Student discussions during Peer Instruction lectures in physics: do students follow the given rules for discussion?

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Acknowledgements

Starting this master’s thesis was a very daunting task, as it marks the end of my education in the Integrated Teacher Programme in Science and Mathematics. Pouring the essence of my entire academic journey into a single paper. Where would I even begin? Without the support of my supervisor, I would be lost in the waters.

At ten years old I decided my fate: becoming a teacher. For 16 years I have studied, worked, volunteered as a scout leader, and done my best to achieve this dream. Becoming a teacher has always been my goal, and I cannot wait to use the knowledge and experience I have attained from my years of study and master’s thesis when I finally go to work.

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Abstract

In modern physics education, Peer Instruction has been established as an excellent method of effectively engaging students in the course material. In Peer Instruction lectures, students are introduced to a conceptual multiple-choice question. The students first try to solve the question with individual thinking, and either write down their answer or show it to the lecturer when prompted. Then they discuss their answer with their neighbor, trying to explain their ideas during group discussions. Again, the students write down the answer, and/or reveal it to the lecturer. During these group discussions, the students engage in Peer Instruction. A potential weakness of active learning, such as Peer Instruction, is its dependency on the participating students: Low engagement from a few students can negatively affect the rest of the group. Having the entire group participate is thus essential. One way to promote participation and good discussions is to provide rules for these discussions.

The given rules should encourage students to participate, explain their answers, address each other's ideas, elaborate on physical principles and concepts, as well as seek agreement on the given problem. These rules, along with two others, are the basis for the research presented in this thesis.

Following a physics introductory class and recording the discussions between students during Peer Instruction, this thesis investigates whether the students follow rules for discussion when given explicit rules to follow. This poses the research question: *Do the students follow the rules for discussion given by the lecturer?*

The findings in this thesis indicate that the students follow some of the rules for discussion, but not all of them. Lack of participation, or exclusion from participation, even prevented good discussion in some cases that were highlighted. Though the students in the study showed a strong understanding of the relevant concepts, and used principles and terminology to explain their ideas, they also showed poor communication skills, and this naturally affected the group discussion.

I conclude this thesis by suggesting that the potential implications from these findings could be: (a) Peer Instruction may be most effective in smaller groups consisting of either two or three students. (b) Practicing methods of "talking in turns" in the discussions could ensure every student in a group gets to contribute to and participate in the discussion. (c) Selecting fewer rules for discussion when preparing for Peer Instruction.

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I – Introduction

I-i – Motivation for the work

Teaching any subject can be a daunting task. Preparation is key, along with good teaching strategies. Being a physics student in teaching trainee placement, it has been clear from experience that physics is a complicated and hard subject for students. In preparation for teaching, researching different teaching methods is important. Traditional lecturing, which is historically the most common method of teaching, where the lecturer teaches from a given textbook, results in a passive audience (Mazur, 1997). A common split is often active learning versus passive learning. Several studies point to students learning more from active learning, than from passive lectures (Crouch & Mazur, 2001; Deslauriers et al., 2019; Freeman et al., 2014). Deslauriers et al. show that students engaged in active learning, when compared to students in a passive lecture, test better on learning when taught the same content. Crouch and Mazur describe results from a specific method of active learning as stable over a ten-year period. Freeman et al. found an increase in performance on exams from attending active learning classes and show that failure rates are lower in active learning as well.

In a study of over 6000 students, it was found that "Interactive Engagement" methods outperformed traditional lecturing on average when considering the normalized gain in force concept test (Hake, 1998). Hake defines Interactive Engagement as methods that has engages students to achieve conceptual understanding. From the results of the study, it is also implied that Interactive Engagement methods enhance student's problem-solving abilities. While Hake points to positive findings about active learning, he also show that classes with poor implementation of Interactive Engagement score as low as traditionally taught courses.

The teaching method Crouch and Mazur describes to achieve these results is Peer Instruction, a method of active learning invented by Mazur for use in physics education (Crouch & Mazur, 2001). In his book, Peer Instruction: A User's Manual, he describes the goal of Peer Instruction to focus students' attention on underlying physical concepts through individual thinking and group discussion (Mazur, 1997). The process introduced provides two valuable outcomes: (a) the students think through their arguments as they are developed, and (b) they can assess their understanding of the concept. The use of Peer Instruction in teaching is through ConcepTests (conceptual multiple-choice questions), consisting of seven steps as the general format. ConcepTests and these seven steps will be described in the next subsection, along with a more thorough explanation of Peer Instruction.

Peer Instruction makes the students active participants in the learning (Mazur, 1997). As Mazur and Crouch explain, using Peer Instruction is a way of modifying traditional lectures (Crouch & Mazur, 2001). This modification engages students by using pre-designed questions (ConcepTests) that engage and uncover difficulties the students may have with the material. The conclusion from their research also points to students' understanding improving from implementing pre-class reading. The pre-class reading is meant to give the students an introductory understanding of key terms (physics principles, technical terminology, et cetera) ahead of the lecture, to prepare them for the discussions. By actively participating in the individual thinking, and then the discussions and explanations in Peer Instruction, the students may apply the key terms from the pre-reading and use their own words and ideas to process the subject's content. During these discussions, students construct their own knowledge based on their own thoughts, moving the emphasis of learning from the teacher to the students (Walshe, 2020). This understanding is then assessed when the lecturer reveals the correct answer. The lecturer gives reason for the correct answer and based on the number of students who chose the correct answer, can either expand or move on, whichever is more suitable in each case.

Changing from a traditional lecture format to an active teaching strategy such as the Peer Instruction format can be helpful both to the attending students, and to increase and incentivize more students to attend (Deslauriers et al., 2019). The discussions from the course I describe in this research have made this change and adapted the active teaching of Peer Instruction in every lecture, forgoing traditional lectures.

One of the potential difficulties of using Peer Instruction in large classrooms is group dynamics (Deslauriers et al., 2019). The group's dynamic affects the outcome and content of the discussion. Research from Deslauriers et al. shows that low engagement from a few students during group work can negatively affect other students in their group. Having the entire group participate is thus essential. They described a method of reducing this poor engagement, by the teacher intervening early on, and by giving an examination early on to incentivize the students to participate in active learning. From their research, they found that the students themselves experience a lack of learning (feeling of learning), even when the results show improved learning (test of learning). Deslauriers et al. propose that this negative correlation may be attributed to several factors, one of which is the students not recognizing their increased cognitive efforts as a sign of effective learning. To potentially avoid this problem, the lecturer should encourage the students to accept active learning leading to deeper learning. With this acceptance, they found that the success of active learning will also be enhanced. Helping the students accept this early on and enter active learning becomes a goal in teaching. However, expecting students to engage in collaboration effectively does not automatically create good learning (Kuhn, 2015). Therefore, another method to reach this goal can be setting certain rules to be followed during the discussion, to train the students' collaboration skills.

