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Abstract
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Keywords
Assessment, Workshops, PLTL, journals, leader development, Calculus

Cover Page Footnote
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Assessing Peer Leader Skill Acquisition and Group Dynamics in a First-Year Calculus Course

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Peer-led team learning (PLTL), specifically the model known as 'Workshops', has been shown to contribute positively and significantly to student success in STEM courses across subjects (Gosser et al., 2001). Our research adds to the SOTL literature describing the effectiveness of Workshops by reporting on the changes in student leaders. We examine the level to which leaders acquired new skills in effective teaching and describe the pedagogical interactions in the groups they led as a result of the combination of training and experience facilitating first-year Calculus Workshop sections. This was a semester-long study on twenty-two Workshop leaders for two multi-section, introductory calculus courses at a small research university. Our method is a novel overlay of two metrics that allows, with some forethought, a robust analysis of Workshop leader outcomes that would complement any assessment of PLTL implementation faculty might choose to undertake.

INTRODUCTION

The peer-led team learning (PLTL), or 'Workshop' model has been in continuous use in STEM courses for over 20 years (Woodward, 1993; Tien, Roth, & Kampmeier, 2002). In this model, students enrolled in a Workshop-bearing course meet weekly outside of lecture in small groups of about 6-10 students with a 'near-peer' facilitator, called a 'leader'. During these sessions, the group collaboratively works on faculty-created problems that are sufficiently difficult so as to require the collective participation of the students and the guidance of the leader to progress successfully to a solution.

The model was originally developed for chemistry courses and inspired by Uri Treisman's "Workshop Calculus", a widely successful program for underrepresented minority students enrolled in Calculus at the University of California at Berkeley. This program aimed at getting the students to work through difficult problems in small groups in order to improve their performance in the class (Treisman, 1985). It has since been adapted to various other STEM courses, including biology, engineering, and some lower-level math courses with success (Felder, Forrest, Baker-Ward, Dietz, & Mohr, 1993; Felder, Mohr, Dietz & Baker-Ward, 1994; Felder, Felder, Mauney, Hamrin, Jr. & Dietz, 1994; Born, Revelle, & Pinto, 2002; Lyle & Robinson, 2003; Reisel, Jablonski, Munson, & Hosseini, 2014). There has been substantial research studying the effects of Workshops on student learning and leader development (Platt, Roth, & Kampmeier, 2008; Dobson, Frye, & Mantena, 2013; Tien et al., 2002). Further, research shows that PLTL improves student grades, especially for women and minority students (Springer, Stanne, & Donovan, 1999) and can enhance critical thinking skills (Quitadamo, Brahler, & Crouch, 2009).

A key part of the Workshop model is the training of the leaders; the near-peer undergraduate students who facilitate discussion at the weekly Workshop meetings, keep proceedings on track, and ensure any potentially disastrous misconceptions and pitfalls are avoided while still allowing students to develop their own mastery of course concepts. This mastery is achieved by allowing students to use their classmates' understanding of the material to attempt challenging problems that they, individually, would find too difficult to solve. To ensure that leaders are well prepared and maximally useful, they take a credit-bearing seminar led by educational developers in the college's Center for Excellence in Teaching and Learning (CETL). This weekly seminar discusses pedagogical approaches for facilitating team-based learning along with course content covered in the Workshops. As a result of these meetings' dual focus, the Workshop leaders emerge ostensibly capable in terms of course content and with a deeper understanding for how best to facilitate students' learning processes.

Workshop leaders themselves are members of the hierarchical learning community that this model creates. Studies have indicated that small group learning should have a positive effect not only on student learning, but also on the leaders in science, mathematics, engineering, and technology courses (Gafney & Varma-Nelson, 2007; Tenney & Houck, 2004). However, research on assessment for the effectiveness of the training course or a leader's overall improvement is limited (Sawyer, Frey, & Brown, 2013). Our goal, then, was to create a tool to retrospectively study leader growth over the course of the semester. Since we had chosen not to directly observe the Workshops, we approached this by analyzing leaders' journals (written weekly for the training seminar) and evaluations.

In the Fall of 2014, the Workshop model was re-implemented (after a seven-year break) in two multi-section, first-semester Calculus courses (called "Calculus 2S" and "Calculus 3S" in this article) at a small R1 university in the eastern US. At this institution, Calculus courses are offered as coordinated, multi-section, large (approximately eighty to one hundred student) lectures. Two tracks are offered. The Calculus 3S sequence covers material for single-variable Calculus in three semesters, whereas Calculus 2S is quicker-paced, covering the same material in just two semesters. Total enrollment in both courses in the Fall of 2014 was approximately six hundred students. Previously, all Calculus students had enrolled in recitations that were led by either graduate or undergraduate students. The format for the recitations was chosen by the course coordinator, a role that rotated between faculty in the mathematics department, and so there was little consistency between semesters. Past recitation models includ-

ed weekly quizzes, unstructured group work, or simply another short lecture on course material. Further, there was little interaction between the recitation leaders and faculty teaching the course. The Workshop model had infrequently been used in lower-level mathematics classes with varied success. However, this was the first time that they were implemented in such a deliberate manner for all introductory Calculus courses.

Workshop leaders were chosen through an application process in the university's mathematics department, which required them to show proficiency in Calculus course concepts as well as the ability to sufficiently explain solutions to selected Calculus problems to a hiring committee. Once hired, leaders enrolled in a 2-credit seminar that met weekly and was co-educated by a CETL instructor and the Calculus course coordinator. During each meeting, the leaders discussed their successes and failures in their Workshops. In preparation for the class discussion, they read pedagogical research on, e.g., team-based learning, cognitive apprenticeship, changing mental models, and microaggressions in the classroom. The end of each meeting was spent discussing the Calculus material covered in the subsequent Workshop. The leaders also journaled (approximately one page per week) on both their experience running the Workshop and their thoughts on the week's readings. Examples of journal prompts are listed in Appendix A.

