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BOARD # 470: Work in Progress: RIEF - An Observational Study of Student Question-Prompted Discussion to Identify Student's Knowledge Level

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INTRODUCTION & BACKGROUND

At [the institution], cooperative learning and research relating to its impact have become a cornerstone of an undergraduate thermodynamics course through the Peer-Led, Study Group (PLSG) model. This model is implemented during required weekly 50-minute recitation sessions, where small peer groups of 4-5 students collaborate to solve 1-3 new and challenging course-related problems during the class period. Every 1-2 groups are supported by one near-peer undergraduate facilitator who monitors progress and provides assistance when necessary. Facilitators play a key role in promoting student discussions and interactions, which are integral to the PLSG model. Compared to the traditional TA-led Recitation (TAR) model, where a teaching assistant or instructor solves problems in front of a class of 25 or more students, the PLSG model has been proven to significantly improve both student course grades and pass rates at [the institution] [1].

The foundation of the PLSG model is inspired by the work of Uri Treisman at UC Berkeley [2]. Treisman observed that Asian students in his calculus course developed self-formed study groups, enabling them to collaboratively enhance their understanding and engage with mathematical concepts at a deeper level. When Treisman instituted structured study groups for Black students in his course, their previously high course failure rates improved significantly [2].

In recent semesters, research on PLSGs has moved from the overarching study of course grade improvements to the in-depth study of student interactions within these groups. A PLSG team-developed methodology based on the Revised Bloom's Taxonomy (RBT) has been instrumental in this effort. The RBT is commonly used in education to classify students' understanding into cognitive and knowledge dimensions [3, 4]. The cognitive dimension consists of six levels, each corresponding to an action verb, including *remembering*, *understanding*, *applying*, *analyzing*, *evaluating*, and *creating* [5]. In comparison, the knowledge dimension categorizes understanding into *factual*, *conceptual*, *procedural*, and *metacognitive* levels [5].

Using this methodology, the team has identified a positive correlation between improved final course grades and the frequency of question-prompted discussions initiated by students. By leveraging the action verbs associated with cognitive levels in RBT, the team has developed a preliminary model for categorizing the levels of knowledge present in these discussions. With this expanded model, the team seeks to address two research questions: 1) What levels of knowledge are observed in question-prompted student discussions within PLSGs? and 2) To what extent do these knowledge levels impact student pass rates and/or final course grades? This evolving research continues to highlight the value of the PLSG model in enhancing academic performance and student engagement.

METHODOLOGY

During one semester of research, eight groups of students were formed and observed an average of 10 times. These groups were divided into four main categories: (1) two or more first-time full-time (FTFT) White men, (2) two or more transfer (TRN) White men, (3) two or more women, and (4) two or more Hispanic/Latino students. Within categories (1) and (2), groups were further stratified by average group-level GPA at the beginning of the term, which acted as a gauge for student course preparedness, into levels of 2.0, 3.0, and 4.0. Categories (3) and (4) were stratified similarly, but only for the 2.0 and 4.0 GPA levels. These groupings were specifically selected to reflect the student population and test differences in interaction levels between genders and between Hispanic/Latino and White students, both being prominent demographic groups at [the institution], which is a Hispanic Serving Institution (HSI). Demographics such as race will be further investigated in future work.

Data were collected from these groups during 20-min observations conducted at various points within the weekly 50-min recitation sessions. Each recorded interaction started with a student question and included the subsequent discussion to provide context, referred to as *question-prompted discussions*. Over the Spring 2024 semester, the team recorded 1,299 question-prompted discussions, totaling ~28 hours of data. Following each collection period, question-prompted discussions were categorized using cognitive levels from the RBT.

Cognitive Model

The cognitive levels from the RBT include *remember*, *understand*, *apply*, *analyze*, *evaluate*, and *create* [4]. However, these levels did not fully encompass the scope of student question-prompted discussions. To address this gap, the team added four additional levels: *facilitator*, *no response*, *social*, *logistic*, and *checking value* [6]. Descriptions of all eleven levels, along with associated action verbs, are listed in Table 1. To categorize question-prompted discussions, 1-3 verbs most closely aligned with the discussion were selected to define the cognitive level. In the rare case where a question-prompted discussion was difficult to categorize, several research team members reviewed the context of the discussion and reached a consensus.