Kuhn found that collaborations between students engaged in each other's thinking were some of the more productive collaborations, where the students would listen and respond to each other (Kuhn, 2015). Before discussing, the students think and commit to an answer individually. Addressing other students' thoughts could then be a part of the rules, to achieve this productive collaboration.

The rules given should be formulated to achieve good learning and good discussions. When these discussions are based on elaboration from previous knowledge, the students connect these discussions to the concept, establishing unique relationships (Stein et al., 1984). Stein et al. emphasized from their research the importance of such relationships from elaboration. If the students remember the significance of the arguments from the discussion, they are more likely to remember the information provided. This information might be the core concept being discussed, a physical principle, or other relevant pieces of information. Since elaboration and explanations are processes that can further students' understanding of a subject, these learning processes should be encouraged (Gjerde et al., 2021a). The rules for discussion used in the class described in this thesis are intended to do just this. The rules the lecturer presents to the students are explained in the next subsection.

In this thesis, student discussions will be examined in a class using Peer Instruction with a certain set of rules for discussion. The main research question for this thesis is the following: *Do the students follow the rules for discussion given by the lecturer?* This thesis will focus on whether the students follow the rules given. Without further research and more specific data, we cannot conclude whether the students follow the rules naturally or because they were explicitly stated.

With this research question, I intend to investigate if the student groups follow the set rules for discussion, as well as if there are any signs of positive/negative effects when they do or do not follow the rules. Using the data from the recordings, I will highlight any findings that support positive or negative effects on learning, through the scope of the rules of discussion.

I-ii – Previous work done in the field

In this section, (a) Peer Instruction, and (b) Rules for group discussions are explained in more detail than in the previous subsection.

Since the research problem is "do students follow the rules for discussion," the latter section, (b), will be discussed later in the findings. The first section, (a) portrays important background and detail for understanding the results.

I-ii-a – Peer Instruction

Mazur introduced Peer Instruction in his book, Peer Instruction: A User's Manual. (Mazur, 1997). In this book, he explains Peer Instruction, ConcepTests, and his results from teaching using this format, along with examples of problems using Peer Instruction in physics education for other teachers to use in their classes.

While students in traditionally taught classes may focus on conventional problems, their understanding of the underlying concepts is lacking (Mazur, 1997). Mazur points to this from his students in a traditionally taught class. On an exam, the students would score higher on a conventional question, where the students were tested on equations and physical laws, than on a simpler conceptual question, designed to test students' fundamental knowledge on the same subject. In his later teaching, after implementing Peer Instruction, the results of concept tests would change drastically (Crouch & Mazur, 2001). Using different measures, such as a Force Concept

Inventory test, the gain from using Peer Instruction lectures is shown as superior to the gain from the same course taught traditionally.

To train the students on their conceptual knowledge and understanding, Mazur created ConcepTests (Mazur, 1997). Mazur explains ConcepTests as short conceptual questions. These questions are introduced after short presentations where key points on the relevant subject are explained. These questions are designed to challenge the students' conceptual understanding of physical fundaments. The general format provided by Mazur for ConcepTests in lectures is listed as follows:

1. Question posed	1 minute
2. Students given time to think	1 minute
3. Students record individual answers (optional)	
4. Students convince their neighbors (peer instruction)	1-2 minutes
5. Students record revised answers (optional)	
6. Feedback to teacher: Tally of answers	
7. Explanation of correct answer	2+ minutes

Examples of ConcepTests can be found in the book Peer Instruction: A User's Manual (Mazur, 1997), or in the article by Crouch and Mazur (Crouch & Mazur, 2001).

Following this format, the students are given time to formulate their answers in step 2 before challenging each other by discussing their answers in step 4. With the students recording their answers in steps 3 and 5, which is optional, the teacher may investigate the number of students who changed their answers or kept the same answers, along with statistics of how many students answered correctly or incorrectly. The teacher may then use this to further improve the classes, as Crouch & Mazur describes to have done and achieved improved results (Crouch & Mazur, 2001).

I-ii-b – Rules for group discussions

In the context of this thesis, the lecturer explicitly provided seven rules for discussion. The lecturer created these rules to enhance a culture of good discussions in the lectures (Gjerde et al., 2021b). The goals defined by Gjerde et al. for the group discussions are as follows: Argumentation by use of physical principles and terminology; good, exploratory group discussions; and everyone can practice explaining and arguing. The rules presented by Gjerde et al. were influenced by the pragmatic ground rules for exploratory talk described by Wegerif, Mercer and Dawes in their research (Wegerif et al., 1999). The rules proposed by Wegerif et al. were created for the primary classroom, which is a different setting from the university lectures Gjerde et al. describes. It becomes natural that the rules are not equivalent, since the two settings are separate, and not every rule from Wegerif et al. is relevant in this setting. In addition, Kuhn (2015) mentions potential benefits of collaboration during problem-based learning, as well as lack of these potential benefits. She explains that collaboration does not automatically yield results in learning but is dependent on the conditions and the participants. Her findings indicate the need for additional rules not found in the ground rules from Wegerif et al.

The rules proposed by Gjerde et al. (2021b), as explicitly stated by the lecturer in every class, were as follows:

1. Put forth all the relevant information
2. Give clear reasons for your answer
3. Challenge each other: Ask for explanations whether you understand or not
4. Respond to others' thought processes before presenting your own
5. Discuss alternatives
6. Make sure everyone partakes in talking and explaining
7. Seek agreement

These are the rules the research question intends to answer whether the students follow. The students were told explicitly to follow these rules during their discussions. Below is a rule-by-rule explanation of why these rules provoke good learning and/or good discussions.

Note, I had no say in the matter on the selection of rules, as my only tie to the course was gathering data. Other than attending some lectures for this purpose, I did not partake in any aspect of the course.