In this project, we retrospectively analyzed overall Workshop leader growth and their facilitation of the Workshop by characterizing group dynamics over the course of the Fall 2014 semester. We developed a tool to study each leader's trajectory by primarily analyzing their accounts of the Workshops through their weekly journals. We built on the work of Pazos, Micari, and Light (2010) to analyze group dynamics and we used a second research model (Dreyfus & Dreyfus, 2004) to measure the leaders' proficiency in conducting Workshops. Looking forward to future Workshop courses, we made suggestions (based on our findings in this research and our experience performing it) on how to evaluate Workshop leaders with this new method of analysis.

METHODOLOGY

We investigated the changes in Workshop leader skill and level of collaborative group interactions through analysis of (1) 176 journals from the 22 leaders' weekly reflections, (2) mid-semester student evaluations of leaders, and (3) anonymous post-semester pedagogy surveys taken by Workshop leaders. The Pazos model was used (Pazos et al., 2010) for characterizing group dynamics of the Workshops and how the leaders facilitated this environment. Additionally, we analyzed whether taking the pedagogy course and experiencing the Workshop practicum affected leaders' developmental status per the Dreyfus model of skill development (Dreyfus & Dreyfus, 1980; Dreyfus & Dreyfus, 2004). Together, the two theoretical lenses - the Dreyfus model to examine individual skill acquisition and the Pazos model to consider the group collaborative learning environment - allowed us reflect on individual changes in light of group facilitation strategies during the semester. Finally, we propose that our approach herein, an overlay of two established models that independently characterize the change in leaders' skills and their facilitation methods (through group dynamics as a proxy), is a novel way of evaluating Workshop leaders. Further, it could be used in any near-peer, collaborative learning environment to assess outcomes.

The participants of this study were the eight Calculus 3S and fourteen Calculus 2S Workshop leaders from the Fall of 2014. All were enrolled as undergraduates at the institution. There were nine female and thirteen male leaders and their ages ranged from 18 through 21. We began by administering an online, post-semester course survey for the Workshop leaders. The surveys were emailed to the leaders and responses were anonymously collected online. Some questions included in the survey (Appendix B) were taken directly from (Pazos et al., 2010). Seventeen out of the twenty-two leaders responded to the survey. An initial review of survey responses indicated an overall positive response from the leaders about the Workshops. Twelve out of the 17 leaders agreed or strongly agreed (4 or 5 on the Likert scale) to the statement "The leader training prepared me to facilitate student-to-student interaction in my Workshop" and 14 out of 17 agreed or strongly agreed to "My contribution as a Workshop leader helped students increase their understanding of course concepts." This prompted us to dig deeper into why roughly three quarters of the leaders felt that this was a positive experience and what information we might be able to glean from their reflections.

Turning to the journals to investigate this further, we used retrospective content analysis to understand the leaders and their growth. We first read each of the leaders' journal entries (submitted weekly for twelve weeks) and individually identified themes in their thinking. We then collectively discussed the themes that were found and noted that they fell into two broad categories of 'novice' and 'more expert' ideas. Exemplar themes we saw as more 'novice' would include a univocal, as opposed to dialogic, way of communicating with students (Lotman, 1988; Wertsch, 1991); a desire for control of the Workshop environment, from rudimentary (desk arrangement and cellphone rules) to more complex (how we group up and how we get our answers into a public space); finishing the handout quickly being a sign of success and/or intelligence; teacher-centric versus student-centered instruction and actions; and student discussion being the only way to constructively contribute to Workshops. In Figure 1, we present a word cloud constructed from all leaders' journals to illustrate these themes. We note the presence of control words, such as "make" and "get" but also the use of positive words like "understand", "good", "try", and "help".

These themes and our naturally sensing a scale of "expert-ness" led us to use the Dreyfus framework for an analysis of the data. The univocal nature of how some leaders described

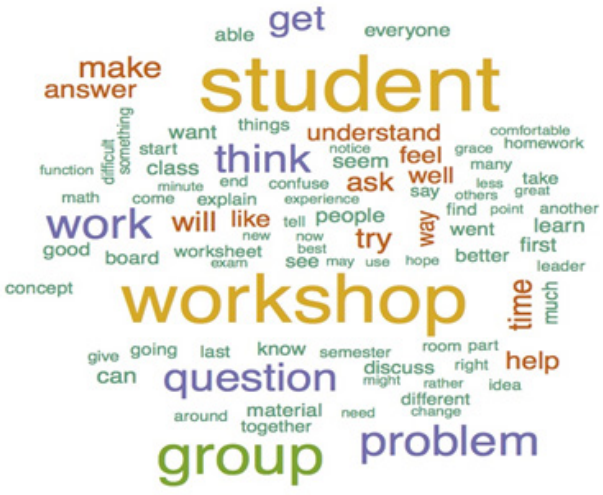

Figure 1. *Word cloud of all leaders' journals exhibiting themes we noted*

their discourse, in particular, brought our attention back to Pazos, as group work and more dialogue about course concepts were emphasized as the desired mode of instruction for Workshops. Subsequently, we analyzed the journal entries a second time to assess leaders within the context of the two models. We paired off into two teams of two readers to analyze the data, one team for each model.

Each pair of researchers met to discuss what qualified as evidence to categorize leaders for their assigned model. In our pairs, we each examined a small, random sample of journal entries to calibrate our respective frameworks. Subsequently, the remainder of the journals were read and evaluated individually by both readers on each team. Each pair met periodically to share analyses up to that point. If a pair disagreed on an evaluation of a particular leader, they would each discuss their evidence and collaboratively come to an agreement on how to categorize leaders. After we had analyzed the journals and categorized them under each lens in our separate pairs, we met as a group to identify common trends among leaders under each of these models.