Table 1. *Categorization of Cognitive Levels Based on the Revised Bloom's Taxonomy [4, 6]*

Level	Description
Facilitator	Student question-prompted discussion directed toward the facilitator
No Response	Question goes without response or is responded to with an additional question
Social	Students discuss non-course-related content
Logistic	Students discuss roles in solving problems and materials required
Checking Value	Student asks question to verify correctness of value with peers
Remember	Recalling relevant information and basic facts
Understand	Discussing and explaining course concepts
Apply	Using prior knowledge in new scenarios
Analyze	Relating ideas and concepts
Evaluate	Justifying reasoning for a particular method or idea
Create	Developing new and/or original work

Knowledge Model

Building on the cognitive model, the team further categorized question-prompted discussions based on the knowledge levels of the RBT: *factual*, *conceptual*, *procedural*, and *metacognitive*. These knowledge levels were mapped to verbs from the cognitive level categorization process. Descriptions of these levels are provided in Table 2.

Table 2. *Categorization of Knowledge Levels Based on the Revised Bloom's Taxonomy [5]*

Level	Description
Factual	Recalling essential basic elements of course content
Conceptual	Understanding macroscale relationships between basic elements

Procedural	Using methods required to solve content-related problems
Metacognitive	Possessing knowledge and awareness of one's cognition

Table 3 shows the knowledge levels of the RBT organized by the verbs associated with each cognitive level. For example, verbs such as list, state, define, and memorize, which are associated with the *remember* cognitive level in the RBT, are categorized under the factual knowledge domain in this study (see Table 3). While this preliminary organization provides a structured framework, some gaps remain in the categorization due to the interpretation of certain verbs and the absence of specific knowledge levels observed during the semester. Notably, the "create" cognitive level is absent in this model, as it was not observed during data collection. The create level is likely not seen due to the expected scope and problems administered during the course. Thermodynamics is a thoroughly researched topic with little room for undergraduate students to discover new science or methods of calculation. The purpose of this paper is to better understand students' level of knowledge.

Table 3. *Intersection of Knowledge and Cognitive Levels of the Revised Bloom's Taxonomy [5]*

	Cognitive Level				
Knowledge Level	*Remember*	*Understand*	*Apply*	*Analyze*	*Evaluate*
Factual	list, state, define, memorize	describe, discuss, report, select	solve, schedule	distinguish	select
Conceptual	NA	classify, identify, locate, recognize	interpret, sketch	differentiate, organize, relate, compare, contrast	support
Procedural	duplicate, repeat	explain, translate	execute, demonstrate, operate	examine, experiment, test	judge, argue, defend, weigh
Metacognitive	NA	NA	use, implement	question	appraise, critique, value

RESULTS & DISCUSSION

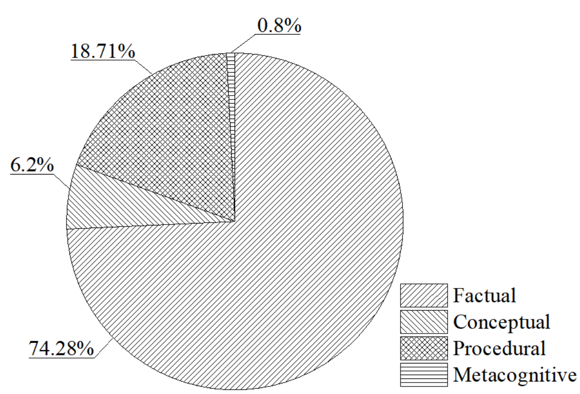

Figure 1. *Question-Prompted Discussions by Knowledge Level*

From the nearly 1,300 categorized student question-prompted discussions, we found that over 60% fell within the knowledge dimension of the RBT (which includes *factual*, *conceptual*, *procedural*, and *metacognitive* levels). Figure 1 shows a breakdown of the knowledge levels observed, highlighting that PLSGs effectively engage students across multiple levels of knowledge and specifically promote factual and procedural level discussions. However, the limited occurrence of discussions at the *metacognitive* level (7 instances, all within the *analyze* cognitive level) indicates that higher-order thinking and self-awareness of learning may not be prevalent. This could either reflect the structure of the PLSG model, the nature of the course material, or both and suggests opportunities for improvement in fostering deeper cognitive engagement. Additionally, all procedural knowledge levels were observed at least once, suggesting that the PLSG model promotes cognitive diversity at the procedural understanding level. This aligns well with the applied nature of engineering courses, where procedural knowledge is critical for solving problems and implementing solutions.