1. Put forth all the relevant information

Explicitly sharing knowledge when discussing alternatives to a problem may help students appropriate specific problem-solving skills (Wegerif et al., 1999). Such hypotheses could indicate the students achieving greater awareness of the problem or task. Translating the information given from a problem, along with other relevant information on the background to solve such a problem, could then benefit students in their understanding of core concepts relevant to the problem. From this, we see the need for rule #1: “Put forth all the relevant information.”

2. Give clear reasons for your answer

Generating explanations, such as self-explaining, increases understanding (Chi et al., 1994). During the discussion after individual thought, the students may explain their understanding to the other students. In the findings from Chi et al., they show a 30-32% gain of correct answers from a pre- and posttest from eliciting such self-explanations, results that apply to both lower and higher ability students. Wegerif et al. (1999) expected reasoning from the primary classes they describe as part of the rules they proposed. These reasoning are explained as characteristics of exploratory talk. Exploratory talk is when students constructively discuss ideas. If the students manage to explain their idea with clear reasons, they might provoke such constructive feedback from other students as well. From this, we state rule #2: “Give clear reasons for your answer.”

3. Challenge each other: Ask for explanations whether you understand or not

Elaborating on ideas can further students’ understanding of core concepts and reveal misunderstandings (Mazur, 1997). When students are introduced to an unfamiliar subject, there are many elements to consider, which may seem confusing for the students (Stein et al., 1984). By asking for explanations, they might lesser this confusion. Using elaborative information on presented ideas may give the students associations related to the relevant concepts being discussed. Thus, in an effort to clarify misunderstandings and improve understanding, we introduce rule #3: “Challenge each other: Ask for explanations whether you understand or not.”

4. Respond to others’ thought processes before presenting your own

When students directly engage with each other’s thinking, their discussions are more likely to be productive (Kuhn, 2015). By addressing each other’s ideas during the discussion, the students show that they listen, and not just ignore the other’s ideas. Then we get rule #4: “Respond to others’ thought processes before presenting your own.”

5. Discuss alternatives

After the group have explained their ideas for the problem, and decided on the correct answer, there might be some time remaining before the students are asked to give their answers. This offers an opportunity for the students to further assess how well they understand the concept, by discussing the other alternatives in the question. These discussions provide the students with reasons for why their answer must be correct. If they pick wrong initially, this rule might also help correct their mistake, as they explore other alternatives. For this benefit, we see the importance of rule #5: "Discuss alternatives."

6. Make sure everyone partakes in talking and explaining

When one member of the group becomes certain of their answer, they might dominate the discussion (Kuhn, 2015). If this student is unable to transmit the knowledge to the rest of the group, the group suffers, in that they do not understand the problem. To avoid this, all the students should be encouraged to participate in the discussion, and to include the entire group in the discussion. Encouraging students to actively discuss conceptual problems is a core element of Peer Instruction (Mazur, 1997). To achieve this, we introduce rule #6: "Make sure everyone partakes in talking and explaining".

7. Seek agreement

The main goal for the discussions, in the eye of the students, is to agree on the answer. The process the students use to get to this end-goal is through the other rules presented, if they do not agree initially. By seeking agreement, the group collaborate and construct knowledge that will aid them in this goal (Wegerif et al., 1999). If they do agree initially, the other rules are in place to ensure that the group has something to discuss in the given time. By tasking the students with this rule, the lecturer provokes the students into giving explanations that convince the other classmates of their answer. So, to tie this section, and the rules, together, we have rule #7: "Seek agreement."

I-iii – Thesis outline

In this thesis, we show that students do follow the rules for discussion, although not completely. The methods used are described in section II. Section III presents the findings. The thesis finishes with a conclusion in Section IV. Transcripts from the student discussions can be found in the appendices attached.

II – Method Overview

II-i – Participants

The participants were students in an introductory physics course. Of the 186 students enrolled, 8 students participated in this study, all young adults. In most cases, the students in the participating groups seemed to know each other beforehand. The students in the course came from a variety of study programmes, including the integrated teacher programme, physics bachelor programme, meteorological study programme, ocean technology, energy, et cetera. The participating students were not asked about their course or background, as it was not relevant to the study. The students gave written consent for use of interview data in publications.

To recruit students to participate in the study, the lecturer introduced me to the class a few weeks into the semester. In the first class, I gave a brief introduction about what the recordings would be used for and what subject my master's thesis belonged to. I informed the class that the recordings would be completely anonymized. Students who wished to participate would raise their hands, and I would present them with a recorder, along with a consent form.

Since participation was voluntary, the results may have been biased toward the more confident, knowledgeable groups of students. To dissuade a potential lack of participation from weaker students, the class was told that all recordings would be anonymous and could not affect their grades. This was repeated at every introduction in classes with recording. The effect of this statement is unclear, as it was not measured.

Four of the recordings were chosen to have a more in-depth qualitative analysis of the student discussions. These four recordings involved eight students, three in one group (smaller group) and four to five (two recordings with four students and one recording with five students) in the other group (bigger group). The four recordings consisted of one recording from the smaller group and three recordings from the bigger group. The reason for this choice was to investigate if the smaller group would become a potential contrast to the bigger group while having a deep analysis of the bigger group across several days of recording.

The smaller group consisted of three males. The bigger group consisted of one to two females and two to three males. The final grades from the eight students were: 3 A's, 2 B's, 2 C's, and 1 case of no final grade. The reason for one of the students not receiving a final grade is unknown. The grades were distributed equally among the groups, giving both groups at least one A-student and at least one C-student. Based on this, and the content of their discussions, the students participating have reached a relatively strong grasp on the content of the course.

II-ii – The setting – Lectures and course

The student discussions described in this text have been recorded from an introductory mechanics course, during the spring semester of 2022. Any names mentioned have been altered for anonymization. Any other mentions of students outside of their groups have also been altered for anonymization.

The course was part of a research project, "PAFYS: Prinsippbasert Aktiv Undervisning for Sterkere Fysikk og Ingeniørstudenter" (Principle-based Active Instruction for Stronger Physics and Engineering Students) (Gjerde et al., 2021b). There was a focus on integrating learning strategies into the course before and during lectures, the most relevant for this study being: (i) short introductory videos intended to get students to actively elaborate on physics principles: and (ii) weekly 5–10-minute sessions of retrieval practice of physics principles during the first lectures of the week, before Peer Instruction. In the introduction of the Peer Instruction session, the lecturer presented the rules for discussion in a PowerPoint slide, along with a highlighted "rule of the day" on each slide to encourage discussion.