Pazos Model

We used the Pazos learning group classification model (Pazos et al., 2010) to assess the quality of collaborative learning in the Workshops. This model assumes, based on previous educational research on active learning (Freeman et al., 2014), that PLTL groups are more effective when the facilitator uses student-centered, active learning methods. The Pazos model characterizes groups using two axes: problem-solving approach and group interaction style (see Figure 2). The model is not a continuum but instead helps classify Workshop dynamics into four categories: simple instruction, elaborated instruction, supported discussion, and guided discussion. The goal of the pedagogical training was to have groups that were mostly (although not exclusively) characterized by guided discussion. To help support this, Workshop leaders were trained in various active learning pedagogies such as reciprocal questioning (King, 1990) and cognitive apprenticeship (Collins, Brown, & Holum, 1991) that promoted collaborative group interaction and elaborated problem solving.

		GROUP INTERACTION STYLE	
		Individual-Oriented	*Collaborative*
PROBLEM-SOLVING APPROACH	*Simple*	Simple Instruction	Supported Discussion
	Elaborated	Elaborated Instruction	Guided Discussion

Figure 2. *Reproduced from Pazos 2x2 Framework (Pazos et al., 2010)*

Since instructors did not attend these Workshops or use peer observations as recommended in (Pazos et al., 2010), we relied on retrospective data to classify each leader's group. We first analyzed each leader's journals to assess their group's learning strategies. However, since this approach only presented the leader's perspective, we also consulted students' midterm evaluations of their leaders to better characterize the groups. These student evaluations were only used to provide supporting evidences or clarifications on data from leaders' journals, since the evaluation questions were different for some leaders, having not been coordinated between class sections. The journals and midterm evaluations together provided a rich data set for our analysis.

Rather than treating each of the dimensions of group dynamics as categorical (as the Pazos model does), we identified them as ordinal variables. We did this because the Workshop groups progressed along the two different dimensions of the Pazos model through the semester, instead of simply falling into one of four bins from a one-time observation. In addition, we found that groups at times showed evidence of, for example, elaborated problem solving, even though the group did not always follow this trend. Thus, we considered each axis of the Pazos model as a spectrum and placed groups on the 2x2 Pazos grid accordingly, based on the prevailing dynamic of the group. It is important to note that this was a qualitative assessment; we certainly did not quantify our placement of the groups along each axis, although we did intentionally identify them as transitioning within and between categories during the span of the semester. Further, we positioned leaders with respect to one another along each of the two axes. The pair analyzing using the Pazos model agreed on the characterization of the group dynamic 16/22 or 72% of the time. When we disagreed we would have a discussion as to how each of us came to that determination. We brought forward evidence in the form of student quotes from journals or mid-semester ratings. We then compared our evidence to the descriptions of each group type, and made a joint determination of best fit.

Simple instruction is the most straightforward of the four categories, utilizing individual-oriented group interactions and simple problem solving strategies. In this type of group, the leader lectures and there is little evidence of student-to-student interaction. The leader takes responsibility for solving problems and does not provide space for discussion of alternative problem solving approaches. Minimal attention is given to different strategies for solving problems, and the focus is on the answer, not the approach. Examples of simple instruction include students relying on the leader for answers to problems or a leader spending time lecturing on course material.

Supported discussion groups are characterized by a noticeable shift in the role of the leader from an explainer to a facilitator who is there to step in when needed. Another key difference is that the group does the majority of the explaining to each other. The main goal for this type of group dynamic is to get to succinct answers to the Workshop questions without digging deeper into the theories and ideas behind them. Some evidence for a group's transition to supported discussion can be found when the leader makes a choice to step back and let the students work together on their own, only interjecting if necessary. Another is when a leader encourages the students to work through a problem at the board or turn to each other for help. However, the group still concentrates on the 'correct way' to solve a given problem, rather than thinking about multiple solutions or overall concepts.

In groups categorized as using elaborated instruction, there is again minimal student-to-student interaction with the leader doing the majority of the talking. The main difference with that

of simple instruction is that there is some discussion of concepts related to the problem. The group moves beyond simplistic answers to problems and elaborates on reasoning for the answers. Examples of elaborated instruction can be found in groups where the leader focuses on explaining concepts from the course or illustrating other methods of solving a problem. In these situations, there is a clear emphasis from the leader's perspective on 'my thinking' or 'my explanation' of a topic rather than a more student-centered approach.

A guided discussion group is characterized by a leader who acts primarily as a facilitator that actively guides the group through questions. In this type of group, students discuss conceptual reasoning behind their solutions, and sometimes present alternative strategies for approaching problems. The group engages in most of the discussion and explanations with each other, and the leader stands ready to provide help or hints as necessary. Leaders whose groups exhibit guided discussion primarily employ pedagogical strategies to get the students to talk to one another. Some examples of this include encouraging students to work at the board, employing the jigsaw method (Aronson et al., 1978), or simply asking one group to explain their solution to another. Leaders may also ask conceptual questions related to the problems to get their students to deeply engage with the material. They prompt the students to explain their reasoning without telling them the exact answer to a problem.

Dreyfus Model

Using an adaptation of the Five-Stage Skill Acquisition Model (Dreyfus & Dreyfus, 2004), we observed how the Workshop practicum affected leaders' developmental status. Adapted from their seminal 1980 article (Dreyfus & Dreyfus, 1980), the 2004 model has been the basis of examining individuals' progressions through skill acquisition stages in many different fields. Notably, nursing education has used this model, adapted to the field and updated extensively in the decades since (Benner, 1982; Benner, 2004). Recently, the model was also used to analyze teaching expertise in an analysis of dental school faculty (Lyon, 2015). The Dreyfus model has also been applied to more general educational paradigms (Berliner, 1988).

