-assess could, for example, be used to give feedback on the student's learning process and problem-solving strategies.

Much effort goes into producing feedback on assignments, but students often do not read or use the feedback or understand it if they do (Jonsson, 2013). Dissatisfaction with how many of our students did not seem to learn from feedback was an important motivation for modifying the assignments. By having students self-assess rather than only receive feedback from the instructor, many are already engaging more with feedback than before. Ideally, students would also begin a new SRL cycle to address the identified challenges. However, only a minority of students prioritized working on those challenges.

Self-reflection exercises are one way to encourage students to practice metacognitive and self-regulation skills, by reflecting on their learning process and improvements going forward. Lovett (2013) found that exam-related reflection forms improved students' ability with different study strategies, and Mota et al. (2019) observed improved metacognition and self-assessment skills through reflective homework. For our study, we looked at the students' experiences and perceptions of these kinds of exercises, and we found that reception was mixed, with a relatively high proportion of students not finding this part beneficial for their learning process. On the other hand, the reflection exercises helped some students and were a small additional burden for the students and the instructor.

5 Conclusion

In this paper, we have described an alternative approach to written mandatory assignments in tertiary physics education in Norway, which strengthens the formative aspect of the assignment by incorporating self-assessment, peer learning, and reflective practice. Student evaluation indicates a positive reception overall, though slightly more so in the introductory course, with a majority feeling that their needs were effectively met compared to the traditional method, which suggests the modified assignments have merits in enhancing student engagement in the feedback process.

Several limitations must be considered. The study used a convenience sample from two specific courses at one university, thus limiting generalizability. The presence of many potentially influencing variables between the two courses and the absence of a control group means we can only speculate about causality. Additionally, students may inaccurately judge which learning activities are most beneficial (e.g., Deslauriers et al., 2019), so their self-reports should be interpreted cautiously as reflections of experiences and perceptions rather than evidence of learning. Furthermore, the dual role of researchers as teachers may have introduced bias despite our efforts to mitigate it.

Future research would benefit from incorporating data on student engagement and learning outcomes beyond self-reporting, such as analyzing the content of student discussions and deliverables to better gauge the quality of the self-assessment and peer learning processes. Longitudinal studies over several semesters and courses are an avenue that could potentially reveal how students' SRL skills evolve when they start at university and enable us to tailor the activity to different student groups. Further, it would be beneficial to investigate the nature of the self-generated feedback from the collaborative self-assessment phase and the role and impact of instructor feedback in this context.

References

Boud, D., & Molloy, E. (2013). Rethinking models of feedback for learning: The challenge of design. *Assessment & Evaluation in Higher Education*, *38*(6), 698–712. https://doi.org/10.1080/02602938.2012.691462

Burkholder, E. W., Miles, J. K., Layden, T. J., Wang, K. D., Fritz, A. V., & Wieman, C. E. (2020). Template for teaching and assessment of problem solving in introductory physics. *Physical Review Physics Education Research*, *16*(1), 010123. https://doi.org/10.1103/PhysRevPhysEducRes.16.010123

Creswell, J. W., & Plano Clark, V. L. (2018). *Designing and conducting mixed methods research* (3rd ed.). SAGE Publications, Inc.

Deslauriers, L., McCarty, L. S., Miller, K., Callaghan, K., & Kestin, G. (2019). Measuring Actual Learning Versus Feeling of Learning in Response To Being Actively Engaged in the classroom. *Proceedings of the National Academy of Sciences of the United States of America*, *116*(39), 19251–19257. https://doi.org/10.1073/pnas.1821936116

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School Engagement: Potential of the Concept, State of the Evidence. *Review of Educational Research*, *74*(1), 59–109. https://doi.org/10.3102/00346543074001059

Haugan, J., & Lysebo, M. (2018). Hvorfor antall arbeidskrav bør reduseres: Om formativ vurdering i ingeniørutdanning. *Uniped*, *41*(3), 347–360. https://doi.org/10.18261/issn.1893-8981-2018-03-13