The students were asked to watch the short introductory videos in preparation for the lectures. There were no traditional lectures; instead, the lectures began with one hour of discussion questions covering the principles, then usually two hours of Peer Instruction. The students would occasionally get rich-context problems to solve, while the lecturer gave progressively more support. These problem-solving sessions were designed to teach students how to structure their solutions, based on a five-stage problem-solving strategy.

The exam consisted of seven traditional text problems, counting 70% of the grade, along with five conceptual multiple-choice problems, counting 10%, with an additional 20% for giving a formally correct and principle-based written argumentation for their choice in the multiple-choice problem. This was to have a constructive alignment between the lectures and the exam, giving students an opportunity to prepare for the argumentation part of the exam through the Peer Instruction assignments in the lectures.

II-iii – Peer Instruction in the lectures

Peer Instruction is a sizable part of the lectures in this physics course, as described in the previous subsection. Using a Peer Instruction format in the lectures, the lecturer poses conceptual multiple-choice problems to the class, followed by individual thinking and group discussions (Gjerde et al., 2021b). After both individual thinking and group discussions, the students were asked to show their answers. This would indicate to the lecturer whether the majority of students understood the concept. If more than 70% of the students gave the correct answer at the end, a long explanation was not needed.

The steps presented by Gjerde et al. (2021b) are listed as follows:

1. Presentation of conceptual multiple-choice question
2. Individual thinking — 1-3 minutes
3. Individual answer
4. Group discussion, groups of 2-4 students (Peer Instruction) — 1-3 minutes
5. Individual answer
6. Plenary discussion* and explanation

The analysis in this project is based on the conversations from step 4 above.

* This list follows the steps for using the conceptual multiple-choice questions from Gjerde et al. (2021b) as written in their report. During the lectures, there were no plenary discussions, only plenary explanations. The lecturer explained that this was because of the size of the course.

Note, these steps are posed differently from the steps explained in section *I-ii-a Peer Instruction*. In the original format, consisting of seven steps, steps "5. Students record revised answers" and "6. Feedback to teacher: Tally of answers" are two different steps. In the lectures in this study, these two steps become one, "5. Individual answer." The other steps are similar to the original format, the only other difference is the formulation.

The conceptual multiple-choice questions given were designed specifically by the lecturer to challenge students' understanding of core concepts (Gjerde et al., 2021b). Below is a picture of one such question.

A ball rolls without slipping on a horizontal surface. Then it comes to a hill that rises at a constant angle above the horizontal. How does friction affect how high it reaches?

A) It reaches its highest if the hill is frictionless.
B) It reaches its highest point if the hill exerts friction on the ball.
C) Friction has nothing to do with how high it reaches.

Picture 1 *– An example of a conceptual multiple-choice question used by the lecturer. This question was used in the final examination. The correct answer is A).*

In these Peer Instruction lectures, there were three diverse types of assignments:

a) Traditional conceptual multiple-choice questions with a prompt for principles
b) Traditional conceptual multiple-choice questions without a prompt for principles
c) Model based self-explanation questions

The lectures recorded mostly consisted of the b) type of assignment, and a few cases of a). There may be some differences in the discussions between the types of assignments. With the number of transcribed recordings, it will not be reasonable to extend any conclusions in this difference, though it may be noted in the results that certain discussions only happened when a prompt was introduced.

II-iv – Data gathering

Data were gathered during the group discussions in Peer Instruction. The time span of the recordings was about a month and a half between the first and last recordings. In the first recording session, the groups had the recorder on throughout the entire class, but this led to some technical issues. These issues were mostly related to the recorder, such as a faulty battery after being dormant for a while, the memory card being full, or a system error. Some human error was also a cause because both the students and I were unfamiliar with the device. Ending the recording early by pressing stop instead of pause, not selecting a memory unit, or choosing the wrong settings for recording, making the file unreadable or the voices hard to decipher. These problems were fixed between lectures so that the next recording session would come and go without technical errors.

In the later sessions, the student groups participating were instructed to only push the play/pause button when it was time for group discussion. This worked well, the groups themselves naturally picked someone to oversee the recorder each session. The instructions on how to operate the recorder were repeated at every session, to make sure there were no problems or misunderstandings.

The instruments for recording were:

- Olympus Linear PCM Recorder LS-P4, 3MIC
- Olympus Linear PCM Recorder LS-10

One of these was placed between the students in a group, one for each group. The recordings were then edited down using the program iMovie to remove unnecessary silence, take out any non-discussion material and reduce background noise. Thus, the only part that remained in the recording was point four on the proceeding from section *II-iii – Peer Instruction in the lectures.*

II-v – Transcripts

The recordings were transcribed intelligent verbatim to capture the meaning without unnecessary details, such as non-meaningful repetition, as well as fillers such as "uhm" and "ahh." The students were anonymized by assigning the speakers names "Student 1-5". Any names in the transcripts have been altered, by a [name] with a random name selected. Some cases have [lecturer] when they would for example say, "he just said," making it "[the lecturer] just said."

Sometimes during the discussions, the students would speak over each other, which made some parts difficult to transcribe completely accurately. In some parts, a word or the start of a sentence would be incoherent, or unintelligible because of the surrounding noises from the other students. In these cases, I have added "cannot discern what is being said" in bold letters and parentheses (**(forstår ikke hva som blir sagt her)** as it is written in the transcripts).

In some cases, the meaning of the speaker would be lost outside the audio, based on the circumstances, such as them being cut off mid-sentence by other students, or others. In these cases, I have added the perceived intention with [continuation], as seen in the example under findings, with:

> Student 1: I was so confused, I just [gave the same answer as you]

Where it appeared clear in the audio what the student was trying to say, but they did not complete the sentence.

The entire transcript of the four recordings, altered to assure anonymity, can be accessed in the attached files, in Norwegian. Some irregularities in translations and vocabulary happen, but they will be explained when necessary.

II-vi – Analysis

Analysis of the recorded conversations is based on the content of the students' discussion compared to the rules for discussion given by the lecturer. The categories described in chapter III – Findings are based on which, how often, and when the students enter the different sections of the rules.

The transcripts were coded using the program NVivo. Using this program, the discussions from the transcripts are categorized by codes. These codes will be used in the findings to describe the themes of the discussions. This is a brief explanation of codes and themes, with examples.