We evaluated every journal of each leader for evidence of language that indicated, based on their comments regarding what they did in Workshops to facilitate students and their attitudes and reactions to students' work, leaders' being situated at a particular stage in the Dreyfus model. When the evaluators agreed on the stage or stages seen in a leader's journals, a brief discussion of the evidence sufficed. When the evaluators disagreed on the stage assignment (which happened four times over the evaluation of 22 leaders, being in independent agreement on 82% of leader placements) we compared our evidences and came to a mutual decision on the categorical assignment for that leader. No disagreement on any leader's assignment was irreconcilable after a comparison of evidences.

Each leader was assigned, based on an analysis of their journals, one of the following categories, which are adapted from the Dreyfus model: novice (abbreviated as '(N)'), transitioning, '(T)', or advanced beginner, '(AB)'. The (N) label indicates that the leader showed evidence of beginning at a Dreyfus-Novice stage and remaining in that stage throughout their journal entries. The (T) label indicates the leader showed evidence of beginning at a Dreyfus-Novice stage and then eventually transitioning into a Dreyfus-Advanced Beginner stage of skill acquisition. It should be noted that while (T) is not a stage in the Dreyfus schema, since we measured leaders' skill levels across time, we needed labels that indicated movement (Dreyfus levels being static in

	Novice	Transition	Advanced Beginner	Competence
Definitions	"Uses context-free features which [the leader] can recognize without benefit of experience . . . [that are] non-situational . . . [and] rules for determining an action on the basis of these features" (Dreyfus & Dreyfus, 1980, p. 7).	Begins with aspects of the Novice, but by the end of the semester exhibits significant evidence of progress into the Advanced Beginner stage.	"Uses ... [situational and non-situational] aspects and maxims . . . to cope with real situations (Dreyfus & Dreyfus, 2004, p. 251).	"[By adopting] a hierarchical view of decision-making," the performer hasn an "emotionally involved experience of the outcome" (Dreyfus & Dreyfus, 2004, p. 253).
We looked for...	. . . applying set "rules" without regard to context. Focusing on controlling the students' processes based upon leaders' understanding.	. . . making comments that are labeled (N) in early journal entries, but a significant number of comments labeled (AB) later.	. . . using their senses about the context for applying rules to cope with situations. Flexibility around student needs.	. . . statements regarding a personal responsibility or emotional involvement in student outcomes – "ownership" of the results of their decisions.
Leader Journal Examples	"It's hard for me to know if I should change anything or not because one person says they love working on the board and explaining things to peers helps them learn, whereas another person said that they hate the boards and they'd rather me teach them lecture style."	In week 2: ". . . I had to try to explain . . . I think from the examples I used most of them sort of understood how to use it." In week 9: "Give them the tools they need to make progress on their own . . . [and] allowed them to show each other the answers even if not everyone got to every problem, and it was them doing the teaching rather than me . . ."	"Since the first question was [not clearly] worded . . . I decided to approach it as a whole group . . . I discouraged them from using paper so they would have to cooperate, and couldn't just do the problems by themselves, apart from their groups . . . I tried to make interactions as dialogic as possible to help them reach the realizations themselves . . ."	Examples would have been: Leaders being upset and possible questioning the appropriateness of their approach when students discussed underperforming on an exam. Discussing their feelings of failure when students are struggling with material in Workshops or taking personal pride and joy when students succeed.

Figure 3. *Definitions, rubric, and examples of journal comments that led to individual leaders being assigned a Dreyfus level of (N), (T), and (AB). Competence is also included, though no leaders were found to have reached this level.*

nature), or 'progression' along the scale, over the semester. The (AB) label indicates the leader showed evidence of beginning at a Dreyfus-Advanced Beginner stage from the start of their journals and remaining in that stage throughout the semester. Only these three labels were used as no leader was found to have significantly or permanently regressed in their skill acquisition, and no leader was found to have reached the Dreyfus-Competent, '(C)', stage or further.

Definitions of the skill-acquisition levels, the contextual traits we looked for to label a comment as 'coming from' a specific skill level, and examples of journal comments used as evidence are summarized in Figure 3. An (N) Workshop leader 'clings' to the instructors' words and takes suggestions as hardline rules, whether they were intended as so or not. An example of this implementation is the suggested non-use of cellphones in Workshop. Leaders were not told to 'ban' cellphones from Workshop classrooms. However it was indicated that instructors felt that phones should be put away for the duration of the time. This, unfortunately, became a focal point for some (N) leaders; they often wrote about needing to reiterate this "rule" to students, particularly without regard to context (a call from a parent or text from a friend versus looking at Facebook, e.g.). Another example is leaders' assumption that talking is the only way students can substantially contribute to a Workshop. This likely arose from instructors' comments about the need to get 'all students' to contribute and that the students should be the ones doing 'most of the talking' in Workshop (meaning, leaders should not lecture to students). However, a leader who understands both the need to 1) ask a student on Facebook to put their phone away and 2) allow for a student to quickly answer a text from their parents or friends and not lose focus on math work would be classified as an (AB) (Figure 3). More importantly, they would also understand that a student who jumps to the board to scribe the words of others or who preemptively pulls out their textbook to have the statement of the Squeeze Theorem at hand for the group is contributing equally to the group work as those who talk more. Another example might be a leader choosing to indicate that a student's work is 'right' so that they do not continue to be confused, despite the leaders being told to not 'give the students the answers.

