Pre-class preparation and team dynamics: evaluating the readiness assurance process in physics education

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This study investigates the role of the Readiness Assurance Process, a component of Team-Based Learning, in enhancing pre-class preparation and group discussions in a Flipped Classroom physics course. By integrating a sequence of individual and team readiness tests before more complex group problem-solving activities, the RAP aims to improve the quality of in-class teamwork. Data from self-reports indicates that almost all students met preparation guidelines. Preliminary results from analysis of one team's discussions during team readiness testing showed that most in-class discussions were productive. However, the uneven distribution of verbal contributions among team members indicates group dynamics that could impact the learning environment's effectiveness. This underscores the importance of interventions to ensure equitable participation. This study contributes to the broader discourse on active learning strategies in physics education by highlighting the role a structured preparatory process can play in enhancing preparation and effective teamwork.

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I. INTRODUCTION

Different forms of active learning in physics courses have been shown to increase learning gains, improve exam results, and lower students' failure and withdrawal rates [1, 2]. Active learning refers to a range of teaching strategies where students learn through problem-solving and discussion rather than passively receiving information through lectures. Many instructors use a Flipped Classroom approach to facilitate more time for such activities, where content transmission is shifted to a pre-class activity through readings or video lectures.

In the Flipped Classroom approach, all students must prepare before class and be ready to contribute to team discussions in order to uphold classroom norms and foster positive group dynamics. Research on students' reading habits has found that typically only 20-40% of students read the textbook and prepare for class [3–5]. However if students are incentivized through reading quizzes or other activities, this can increase to 80% [6, 7]. Students ' motivation for preparation varies widely, influenced by different experiences and study habits developed from former schooling and courses that often do not require as much preparation and active engagement. Ideally, students would be intrinsically motivated by the course content and enjoyment of the activities. However, maintaining high intrinsic motivation can be challenging, particularly in foundational courses that may only appear relevant to some students.

Many active learning strategies involve having students work together in small groups in the classroom. Several theories suggest how collaborative group work can enhance learning. For instance, explaining one's thinking can improve the organization and elaboration of the subject matter [8]; cognitive conflict between existing and new ideas can lead to higher levels of understanding [9]; scaffolding by more knowledgeable peers can support one's learning [10]; and students can collaboratively co-construct knowledge and develop problem-solving strategies which no student had at the beginning of the discussion [11].

In the study reported here, we will draw on Mercer's sociocultural discourse analysis [12], which offers a way to examine how students interact with each other's ideas and build knowledge together. It identifies three archetypical types of talk: disputational talk, characterized by disagreement and individual decision-making; cumulative talk, in which speakers build on each other's utterances uncritically; and exploratory talk, in which speakers engage critically but constructively with each other's ideas. In exploratory and cumulative forms of interaction, students are co-constructing understanding [13], and especially the presence of exploratory talk has been linked to increased team performance and learning gains [14, 15].

Our work will also be informed by an example from high school physics, where Bungum et al. [16] applied talk types to analyze small group discussions on quantum mechanics. They modified the category of 'disputational talk' to 'independent statements' to encompass discussions where students shared separate pieces of knowledge without building on one another's contributions, removing the implication of conflict inherent in the term 'disputational.' They also introduced 'confirmatory talk' as a new category, which captured instances where students simply repeated or confirmed their peers' statements.

Social interdependence theory [17] suggests that effective peer learning is more likely when activities meet specific requirements: individual accountability to ensure all students contribute; positive interdependence to ensure each student's success is intertwined with that of the entire group; mutual encouragement of effort; development of teamwork skills; and reflection on ways to improve group performance. The Readiness Assurance Process (RAP), a key component of Team-Based Learning (TBL) [18], is an activity that promotes these processes. At the core of the RAP is a two-stage testing mechanism at the beginning of each instructional unit: the individual Readiness Assurance Test (iRAT) and the team Readiness Assurance Test (tRAT). The objective of the iRAT is to ensure that students arrive in class well-prepared using grading incentives to motivate preparation. The tRAT is designed to foster the rapid development of team dynamics so that teams are ready to tackle the more complex, subsequent active learning activities. Team development progresses through different stages as members adapt to working together [19]. Over time, as these dynamics improve, teams often perform better and become more efficient in solving problems [20].

This paper reports on the preliminary results of a project investigating student engagement in pre-class preparation and group discussions during the tRAT in an intermediate Newtonian mechanics course. Specifically, we report on 1) the extent to which students are preparing before class, 2) the types of talk that characterize the collaborative problem-solving discussions during the tRAT, and 3) how different students are contributing to the discussion.