However, the absence of certain combinations (e.g., *apply*, *analyze*, and *evaluate* at the factual knowledge level, *remember* at the conceptual level, and several cognitive levels at the metacognitive knowledge level) reveals that the current model does not fully capture all possible interactions. (Note: only 13 of the 20 categories outlined in Table 3 were represented in the analyzed data.) This gap might be due to limitations in the observation framework, the course content, or the PLSG design. Future research should explore whether these missing levels are inherently less relevant in this context, whether the model could be further refined through the addition of more appropriate cognitive dimension verbs that better align with the knowledge dimension or through reevaluation of the existing verb categorizations, or if modifications to the instructional design could encourage their emergence.

A general linear regression model was used with the R Project for Statistical Computing program to analyze the impact of question-prompted discussion knowledge levels on student outcomes, particularly student pass rates and final grades. The analysis considered all four knowledge levels, along with factors such as GPA at the beginning of the term, gender, and instructor. The model showed an R-squared value of approximately 0.8, indicating that the relationship between knowledge levels and student outcomes (final grades or pass rates) is complex and likely influenced by factors beyond those considered in the model, which requires exploration in future work. Additionally, the lack of statistically significant results for individual knowledge levels implies that while these levels may contribute to the learning process, their direct impact on grades or pass rates is difficult to isolate in this dataset, perhaps due to small sample sizes.The limited presence of certain knowledge-cognitive level combinations also introduces challenges for accurately modeling the relationship between discussions and student outcomes. A more comprehensive dataset that captures a broader range of interactions may yield more meaningful insights. By improving the current knowledge model and addressing gaps in the data, future research may uncover stronger relationships between knowledge levels, student outcomes, and the overall effectiveness of the PLSG model.

IMPLICATIONS & FUTURE WORK

The findings of this study reveal important implications for the PLSG model. The rarity of metacognitive knowledge levels and the absence of certain cognitive-knowledge combinations suggest that the current model does not fully promote higher-order thinking and self-regulated learning. Targeted interventions, such as enhanced facilitator training or the integration of specific prompts, may help foster deeper reflection, analysis, and synthesis during discussions. Additionally, gaps in the knowledge-cognitive framework highlight the need for refinement. Reassessing verb categorizations and expanding the model to align with the RBT more closely could capture a broader spectrum of student interactions. Addressing these gaps would provide a more comprehensive understanding of student engagement and support the development of strategies to encourage more conceptual and metacognitive knowledge.

The strong representation of procedural knowledge underscores the model's effectiveness in building problem-solving skills critical for engineering students. However, balancing this focus with efforts to enhance conceptual understanding and metacognitive development will better prepare students for both academic and professional challenges. Future work should also explore alternative measures of success, such as retention of material and confidence in problem-solving, to complement traditional metrics like grades and pass rates.

Future research will focus on reworking the current model to capture all 20 levels of the RBT within PLSG interactions. This may involve reassessing existing categorizations, introducing additional action verbs, and exploring alternative methodologies to address the gaps identified in this study. By creating a more comprehensive framework, we aim to understand the full range of student interactions within the PLSG model.

If revisions to the model still fail to capture all levels, broader interventions in the course structure or the PLSG model may be necessary. These could include adjustments to group activities or facilitator training to encourage discussions that promote higher-order thinking, such as metacognitive reflection and application-based problem-solving. Such changes would ensure students are building the necessary engineering skills for success in their future courses and careers. Future studies will also examine the relationship between knowledge levels and broader measures of success, such as material retention, problem-solving confidence, and performance in subsequent courses. By addressing these areas, we can further optimize the PLSG model to enhance learning outcomes and prepare students for academic and professional challenges.

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