Heller, J. I., & Reif, F. (1984). Prescribing Effective Human Problem-Solving Processes: Problem Description in Physics. *Cognition and Instruction*, *1*(2), 177–216. https://doi.org/10.1207/s1532690xci0102_2

Hellem, V., & Lorås, M. (2020). The Effect of Mandatory Assignments on Students Learning Outcome and Performance in Introductory Programming Courses. *2020 IEEE Global Engineering Education Conference (EDUCON)*, 704–712. https://doi.org/10.1109/EDUCON45650.2020.9125198

Jansen, R. S., van Leeuwen, A., Janssen, J., Jak, S., & Kester, L. (2019). Self-regulated learning partially mediates the effect of self-regulated learning interventions on achievement in higher education: A meta-analysis. *Educational Research Review*, *28*, 100292. https://doi.org/10.1016/j.edurev.2019.100292

Johnson, D. W., Johnson, R. T., & Smith, K. A. (2014). Cooperative Learning: Improving University Instruction by Basing Practice on Validated Theory. *Journal on Excellence in College Teaching*, *25*(3&4), 85–118.

Jonsson, A. (2013). Facilitating productive use of feedback in higher education. *Active Learning in Higher Education*, *14*(1), 63–76. https://doi.org/10.1177/1469787412467125

Krou, M.R., Fong, C.J. & Hoff, M.A. (2021). Achievement Motivation and Academic Dishonesty: A Meta-Analytic Investigation. *Educational Psychology Review, 33*(2), 427–458. https://doi.org/10.1007/s10648-020-09557-7

Lei, H., Cui, Y., & Zhou, W. (2018). Relationships between student engagement and academic achievement: A meta-analysis. *Social Behavior and Personality: An International Journal*, *46*(3), 517–528. https://doi.org/10.2224/sbp.7054

Lovett, M. C. (2013). Make Exams Worth More Than the Grade. In N. Silver, M. Kaplan, D. LaVaque-Manty, & D. Meizlish (Eds.), *Using reflection and metacognition to improve student learning* (pp. 18–52). New York, NY: Routledge.

Mason, A., & Singh, C. (2010). Helping students learn effective problem solving strategies by reflecting with peers. *American Journal of Physics*, *78*(7), 748–754. https://doi.org/10.1119/1.3319652

Mazur, E. (1997). *Peer Instruction: A User's Manual*. Prentice Hall.

Michaelsen, L.K., Fink, L.D. and Knight, A. (1997), Designing Effective Group Activities: Lessons for Classroom Teaching and Faculty Development. *To Improve the Academy, 16*(1): 373-397. https://doi.org/10.1002/j.2334-4822.1997.tb00335.x

Michaelsen, L. K., Knight, A. B., & Fink, L. D. (Eds.). (2002). *Team-based learning: A transformative use of small groups*. Praeger.

Miller, A.L., Fassett, K.T. & Palmer, D.L. (2021) Achievement goal orientation: A predictor of student engagement in higher education. *Motivation and Emotion, 45*, 327–344. https://doi.org/10.1007/s11031-021-09881-7

Mota, A. R., Didiş Körhasan, N., Miller, K., & Mazur, E. (2019). Homework as a metacognitive tool in an undergraduate physics course. *Physical Review Physics Education Research*, *15*(1), 010136. https://doi.org/10.1103/PhysRevPhysEducRes.15.010136

Nicol, D. J., & Macfarlane-Dick, D. (2006). Formative assessment and self-regulated learning: A model and seven principles of good feedback practice. *Studies in Higher Education*, *31*(2), 199–218. https://doi.org/10.1080/03075070600572090

Schoenfeld, A. H. (1992). Learning to think mathematically: Problem solving, metacognition, and sense making in mathematics. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 334–370). New York, NY: Simon and Schuster.

Thomas, D. R. (2006). A General Inductive Approach for Analyzing Qualitative Evaluation Data. *American Journal of Evaluation*, *27*(2), 237–246. https://doi.org/10.1177/1098214005283748

Zimmerman, B. J. (1986). Becoming a Self-Regulated Learner: Which Are the Key Subprocesses? *Contemporary Educational Psychology*, *11*(4), 307–313.