II. BACKGROUND

A. Course context

This study was conducted during a third-semester course at a Norwegian university in the fall of 2022. The course was primarily focused on Newtonian mechanics but also introduced waves and special relativity. The curriculum was organized into ten modules spanning 1-2 weeks. The course was primarily attended by students enrolled in physics and mathematics programs, including pre-service teachers. Forty-two students attended the end-of-year exam.

The weekly course instruction included two 90-minute TBL sessions involving the entire class and one 90-minute recitation. For the TBL sessions, long-lasting teams of 4-5 students were formed following recommendations about team formation [21]. Specifically, each team had a diverse mix of scores on a pre-test with the Force Concept Inventory, and efforts were made to avoid groups with only one female student. The first author of this paper was the course coordinator and facilitator of the TBL sessions.

B. Readiness Assurance Process

The Readiness Assurance Process (RAP) is a mechanism used at the start of each TBL-based instructional unit that is designed to enhance student engagement by ensuring they are adequately prepared before engaging in more complex active learning activities as part of a team [22, p. 74]. It is not about testing. It consists of the following stages:

1. Initially, students engage with assigned preparatory materials outside of class. For this course, students read a text in the university's learning management system (LMS), supplemented by short embedded videos.
2. Students then complete an individual Readiness Assurance Test (iRAT) on the preparatory materials. The iRAT questions focus on the foundational concepts students need to begin problem-solving successfully. Some questions should still be challenging, so students do not typically get a 100% score, to maintain the learning potential of the next phase.
   In this course, the iRAT was administered pre-class as a quiz in LMS, except for the first unit, when it was conducted in class. It included between 10 and 13 questions, varying in format from multiple-choice to numerical and multiple-right-answer questions. Many questions utilized randomization of parameter values or other surface features of the problems to minimize the incentive to collaborate on the online tests.
3. After the iRAT, students retake the same test as a team (tRAT), where they all have to agree on which answer to choose. In this phase, the aim is that the students obtain a deeper shared understanding as they work to reach a consensus on the problems.
   The tRAT was conducted in class using a scratchcard system known as the immediate-feedback assessment-technique (IFAT) [23], where teams scratch off options until they arrive at the correct answer indicated by a star as illustrated in Fig. 1. Ten of the questions from the iRAT were chosen and, if necessary, converted to multiple-choice format to fit the IFAT form. After the tRAT, a whole-class debrief is conducted to clear up any remaining difficulties.
4. The rest of class time (2-6 hours, depending on whether this was a one- or two-week module) was spent working in the same teams on relatively more challenging problems.

The literature on TBL suggests incorporating the average of the iRAT and tRAT scores as a component of the final course grade (see e.g., [18, 22]). This approach holds individual students accountable to the instructor and promotes positive interdependence as each student benefits from the

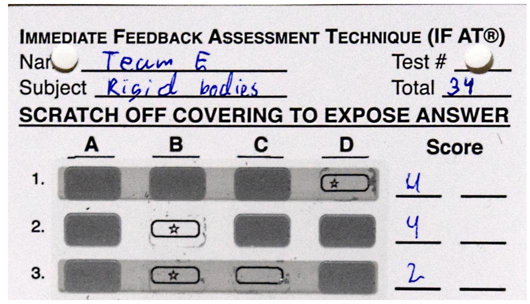

FIG. 1. Example of used IFAT-form. Rows represent questions, and columns represent answer options. Each form has space for 10 questions.

team and all the other members doing well. However, due to administrative difficulties in the Norwegian university system, incorporating coursework as a part of the final grade proved challenging. Another major component of the course was four large written mandatory assignments that students had to pass to be allowed to take the end-of-semester written exam, which accounted for the entirety of the student's grade. To give an incentive to perform well on the tests, students who achieved an average of 70% on the tests and regularly attended class could choose not to turn in one of the mandatory written assignments. However, most students still completed all of the mandatory assignments.

III. METHODS

At the beginning of the semester, all students were informed about the study and invited to participate in different data collection forms. They were assured that participation was voluntary and would not influence their course experience. Moreover, it was emphasized that their data would be treated confidentially and anonymized in any published reports and that students could withdraw from the study at any time without any consequences.

The data collected for this study included:

- **Self-reports of preparation time**: At the beginning of each iRAT, students answered a numerical response item estimating the number of hours they had spent preparing for the quiz. Explicit assurances were included each time that these numbers would not influence test scores, aiming to avoid over-reporting.
- **Video observation of discussions during tRATs**: On three occasions, during modules 5, 8, and 9, two teams whose members had all consented to participate in video observation were recorded while completing the tRAT in a separate room. The first recorded discussion was in the fifth module to allow the students to become accustomed to the test format.