It is worth noting that, anecdotally, the Calculus faculty and the pedagogical instructors recall seeing leaders' behavior that could indicate having moved into the (C) level of skill acquisition. However, we were reluctant to use such anecdotal data in this analysis. In our search for journal evidence that leaders had reached the (C) level, we could identify isolated instances where there might have been comments indicative of such, but we were left with enough uncertainty that we instead report the leader to be at an (AB) level. This is not surprising, keeping in mind that this cohort is measured over the span of only one semester of leading Workshops. Such a move, into a mindset of sharing the 'blame' with students for their failures or successes, would require an enormous amount of development on the leaders' parts, and there likely was not enough time for that. It should be noted that the journal prompts also did not ask leaders for this analysis; had the instructors realized the need for such questions, prompts could have been designed to unpack leaders' thoughts in a way that might have better revealed their level of emotional involvement in outcomes. Examples of this approach are included in Appendix C.

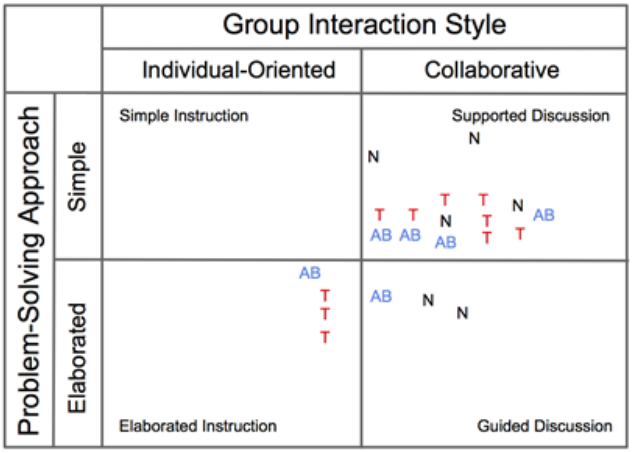

Figure 4. *Individual Leaders scored as novice (black N), transitioning from novice to advanced beginner (red T), or advanced beginner (blue AB), according to the Dreyfus model of skill acquisition, then mapped to their independently-scored position on the Pazos grid. Adapted from Pazos et. al.., 2010 with permission.*

Overlay of Both Models

Once both teams of authors had separately evaluated students according to the Pazos and Dreyfus models of analysis, the two models were graphically overlaid by identifying the Dreyfus code assigned to specific leaders and placing that code where that leader fell, per our evaluation, in the 2x2 Pazos framework (see Figure 4).

RESULTS/DISCUSSION

Pazos Model

Overall, our analysis revealed that all leaders' groups exhibited collaborative group interactions or elaborated problem solving (or a combination of the two) over the course of the semester. We saw no difference in leaders' location in the 2x2 framework with respect to them having led a Calculus 2S or 3S Workshop. We determined that none of the twenty-two leaders led groups predominantly categorized by simple instruction. This is not surprising because the pedagogical instructors early and often stressed the importance of creating a student-centered environment that fostered critical thinking and inquiry. Despite this, it was not uncommon for leaders when faced with conceptual issues to quickly fall back into instructing throughout the semester, especially at the beginning during the 'student buy-in' period. Some would prepare mini-lectures; as one leader reported, "I prepared a quick overview on chain rule, product rule, basic log rules, and some derivatives." Others would spend most of the Workshop answering their students' questions, rather than encouraging more peer-to-peer interaction, "People were constantly raising their hands to ask me things." In these cases, students in the Workshop were more dependent on their leaders to help them through the problems; as one leader put it, "When I was with them helping to work through the problems they were really attentive, but when they got stuck it was harder for them to be motivated."

A majority of the leaders (fifteen out of twenty-two) showed evidence of primarily leading groups that functioned within the supported discussion category, mostly encouraging group work on the specific worksheet problems. This was expected, as the worksheets were created to stimulate discussion, and the leaders were told in their pedagogical course that they needed to

encourage the students to talk to each other. The leaders would facilitate this atmosphere in different ways. Some simply used a different set-up for their Workshop room. According to one leader, "I implemented the idea of having students sit in the front of the class while I sat in the background…. It seemed….that they were more engaged and more dedicated to the idea of teaching one another." Others got the students to talk to each other by utilizing the chalkboard; one leader shared that having the students solve problems at the board helped the leader "easily follow their explanation, and add in comments here and there when need be." Another leader effectively used guided questioning, "Whenever students would ask a question, I would either direct them to another group that was able to do the problem or direct a question back at them that would try to get them thinking in the right direction."

In the post-semester leader surveys (sent to all leaders), we found more evidence for supported discussion. Out of the seventeen leaders that responded to the survey, eleven answered 4 (agree) or 5 (strongly agree) to the question of whether their students did most of the talking in their Workshop. We note that this is a smaller percentage than we found in our journal analysis. However, it is important to point out that the small sample size, lack of full participation in the survey, and broad interpretation of the term "most" may account for this discrepancy.

Along the problem-solving dimension, nineteen out of twenty-two of the groups showed evidence of some elaborated problem solving in their Workshops. Four of the leaders heavily relied on elaborated instruction throughout the semester in their Workshops, only infrequently showing evidence of a more collaborative group-interaction style. These leaders were more heavily concentrated in Calculus 2S. For many of these leaders, it was clear that they thought it was necessary to give their own explanations to the students. In one leader's words, "I like to provide my own view on the matter. That way the other students that may not like the first student's way of thinking can use my way." From a student's perspective in the midterm evaluations, one Calculus 3S leader took "...time to not only explain the formula as a whole, but...also [to] show…[us] how to think of a problem in different ways, as well as sometimes showing us the real world application."

As the semester progressed, students in some leaders' Workshops began thinking about the concepts in a collaborative setting. The leaders of these groups focused on their students' understanding of course concepts, rather than their own ideas. For example, "I noticed that…the students were actually engaged at a deeper, conceptual level regarding the questions, and weren't just satisfied with superficial answers." Of the fifteen leaders who led groups within the supported discussion phase, four indicated movement towards more elaborated problem solving by the end of their semester. These leaders learned to encourage discussion about problem solving approaches, rather than just the answer. One such leader shared, "It was open to discussion what the students did to solve the problem so that everyone in the room could come together and reach a consensus answer in addition to…discussing problem-solving approaches and strategies." Between the two courses, there were more leaders in Calculus 2S that seemed to more frequently use guided discussion, but due to the small sample size, we cannot say whether this is a general trend.