- Code – a word or phrase which represents a single idea.
    - Example: "Explaining their own idea"
- Theme – a word or phrase to describe a broader, overarching idea.
    - Example: "Supporting good learning and good discussions"

In the findings section, all the codes and themes are listed in a table, along with explanations. In some cases, examples are also provided.

Initially, the transcripts were coded independently to give an overview of the content. After listening to and reading the transcripts several times while coding, the first draft was made. This was presented in a discussion with my supervisor. I then went back and worked on improving the codes to better fit the narrative of the research question in this thesis. From this, a list of more in-depth codes was made, along with a mind map of how the discussions would usually turn out. After a discussion, and another round of going through the transcripts and recoding, the final list of codes was made. This final list was then discussed, and some of the names were slightly modified to be more descriptive. These changes were made to ensure a reliable set of codes that could be replicated when going through the transcripts again. The final product of codes was stable when recoding the transcripts.

When there has been doubt about whether a code should be applied to the statement, I have followed examples and explanations as my own personal guidelines (these can be found in section *III-i Explanation of the findings*). This has been done to ensure consistency. In some cases, I have read similar cases on other parts of the transcripts and seen if these statements have the code or not. If the code were present or not, I would assess whether both cases suit the code based on the explanation and/or examples.

II-vii – Validity and reliability

Can the findings be transferred to other contexts? As student group dynamic differs from setting to setting, and group to group, it is hard to propose a one-to-one comparison of the findings in these groups, to potential findings from other groups in other settings. The main issue addressed in the findings is the consistency of the groups in this research, and how closely they follow the given rules for discussion. Given a different Peer Instruction setting, with the same rules, but different students, the question "do the students follow the rules for discussion" may have a different answer than the one I propose in the conclusion. Any reader should assess whether the findings are transferrable to their context, based on the descriptions I have given of the participants and setting (Lincoln & Guba, 1985).

Are the findings reliable? During the analysis, the content of the transcripts has been listened to several times, read several times, coded, discussed, and recoded. That I achieved stable codes at the end of this process indicates reliability in the findings. The end results of codes were intended to be as descriptive as possible, along with thorough explanations so the results I found could be replicated over time, and by other researchers.

Are the findings credible? The process described in the method chapter has been intended to make the findings credible, based on a thematic analysis of the data. When presenting themes from data, considering the method and analysis is essential (Braun & Clarke, 2006). To expel doubt from the analysis, the method described has attempted to clarify the steps between receiving the data and achieving the results. Whether the reader judges these findings as credible should be based on their impression of whether the findings are accurate depictions of the available data. The findings here do not represent all student discussions. Some potential weaknesses of this study are described in the section *IV – Conclusions*.

III – Findings and discussion

III-i – Explanation of the findings

The intention of giving the students rules for discussion was to promote good learning processes and content in their discussions. With this intention in mind, codes were created to find instances that support such processes and content, by following the rules. Alternatively, to indicate issues that prevented the students from engaging in good learning and/or good discussion, by preventing them from following the rules.

Ultimately, the goal of the codes was to indicate whether the students follow the rules of discussion. After deliberating, the codes were further categorized into themes to indicate whether the discussion was meaningful in terms of learning or not, still based on the rules of discussion. Additional codes were created that would be relevant where learning and good discussions were prevented. Therefore, the two themes “Supporting good learning and/or good discussions” and “Preventing good learning and/or good discussions” were created. In this section, another theme will be addressed, after the lack of content from the transcripts, “Lacking from the discussions.”

Thus, the findings are categorized into three different themes as follows:

1. Supporting good learning and/or good discussions
2. Preventing good learning and/or good discussions
3. Lacking from the discussions

To say whether the students follow the rules of discussion, we must find in which of these themes the rules are placed. The second theme, “Preventing good learning and/or good discussions,” is important to include, because some of the discussions would enter this theme. When the discussions enter this theme, they are indirectly not following the rules. Examples of this are such as “Not everyone in the group speaks” and “Fail to reach final agreement.” These both work to prevent good learning and or good discussions, and go against the last rules of discussion, rule 6, “Make sure everyone partakes in talking and explaining,” and rule 7, “Seek agreement.” Because of this implication, these rules are also included in the explanation of this theme.

The intention behind the rules is to support good learning and good discussions. Therefore, one would think that all the rules should be placed under this theme. The rules lacking from the first theme are placed under the last theme, because the group consistently did not perform them, or failed to perform that rule often. None of the rules presented prevent good learning and good discussions by themselves, but the failure to follow them does. In these cases, the rules are discussed under this theme because of these failures to follow them.

The table below shows the themes with the codes that match. Since the themes will be addressed often, they are each given a shorter name that will be used when the full name is not needed.

Theme	Codes
Supporting good learning and/or good discussions “Supporting”	Shares answer, agree Shares answer, disagree Reach final agreement Explaining their own ideas Explanation based on technical terminology Explanation based on physical principles Challenge ideas Elaborating on idea (asking) Elaborating on idea (providing) Discussing other alternatives Everyone in the group speaks
Preventing good learning and/or good discussions “Preventing”	Not enough individual time to process Misunderstanding problem text/alternatives Misunderstanding other students Frustration Fail to reach final agreement Not everyone in the group speaks
Lacking from the discussions “Lacking”	Addressing other’s ideas before presenting their own Everyone in the group speaks

Table 1 *– The codes used to express the use of different rules, and under which of the themes explained they belong.*

A brief explanation of the codes:
The four codes for (dis)agreement are in the initial phase of the discussion, and by the end. As the students share their answers, they either all initially picked the same answer, or they did not. Part of the rules for discussion was to “seek agreement,” thus the “(fail to) reach final agreement” becomes relevant.

“Explaining their own ideas” point to the second rule of discussion, “Give clear reasons for your answer.” The content of the explanation was also coded based on the use of technical terminology or physical principles. These two codes were also used to describe content during “Elaboration on idea (asking/providing),” “Discussing other alternatives” and “Addressing other’s ideas before presenting their own.”

The difference between “Addressing other’s ideas before presenting their own” and “Challenge ideas” is the content of the reply. Some examples:

1. “No, you’re wrong.”
2. “Have you considered the gravitational force?”
3. “You must also consider the gravitational force. Then your idea of a zero-sum force situation no longer applies, and the object accelerates.”