On average, 33 students who had consented to participate in data collection through the online tests took each iRAT. To illustrate the distribution of the time students spent preparing, a box-and-whiskers plot was made for each iRAT to effectively summarize the median, quartiles, and extremes of their preparation times. The whiskers extend up to 1.5 times the Inter Quartile Range, with outliers plotted separately.

The first author transcribed the six tRAT discussions in full. The transcripts were split into segments, each representing an attempt to answer a specific question, so there were at least ten segments for each group answering a tRAT.

To develop the analytical framework for describing the discussions, we engaged in a preliminary coding exercise where we coded a total of 12 segments from all six discussions using the three archetypical talk types described by Mercer [12] and the two categories proposed by Bungum et al. [16]. During this process, we saw:

- **Exploratory talk:** Engagements where students critically and constructively interact with each other's ideas.
- **Cumulative talk:** Dialogue is characterized by students building on each other's ideas positively and uncritically.
- **Confirmatory talk:** Only one student brings substantial ideas, with other students simply repeating or agreeing with what was said.
- **Disputational talk:** Marked by disagreement and individual viewpoints without constructive engagement with each other's ideas.
- **Other talk:** We also saw the need for a category to capture other talk unrelated to physics. For instance, coordination (e.g., calling for a vote) or non-content-related discussions (e.g., celebrating correct answers or discussing multiple-choice question strategies).

Following the initial coding round, we analyzed all three discussions from one particular group in full. To minimize bias and bring our independent perspectives to the analysis, all three authors prepared individually by reviewing the transcripts and familiarizing themselves with the content. During this process, the first and second authors would code all transcripts, marking any segments that were difficult to interpret or code for further discussion. After completing their independent preparations, all three authors met to discuss the coding and reach a consensus on all coded segments.

We counted words in each category as a simple quantitative measure of student interaction. We excluded utterances consisting of less than four words, such as brief acknowledgments, to exclude minimal responses. While these utterances are common, their exclusion does not substantially change the overall picture.

IV. RESULTS

At the beginning of the iRAT, the students were asked to indicate how much time they had spent preparing before starting the test. Figure 2 illustrates how the time spent preparing was distributed for each module. As the semester progressed and students became familiar with the test format, a clear majority of students reported spending at least two hours preparing for each test. On average, at least 90% of students reported preparing to some degree before the individual test.

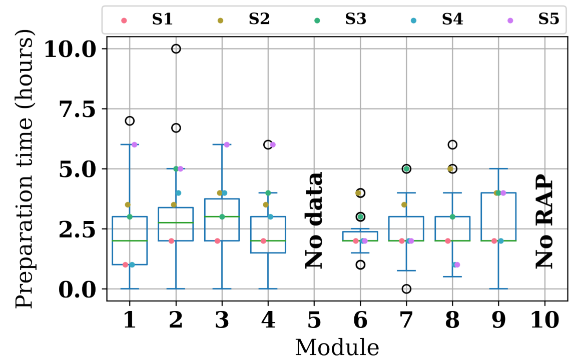

FIG. 2. Time students reported spending preparing before the individual test. The five students from the group in focus is highlighted. The questions on preparation was inadvertently not included on the fifth iRAT.

The discussions within this group featured predominantly exploratory talk (52%) followed by a similar amount of other (24%) and cumulative talk (18%). The remaining 6% of the dialogue was predominantly characterized by confirmatory talk. Like Bungum et al. [16], we considered the discussions characterized by exploratory and cumulative talk productive.

In addition to looking at the discussion itself, we wanted to investigate how different students contributed to the discussion. Figure 3 illustrates the distribution of verbal contributions by students across different categories of talk during the three tRAT discussions by a simple measure of word count.

Over the semester, S1 consistently showed high levels of engagement in all talk types, particularly exploratory and confirmatory. S1 spoke about three times more than the student who spoke the least in all three discussions. S2 also generally showed high levels of engagement and was notably saying as much as S1 in the 'other' category, which may be partially due to interacting with the IFAT form in most of the modules. The other students also contributed to the discussions. S3 and S4 notably contributed primarily to cumulative and exploratory talk sequences and significantly less in the 'other' category.