Only three out of the twenty-two leaders seemed to indicate that their groups were acting predominantly in the guided discussion phase by the end of the semester. Some would at times show evidence of elaborated instruction or supported discussion, but overall, the students in these groups were working with each other to gain a conceptual understanding of the material. The leaders of these groups wrote about how their students were answering each other's questions and working primarily on their own, only needing some occasional guidance from their leader. According to one leader, "Not only was everybody contributing, but they were actively calling each other out to explain why they did problems a certain way." These leaders seemed to recognize that this was an ideal setting for students to better understand the course material; for example, "Often students who seemed to have jumped to a certain conclusion regarding a problem 'caught' themselves out while describing their thought process … and I didn't really have to say anything…. I felt this form of learning made a lot of students understand critical concepts." The survey responses from the leaders were actually stronger than these findings. In fact, seven (out of seventeen) agreed or strongly agreed to the statement, "In my Workshops, I occasionally observed the groups continuing to discuss a problem even after an answer had been determined," a question used in the Pazos model peer evaluations as evidence of elaborated problem solving (Pazos et al., 2010).

Dreyfus Model

Of 22 Workshop leaders, six started in the (N) category and remained there throughout the semester, and six leaders started in the (AB) category and remained there. Interestingly, ten leaders were found to have transitioned (T). No Workshop leader was found to have moved to a level of competence or higher (Figure 4). Journal analysis showed no discernible trend with regard to either Calculus 2S or Calculus 3S having more (N) or (AB) at the start or in leaders experiencing a change from (N) to (AB), though it is possible that the sample size is too small to be certain that a leader working with one or the other Calculus course led to more or less change in the Dreyfus dimension of analysis. Journals did contain quotes that suggested a need for control and univocal methods of instruction, even in (T) leaders, suggesting that evaluation solely based on the Dreyfus model might be inadequate to analyze the kind of instruction that was implemented in Workshops. There was also evidence that leaders were temporarily reverting back to a more novice way of facilitation when they encountered difficult Workshop situations (e.g., poor student evaluations and comments, poor student exam scores, students misunderstanding and showing confusion, etc.).

Most (N) leaders disproportionately fixated on their understanding of the rules; usually from their experiences of recitations, as opposed to Workshops. That is, they would fall back to the rules they were comfortable with, even if these rules disagreed with the paradigm established for their Workshop leader role by their instructors. For example, one Calculus 3S leader commented, in the eighth journal entry (of 12), on the struggle of students wanting more lecture (Figure 2). At two-thirds of the way through the course, this leader was still expressing confusion in the face of student demands that disagreed with the rules their instructors had given them. They still did not understand which rules were flexible and which were not. This mindset was also seen in Calculus 2S leaders. They were so set in their previous understanding of recitations that they could not reconcile the allowance for some 'healthy confusion' in their Workshops with how to do so, saying, for example, "I don't like to leave the students unless they have a

firm understanding of the material…." Another leader shared, in the eleventh journal, "I had all of the students check their...value with me before moving on….", clearly indicating the leader's emphasis on the need for the students to get the "right" answer. The prioritization of controlling the students' process proved very difficult for some (N) leaders to move past.

Leaders who fell into the (T) category usually expressed a willingness to try new suggestions, or try old rules applied in new ways (Figure 2). One Calculus 2S leader said, in the first week, "...I think this problem is impossible to fix completely because math isn't everybody's favorite, but I am trying to make the students see how the material is important." This same leader, in week seven, says, "...giving each student his own worksheet is not working out so well. ...[T]he room is generally much quieter because people aren't working together as much. I will probably go back to handing out only one worksheet per group next week to see if that changes anything."

The few leaders who were (AB) throughout the term were flexible almost from the very beginning. They realized that the way they had experienced Calculus recitations was not how they were being instructed to lead, and they tried new things to find what felt 'right' to them, even regarding the overarching goals of Workshops. One Calculus 2S leader said, in the first week, "I realized that success looks different for each person… I want them to think of Calculus as useful and of math as an important tool whether or not they are passionate about it…. I want them to feel more confident in their own critical thinking skills and more capable of future success in math and science. Of course, I would also like them to be able to complete the assigned problems with accuracy, but after our discussions in our first class I think it's more important that they are able to recognize and express what they understand and what they don't understand than it is for them to be able to complete each problem without error." (AB) leaders also played with the construct of the Workshop, saying things like, "The primary thing that I learned was that a [W]orkshop ought to be planned with more flexibility than I planned mine…. I am going to try...to have everyone do the discussion questions together, rather than in their groups. I think that this would be a good way to get a better handle on how to re-divide the groups, according to capability and tendency to communicate." These leaders were willing and able to push through their conceptions of what a Workshop should look like (in light of having been in recitations themselves), and implement plans that tried new things from a student-centered perspective even in early weeks.

Quotes from the anonymous post-semester surveys also supported some leaders having reached an (AB) level, or at least what would have been described as (T). In another example of leader experimentation, one leader noted, "I found it most useful to let the students do whatever they want as long as they stay on topic, because they seemed to work best when they were doing things by choice." While not antithetical to the 'rules' laid out for leaders, this is impressively radical on the part of the leader if they ran their Workshop classroom in such a way. Also, another leader noted, "I feel the best thing I did for my students was foster a safe and comfortable environment. … Guiding them to being okay with talking with me and more importantly with each other really made a difference in their understanding." This, for example, is a quote that the authors view as bordering on (C) level. Leaders focusing on the emotional and affective well-being of their students is something the faculty and pedagogical instructors hoped would happen, so seeing evidence of it is heartening.