(Note, these are not examples from the transcripts. These examples are guidelines I have used consistently throughout the coding, to differentiate between similar codes.)
Although they are all responses to a statement from another student, these three examples would all receive different codes. In the first example, none of the codes would apply. This statement is non-progressive and does not add any meaning or value to the discussion. The second example would be coded with “Challenge ideas,” as it challenges the other student to consider an integral part of the assignment that they might have missed. This statement helps provide value to the discussion if they continue the thread of why gravity is important in this case. The last example would be coded with “Replying to other’s ideas,” because it explains why gravity is important and gives context to improve on the first idea.

Elaborating happens either when a student asks for clarification or another kind of explanation, or when a student provides clarification or explanation.

Here is an example from Transcript 1 – Discussion 2, where student 1 is asking for elaboration, while students 3 & 4 are providing it.

> Student 1: “Then someone has to explain the word [Norwegian word for tension that also means voltage] to me”
>
> Student 3: “Tension, think tension on the rope.”
>
> Student 4: “It’s just the force, practically.”

This specific example was caused by the other students using the Norwegian word that means both tension and voltage, which confused the first student. Student 3 used the English word tension to explain their intention, by translating it, then Student 4 continued to explain how tension was relevant in this case.

“Discussing other alternatives” is about discussing the alternatives not already mentioned. If every student agreed on the same answer, they would discuss the remaining alternatives. If they disagreed, they would mention why the remaining answers had to be false. Example: student 1 and student 3 picked A as their answer. Students 2 & 4 picked C. If they discuss alternatives B and D, then they are discussing other alternatives. Discussing A and C entails explaining their ideas or addressing other ideas in this case.

The discussions were sometimes more of a dialogue between two of the students than a group effort. Especially in the bigger group, there would be entire discussions where some students would either not be participating or be cut off when attempting to give their opinion or explanation. Because of this, every discussion is either coded with “Everyone in the group speaks” or “Not everyone in the group speaks.” If a student tries to speak after the initial “Shares answer” section but is cut off, and this happens for the entire discussion, it is considered “Not everyone in the group speaks.” Also, if the student only speaks in the “Shares answer” section, and stays quiet for the rest of the discussion, it is considered “Not everyone in the group speaks.” The students must all partake in the discussion following the introductory “Shares answer” for the discussion to be considered as “Everyone in the group speaks.”

The last four codes on this list are additions that would affect the discussion. “Not enough individual time to process,” “Misunderstanding problem text/alternatives,” ”Misunderstanding other students,” and “Frustration” are all codes that describe unfruitful events.

Note, one of the rules for discussions did not have its own code. The first rule, “Put forth all relevant information,” was in this case not essential, since all the relevant information was already available for the students as context for the problem. This will be addressed later, in the “Lacking” theme.

Overall, the participating students showed a good understanding of the subject in their discussions. This is not surprising, based on their final grades.

III-ii – Examining the findings by the themes

As noted in the introduction, this thesis has the given rules for discussion as a focus. Here the transcripts will be assessed on whether the groups followed the given rules or not.

These subsections will be divided by the themes, “Supporting,” “Preventing,” and “Lacking.” Each of the rules for discussion relevant to that theme will be discussed, along with an overview of how the given rule would affect the discussion, or in some cases, why it might be lacking. Some rules occur in several themes, this will be explained when relevant.

Before going into each of the themes, here is the full list of the rules the students were told explicitly to use in the discussions:

1. Put forth all the relevant information
2. Give clear reasons for your answer
3. Challenge each other: Ask for explanations whether you understand or not
4. Respond to others’ thought processes before presenting your own
5. Discuss alternatives
6. Make sure everyone partakes in talking and explaining
7. Seek agreement

Note: 6. “Make sure everyone partakes in talking and explaining” appear in all three themes. This will be commented on in each theme.

III-ii-a Supporting good learning and/or good discussions

The rules for discussion were created to stimulate good learning and good discussion for the students engaging in Peer Instruction. Therefore, it is natural that they appear in the "Supporting" theme. However, not every rule is included. The rules for discussion that fit the "Supporting" theme are as follows:

2. Give clear reasons for your answer

3. Challenge each other: Ask for explanations whether you understand or not

5. Discuss alternatives

6. Make sure everyone partakes in talking and explaining

7. Seek agreement

Note, I have chosen to exclude 1. "Put forth all the relevant information" and 4. "Respond to others' thought processes before presenting your own," not because they do not fit under "Supporting," but because they were consistently lacking from the discussions. Therefore, they will be discussed later, in the "Lacking" section.

2. Give clear reasons for your answer

The students in the discussions would often use technical terminology and physical principles when explaining their answers. Most of the discussions would start with the students explaining their ideas, after sharing the answers. If all the students agreed on the answer initially, they would still self-explain the answer they had chosen, and when everyone then agreed again move on to discuss alternatives. This shows that the rule "give clear reasons for your answer," was followed, and that the groups followed it well.

3. Challenge each other: Ask for explanations whether you understand or not

To see if the groups followed this rule, I used the codes "Elaboration (asked/provided)." From the transcripts, we can see that they would sometimes elaborate or ask for elaboration. However, most of these cases of elaboration would happen because a student did not understand either something the other students say or part of the problem/text. The students could do better here, and it becomes unclear whether they ask because they are following the rules, or because it's natural. The research in this thesis is not aimed to answer this, only whether the students follow the rules. Because there are clear examples of the students actively seeking elaboration, we can say that the students follow the rule "challenge each other: Ask for explanations whether you understand or not," but not in its entirety.

5. Discuss alternatives

"Discuss alternatives" was the most prominent rule from the transcripts. By this, I mean that without knowing the full extent of the rules, someone reading the transcripts could point to "discuss alternatives" as a rule the students were given. Students would often refer to this rule, saying for example "we have to discuss other alternatives as well." When prompted by a student, the group would then discuss the rest of the alternatives. These discussions were often brief and mostly consisted of a student saying, "it can't be X because Y", where X was an alternative, and Y was an underlying concept or principle that should prevent X from occurring. Many discussions did not include a separate discussion of alternatives, but that was often because of students trying to convince each other of the correct answer. If the time given allowed it, the students would follow this rule.