In addition to the data on preparation for the class as a whole, we present some initial findings from our analysis of tRAT discussions within one of the two groups. This group featured a diverse gender balance and a heterogeneous range of scores on the FCI pre-test. As it mostly maintained a stable composition throughout the semester we can meaningfully compare the students' interaction dynamics over time. We use the labels S1 through S5 to refer to the different students in this group. S5 was only with this group for the first discussion. The students had FCI scores of 27, 19, 18, 23, and 16 out of 30, respectively. S1 and S4 were male, while S2, S3, and S5 were female.

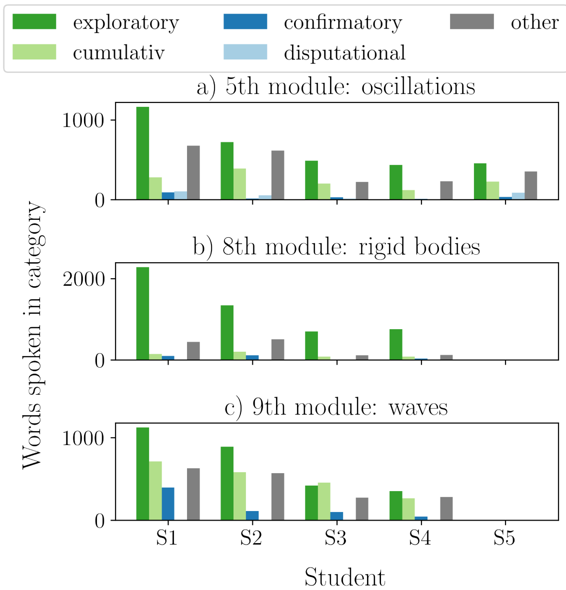

FIG. 3. Student participation in each tRAT-discussion, by talk type. Students are ordered by the total amount of words spoken.

V. DISCUSSION

Our findings indicate that most students engaged in pre-class preparation to the degree expected by the TBL facilitator. The motivation to prepare can arise from multiple sources. Extrinsic motivation, such as a desire to achieve a high score to pass the activity, undoubtedly plays a significant role for some. Additional social motivations are likely also involved, like avoiding disappointing peers.

However, it is important to note that these were self-reported numbers that may be inaccurate. Furthermore, there is no comparison group with other ways of incentivizing preparation. We cannot, therefore, conclude from these numbers that the RAP causes this degree of pre-class reading. However, it appears at least comparable to other reported interventions [6, 7].

Most of the tRAT discussion content was exploratory or cumulative talk, which are types that are likely to either deepen or widen student knowledge. It is surprising how much of these discussions were characterized by exploratory talk, especially in module 8, considering many of these questions were supposed to be relatively simple. Further analysis is necessary to investigate whether the students have deep discussions regarding simple questions, as sometimes observed in Peer Instruction [24], or are quickly finished with the simple tasks. Future work will also include analyzing individual and team performance on questions and examining the substance of these discussions in more detail better to understand the relationship between discussion types and learning.

A potential concern is the persistent skewed distribution of students' participation since students commonly express concerns regarding a perceived inequality in the effort put in by peers during group work [25, 26]. FCI scores, individual preparation time, or gender does not explain the whole pattern. However, we observed students taking consistent habits and roles within the group, such as who was interacting with the IFAT forms. In the first two discussions, S2 scratched off the team choices on the IFAT form, while S1 scratched off the choices in the last discussion.

Several strategies could be employed to facilitate increased diversity of participation in the group. Some could be structural, like rotating roles and responsibility for key tasks (e.g., marking answers on the IFAT form or reporting the group answer). Setting aside more time for group processing, where students and groups reflect on helpful or unhelpful behaviors, altering expectations and status relationships within a group, or assigning roles can also create a more equitable discussion [27].

VI. CONCLUSION

This study aimed to examine the role of the Readiness Assurance Process (RAP) as a first active learning activity in an intermediate Newtonian mechanics course. The findings suggest that the students were motivated to prepare before class and that the discussions during the tRAT were characterized mainly by exploratory and cumulative talk. Such talk, where students share and build on each other's ideas, is likely conducive to learning and deeper understanding. This suggests that the RAP can be a valuable tool for instructors using a Flipped Classroom approach. However, the data also shows an uneven distribution of contribution within the group, which may reflect issues with group dynamics. This could limit the activity's learning potential for some students and suggest a need for more strategies to promote balanced involvement among all team members.

This study is limited by the lack of a comparison group. It remains unclear whether similar preparation and discussion characteristics would occur if students were simply asked to read the materials or if another method was used to incentivize preparation. Future research could consider experimentally comparing other methods and the effects of individual, team, and grading components of the RAP in isolation.

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