Since 10 out of the 16 leaders who started in the (N) level transitioned to (AB) throughout the course of the semester (with the remaining six leaders starting and ending in the (N) level), overall, we would consider the outcome of the leader training course to be successful. While we cannot definitively say that the course is what caused this transition (remembering that six started out and remained (AB)), we can note that no one regressed along the Dreyfus scale.

Overlay of Both Models

All leaders, regardless of Dreyfus level, tend to skew to the collaborative end of the x-axis (as opposed to the individual-oriented end) on the 2x2 grid (see Figure 4). As discussed below, placement of (T), (N), and (AB) leaders seems to fit well with their placement on the Pazos grid; this clustering suggests compatibility between the two models since they were fit independently by the authors. It also suggests that the labeling of leaders has some degree of complementarity; if leaders did not cluster, and instead were more randomly distributed in the 2x2 Pazos framework, then perhaps these two frameworks would be too independent to be of any use when overlaid. We note again that the placement of each leader on the 2x2 Pazos framework was based on a qualitative assessment; leaders were placed intentionally by the pair of researchers rating them. Each placement on the grid was determined by examining the prevailing group dynamics over the course of the whole semester. We measured the position of each leader with respect to each of the others when arranging the leaders in the 2x2 framework.

It was not necessarily surprising to find that (N) leaders were distributed across the Pazos grid in the problem-solving approach dimension than other levels. (N) leaders, as mentioned previously, adhere to given rules and what their interpretation of those rules are. Despite leaders being told to "guide" in the training course meetings, (N) leaders fell into two groups based off of their understanding of how a Workshop should be run. For some, this was simply getting students to talk to each other while solving problems and making sure students do most of the talking. For others, this was not only talking less, but also getting students to talk about course concepts and multiple problem-solving strategies. Both of these cases demonstrate a lack of contextual understanding of what students need in a given situation because they blindly assume that a leader should never take an individual-oriented approach and lecture to students. This was not the intent of the instructors, who wanted leaders to assess the needs of students on a case-by-case basis and, if necessary, lecture to move the Workshop forward to encourage fruitful discussions, as students might initially lack some fundamental knowledge required to engage in such discussions. This illustrates the usefulness of overlaying the two frameworks; using the Dreyfus framework alone would not have revealed the nuances that using both simultaneously does.

(AB) leaders clustered in the center along both axes of problem-solving approach and group interaction style in the Pazos framework. This could be seen as (AB) leaders taking a more balanced approach to facilitation than that of (N) or (T) leaders. A main characteristic of (AB) is that they take an active role in choosing when to use different approaches in facilitation; these are chosen based on the immediate needs in front of them in the

classroom, so it is not surprising that they might cluster in the center. It would take a very mature approach to Workshop facilitation for a leader to reflectively ask, "What is the right thing to do right now?" in a classroom setting. We therefore claim that the (AB) leaders falling more balanced, on the whole, than (T) or (N) is a result that supports the accuracy of our analysis. Notably, one (AB) fell far more collaborative than the other five (AB) leaders, and also slightly simpler in their problem-solving approach, which we cannot explain.

(T) facilitators also clustered relatively close to the balance between elaborated and simple problem-solving group dynamics but tended to spread more than (AB) along the spectrum of group interaction style of the Pazos model. One possible explanation for this is that our assignment of leaders along the Pazos scale depended on the dominant characteristic of their Workshop groups. It could be that the placement of the (T) facilitators along the group-interaction style axis is dependent on when they transitioned from (N) to (AB). We also speculate that (T) facilitators experimented more in their Workshop in their transition. As they did not know what would work best for their groups, they took different approaches to facilitate effective group dynamics throughout the semester.

Limitations and Contextual Differences

It should be noted that although this study examines leader growth for both Calculus 3S and Calculus 2S, there are significant differences between the two courses. Calculus 3S is a slower-paced version of Calculus 2S and a higher percentage of students in Calculus 2S major in STEM fields. Lecture and Workshop size varied greatly between 2S and 3S. Students in Calculus 3S anecdotally tend to have lower confidence in their mathematical abilities. Calculus 3S is also more racially diverse; about forty percent of students in Calculus 3S come from STEM-underrepresented backgrounds as defined by the NSF (i.e., African-American, Hispanic, and/or Native American) as opposed to fourteen percent in Calculus 2S.

There were further differences between the leaders of the Workshops for the two courses. Most of the Calculus 2S and 3S leaders had not taken the Calculus 3S courses, as they generally were STEM majors and thus enrolled in either the Calculus 2S or a separate, proof-based 'Honors Calculus' sequence. Therefore, we might go so far as to describe Calculus 3S leaders as not 'near peers' with their students. This resulted in somewhat of a disconnect between Calculus 3S leaders and their students. For example, 3S leaders frequently expected that since the material in the Workshops was 'easy' to them that it should come easily to their students. Another difference was that Workshop problems were designed separately by the course coordinators for Calculus 2S and 3S, although there was frequent communication between the coordinators about this as well.

Workshop leader pedagogy courses were held separately for the Calculus 3S and 2S leaders, with two different instructors from the university's CETL acting as facilitators along with the two Calculus course coordinators. The four instructors regularly conversed about course topics but made no effort to normalize instruction across the two courses and acted independently when assigning readings and journal prompts. As a result, the two groups of leaders experienced significantly different pedagogical instruction. While for two (out of twelve) themes a common reading was discussed for both groups, several topics included in the core coursework for one group were not brought up in the other. Journal prompts differed between the two groups and were given only as 'guides' for what leader writing should contain or focus on. However, the message that the leaders received in both courses was relatively uniform; instructors emphasized the importance of active and collaborative learning in their Workshops and minimizing univocal discourse with their students.