An example of the students discussing other alternatives (Transcript 3 – Discussion 1), in a problem with an elevator going at constant speed upward:

> Student 4: We're also supposed to discuss the other [alternatives]
>
> Student 2: So some answer incorrectly because they don't read the assignment, hmm
>
> Student 4: Why is it not C?
>
> Student 5: It would go into the ground
>
> Student 3: It goes down, accelerating downwards
>
> Student 1: In A the elevator accelerates upwards, so the elevator is moving faster and faster upwards

Student 1: And in C, the elevator is moving faster and faster downwards

Student 1: Agree?

Student 4: Yes, agree

Student 2: And D, I don’t understand, it shortens the cable, that’s pulling on it?

Student 2: And then E, if nothing happens...

Lecturer: You may give the answers

Student 1: It’s B

The students shortly, but concisely, discuss the other alternatives. The discussion phase ended before they could give reasons for every other alternative. The group had already discussed their answers, seeking agreement before they all accepted B as the answer, as Student 1 reiterated at the end when the lecturer asked for their answers. This example is quite similar to how the groups would discuss the alternatives in the other discussions as well when they had the time.

6. Make sure everyone partakes in talking and explaining

The smaller group did in four out of their five discussions have everyone partake in talking and explaining. For the bigger group, there were far more discussions transcribed, and with more discussions, came more discussion without everyone talking and explaining. In some discussions, the students actively tried to engage each other. Either ask “what did you answer?” or “what do you think?” to their fellow students, to involve everyone in the group in the discussion.

7. Seek agreement

If the initial sharing of answers did not result in an agreement, the students would spend as much time as needed to reach an agreement, unless the time given expired. Reaching an agreement was important to the students, as they discussed. They would often repeat the answer after reaching agreement to ensure everyone was on the same page. There were no cases of the students agreeing on the answer initially, and then changing this answer, or disagreeing by the end.

The students often reached a final agreement on their answer, an example of this (from Transcript 3 – Discussion 1) highlights this after the students explain their answers:

> Student 4: The sum of forces equals zero, because there is constant speed, and therefore zero acceleration
>
> Student 2: Yes, I agree
>
> Student 1: Oh, it's constant speed, yeah
>
> Student 4: So I'm thinking the sum is equal, so the force up is equal to down. Normal force is equal to mg then
>
> Student 1: You've convinced me
>
> Student 2: I have to agree
>
> Student 5: I'm convinced, it's B
>
> Student 3: It's B
>
> Student 4: You guys answered A, then? Why is that?

The students would proceed to discuss the other alternatives after this. The groups followed this rule well and would mostly manage to agree by the end of the discussion.

III-ii-b Preventing good learning and/or good discussions

In addition to the misunderstanding, frustration, and general lack of time, there were two of the rules for discussion, that was often not followed, and this hindered the group from having good discussions:

6. Make sure everyone partakes in talking and explaining

7. Seek agreement

By mentioning these rules in this section, I am not implying that the rules themselves prevent good learning and/or good discussions. I am instead highlighting how important these rules are for ensuring good learning and good discussions since failure to follow them often led to the prevention of good learning and good discussions.

Failing at rule 6. Make sure everyone partakes in talking and explaining

The bigger group was consistently failing to make sure everyone participated in talking and explaining. There were several discussions where one or two of them would not speak or would be cut off when starting to speak. Of the smaller group, it was only once that not everyone had the chance to speak during the discussion. That was only during the last discussion for the day, which was shorter than the rest. The student who did not participate in the discussion only spoke during the “Shares answer” section.

In the bigger group, this issue was persistent. Some of the students were often cut off when beginning to speak. This seemed to lead to frustration from the students being cut off when starting to speak.

Failing at 7. Seek agreement

The code “Failing to reach final agreement” did not occur often. When it did, it was mostly caused by the students chit-chatting or explaining without considering the other’s ideas.

The codes “Frustration,” “Misunderstanding other students / problem text/alternatives,” and “Not enough time to process” had several incidents that prevented good discussions. Below are some examples of “Not enough individual time to process,” “Frustration,” along with “Not everyone in the group speaks” and “Failing to reach final agreement.” All these happen during Transcript 3 when the bigger group consisted of five students.

In Transcript 3 – Discussion 1, the group commented that they did not read the entire text of the different alternatives, which made them answer the first, “most correct” answer they came across.

In the same transcript, at a later discussion (Transcript 3 – Discussion 5), the group again commented that they did not have time to read all the text on the screen before having to give their answer.

> Student 1: I didn't even have time to think and read all that stuff before we were supposed to show our hands. That's why I answered the same as you guys.
>
> Student 2: Did you answer A?
>
> Student 3: Yes I did
>
> Student 4: I also answered A.

This set the tone for the rest of the discussion. Student 1 would reiterate that they did not have time to read, process, and understand the assignment and alternatives several times in the minutes the discussion lasted. Nearing the end of the discussion, this student tried to understand the problem but was met with some resistance.

In this same discussion, there were a lot of chit-chats and inside references between students 2, 3, and 4, who had all solved the problem initially. This caused student 1 to become frustrated by the end, because they did not understand the discussion, and thus did not feel like the problem was solved. This student also tried to get back into the discussion by using physical principles and terminology, but to no avail: they failed to reach an understanding. In the audio, student 1 was cut-off a few times when starting to talk, which did not make it into the transcript, as it was considered non-essential during the transcription. Student 5 did not speak at all during this discussion.

> Student 1: I was so confused, I just [gave the same answer as you]
>
> Student 4: My first thought was Newton's third law, which means it has to be A or B
>
> Student 2: A, B, or C? Oh, no, never mind, there is no minus
>
> Student 4: A or B, which is the first step I was thinking, which rules out [the rest], and I didn't even consider the rest
>
> Student 1: But I didn't have time to understand what this all meant before [the lecturer] was like "now it's time for talking"

Student 4: So I was thinking, it's kind of logical. There isn't any force affecting it later, so B becomes an odd choice.

Student 1: It's frictionless, so the only force affecting it in the x-direction is... **(gets cut off by the other students)**

Student 4: I have a really bad explanation as to why, but it just feels intuitively wrong to choose B

Student 2: I don't know what F m is, or big M and small m

Student 1: F big M on small m is the little man's force on the big man, and otherwise

Student 2: Yeah, but on B; FM, and Fm, they aren't defined.

Student 4: I don't know what those are

Student 1: Oh

Student 4: It's like inertia? Is it not the person's inertia force?

Student 1: It's frictionless... **(gets cut off by the other students)**

The other students have some indistinguishable chit-chat

Student 1: Can I ask if I have understood it? Because I don't understand anything

Student 2: Yes

Student 1: Thanks, instead of you guys boosting your ego because you've all already understood it

Student 2: No, we're just joking around

Lecturer starts talking

Student 1: Oh, no, now we're finished. Now I won't know if I got it right, ever.

This is how the discussion ended. Only one of the students explained their ideas, but only partially to exclude two of the options, and said they had a "really bad explanation" for their reason to pick option A over B. There were some questions from the other students, but it was mostly answered with jokes, or not at all because they would cut each other off. Some of the discussions were affected by misunderstandings, or not having enough time to process the assignment. In this recording, the group consisted of five students.

This specific group usually consisted of two males and two females. In this recording, there were three males and two females. The student who was most cut off during this recording was the female student 1. This shift in dynamic was interesting to observe but other than showing an unexpected one-time event, it will not have a significant impact on the conclusion. It does, however, point to the group being too big for effective discussions during brief periods like Peer Instruction.

III-ii-c Lacking from the discussions

The rules of discussions that are missing from the transcribed discussions are:

1. Put forth all relevant information

4. Respond to others' thought processes before presenting your own

6. Make sure everyone partakes in talking and explaining

1. Put forth all relevant information

The first rule, "Put forth all relevant information," does not have any codes associated with it. Since the students were given the context of the problem in the introduction, this step was overlooked in every single discussion. The need for this step in the discussion is based on the type of assignment given. When the assignment is based on individual research or presented without context to be worked on, this step is helpful to ensure good discussions by giving necessary context. When the context for the assignment is already given, and the students have a limited time to complete the discussion, this step only wastes time that could be spent on good discussions.

4. Respond to others' thought processes before presenting your own

More surprisingly, there were few to no examples of the students responding to others' thought processes before presenting their own. The students often only focused on their ideas when responding to other students after they had presented their idea, thus not addressing the others' thought processes. In a discussion with limited time, it is possible that the students did not have enough time to address the other's ideas, as well as present their own.

To address others' ideas, the students need time to process the statement and reflect on what to respond with. This is also something that must be trained over time and with practice. The structure of these Peer Instruction sessions does not allow for this time, since there are short intervals of individual time and group discussions. Prioritizing this brief period is an important exercise for the students, but guidance is equally important. Learning by doing is a valuable trait, but it must be exercised to be utilized efficiently.

6. Make sure everyone partakes in talking and explaining

The sixth rule has already been discussed in the previous themes, but I chose to include it here as well because a lot of the discussions lacked the code "Everyone in the group speaks," and instead had "Not everyone in the group speaks." Making sure everyone partakes in talking and explaining is an important part of a group discussion. With the bigger group having this problem more often than the smaller group, it could point to Peer Instruction working better in smaller groups. Smaller groups have more time to explore everyone's ideas, and therefore should be better equipped to make sure everyone speaks during the discussion. In groups where students have this issue, different practices could be introduced to reduce the stress, and provide the students with a method to make sure everyone participates in the discussion. Practices where the students talk in turn could prove effective to help the students follow rule 6. "Make sure everyone partakes in talking and explaining."

IV – Conclusion

In this research, we have investigated whether students follow rules for discussion. Not every rule given was followed, as shown in the findings, but the rules provided a valuable framework for the students to have good discussions. Giving the students well-structured, and easy-to-follow rules for discussion can be helpful to ensure good discussions, which in turn hopefully leads to good learning.

With the exceptions of rules 1. "Put forth all relevant information," 4. "Respond to others' thought processes before presenting your own," and 6. "Make sure everyone partakes in talking and explaining," the students did generally follow the given rules for discussion.
While the rest of the rules, when followed, supported good learning and good discussion, it was noticeable from the transcripts that rule 6. "Make sure everyone partakes in talking and explaining" was essential for good discussions. In the cases where the students failed to comply with this rule, the discussions were chaotic, and the students often had a tough time reaching a final agreement. This was most notable in the bigger group, especially when it consisted of five students. Talking in turns could have alleviated the stress from this issue and ensured that every student could contribute to the discussion, in turn. "Talking sticks" (using pens or other available materials) in discussions where the different parties are prone to talk over each other is an easy method for these students to exercise restraint, since only the person holding the stick may speak. Passing the stick around in turns would give all the students a chance to explain their idea, before passing the stick to the next student.

While the brief time for discussion is a potential factor, one should consider the context on a case-by-case basis when setting rules for discussion. In the lectures, the group discussions would last anywhere between 1 and 3 minutes, depending on the difficulty of the problem, and the engagement of the discussions. The groups were sometimes met with a sudden end of discussion while still arguing, because of this brief time for discussion given.

In this context, rule 1. "Put forth all relevant information" was not necessary since the context was given in the introduction to the given problem. Rule 4. "Respond to others' thought processes before presenting your own" could be considered excessive along with the other rules to provoke explanations, when considering the time available to the students.

The potential implications from these findings could be: (a) Peer Instruction may be most effective in smaller groups consisting of either two or three students. (b) Practicing methods of "talking in turns" in the discussions could ensure every student in a group gets to contribute to and participate in the discussion. (c) Selecting fewer rules for discussion when preparing for Peer Instruction. These implications do not disagree with any other findings from research mentioned in this thesis.

Some potential weaknesses of the study include the small number of participants and having groups of mostly academically strong students. From this study, we cannot conclude whether the students followed the rules for discussion naturally, or because they were stated explicitly. To indicate either way in this case, a more extensive, experimental research would need to be conducted. By including more, and other groups in this study, the findings and conclusions could have varied from the results presented in this thesis in content and quantity.

Further research on the subject could include altering the rules for discussion and building on the findings described in this thesis. Also, experimental research to find whether introducing rules for discussion influences the students or if they follow the given rules naturally could provide interesting findings. Lastly, investigating students' use of physical models during discussions (this might require a video element of recordings for accuracy) could give valuable insight into students' conceptual understanding.

Seeing the discussions and how the students talk and explain during the Peer Instruction discussions shows how important that setting is for them to explore their knowledge and understanding. Using well-defined and meaningful rules for discussion for the students to follow with practice and guidance may help the students discuss and collaborate more efficiently. It is important to give the students a good understanding of how to follow the rules for discussion and make them conscious of their part in the discussion, especially when making sure everyone in the group participates. Peer Instruction and active learning, along with formulating rules for discussion, will be essential to my teaching.

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