In addition to emphasizing different topics, pedagogical instructors had different suggestions on how to best facilitate the groups and encourage collaboration. Based on journal and in-class observations, this led to different Workshop structures for each course. For example, students in Calculus 2S Workshops tended to work on problems in smaller groups of two to three students at desks whereas those in Calculus 3S Workshops worked in groups of four students at the chalkboard. This difference in pedagogical approach likely stemmed from the perceived ability levels of most Calculus 3S students versus those of Calculus 2S. As Calculus 3S students ostensibly have a lower comfort level with math, it was more important that leaders use a 'making student thinking visible' approach for clearer interpretation, and so that students could more easily follow one another's process.

Proposed Future Analysis and Conclusion

As this study was undertaken retrospectively, it should be understood that there were limitations to the granularity in analyzing leaders' growth. With more forethought, it is possible that one might better measure group dynamics and leaders' skill acquisition, or that more information could be garnered as to why some leaders started and ended where they did. As such, we would like to propose suggestions for a future analysis of Workshop leader journals using our overlaid Pazos/Dreyfus methodology. In this way, we might help others learn from our process and make evaluating leaders more accessible to faculty by lowering the barriers they might encounter in implementing this methodology.

We would first suggest a pre-survey to give to leaders at the start of the semester, preferably before the first class meeting, and certainly before they facilitate their first Workshop. Additionally, a post-survey should be developed that might ask leaders to discuss explicitly where they see themselves as having started and ended concerning the Pazos and Dreyfus models. A mid-term evaluation (we would suggest leaders evaluate one another and not have faculty present in Workshops - this inherently changes the dynamics of the Workshop and could affect the data collected) should be arranged, where leaders are given evaluation questions that investigate both Pazos and Dreyfus.

Weekly journal prompts should be thoughtfully scripted to include questions that investigate Dreyfus levels (N) and (AB) in particular at first, in response to our evidence of some leaders starting at the (AB) level from the beginning. As weeks progress, faculty can begin implementing questions that probe for the Dreyfus (C) level, while retaining prompts for (N) and (AB). One difficulty will be in developing prompts that are not 'leading' them to the (C) Dreyfus level, but that simply investigate leaders' perspectives and thoughts. We have no evidence that leaders could reach a Dreyfus Proficient (P) level in just a semester. Questions would need to be developed for a hypothetical leader who reached (P)roficient and (E)xpert if and when leader writing indicated progression to (C) and beyond.

Each week, faculty could have leaders rate their groups on the 2x2 Pazos model. Additionally, leader training courses could

be modified to include specific training on the Pazos model and communicate that the goal of the leader is to find a balanced approach to facilitating groups; encouraging them to have a 'guided discussion', but remaining open to whatever approach meets students' needs.

This assessment strategy can help meet students' learning needs by improving the precision of feedback available to peer leaders. Taken as a whole, we believe that this analysis provides multidimensional insight to the leader development process over the course of one semester. Even having no 'pre' description of leaders' attitudes, beliefs, or approaches toward how Calculus is best taught, we feel that this novel approach provided us with an excellent description of the evolution of the leaders both from an individual and a group perspective. This method is also flexible and content-independent so that it would be equally useful for Workshops in other STEM and non-STEM subjects. It could be used during the semester to provide formative feedback for leaders. Further, we claim that there is value in overlaying these two models. In fact, the two frameworks together provide a stronger assessment than either of them individually could.

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APPENDIX A
Example Journal Prompts

Examples of journal prompts given to Workshop Leaders in the supporting pedagogy courses include:

- How did Workshop go this week? Did you try something new? What efforts improved the learning environment?
- How well did your students work together?
- What would you do differently?
- Are you noticing any changes in Workshop that are because of you, or maybe that are not because of you and are out of your control? How did the exam affect your Workshop, if at all?
- What are your thoughts on "grit" in light of the video from last week and your, now, being a teacher?
- How much of your discourse has been univocal versus dialogic so far in Workshop?
- Where do you think (what Tuckman stage) your Workshop currently is, and what evidence do you have to support that claim? Do you think that the exam performance has affected [this]?
- What misconceptions did you notice in your Workshop this week? Did your Workshop encounter confusion around a problem? How did you handle it?
- How might/did you use the concepts of cognitive apprenticeship in preparing for your Workshop problems this week?
- [List] three concepts you found the most helpful in leading your Workshop and two strategies you implemented that you believe had a positive impact on the learning environment of your Workshops.

APPENDIX B
Survey Given to Workshop Leaders

The purpose of this study is to determine how well the pedagogy class prepared you to lead your Workshops and the overall effectiveness of this model in a first-semester Calculus course.

For the following statements, please indicate the number from 1 to 5 that aligns with your response, where 1 corresponds to "Strongly Disagree" and 5 corresponds to "Strongly Agree".

1. The leader training prepared me to facilitate student-to-student interaction in my Workshop.
2. In my Workshop, the students did most of the talking.
3. My contribution as a Workshop leader helped students increase their understanding of course concepts.
4. In my Workshops, I occasionally observed the groups continuing to discuss a problem even after an answer had been determined.

Please answer the following questions with a few sentences. We encourage you to keep your responses as anonymous as possible.

5. How well did the Workshop class effectively prepare you to be a Workshop leader? Do you think that you are a better student, TA, and Workshop leader because of it?
6. Did your perception of cooperative learning in Calculus change throughout the semester, if at all? If so, how did it change?
7. What concept or concepts did you find the most useful for managing group dynamics in your Workshop?
8. Did you observe improvement in problem-solving techniques in your Workshop? If so, do you think that your role in the Workshop influenced this change?
9. Were you a TA for a previous mathematics course at the University of Rochester? If so, do you prefer the Workshop model over the standard recitation model? Why or why not?

Thank you for participating in this survey! We appreciate your feedback.

APPENDIX C
Proposed Example Journal Prompts for Deeper Analysis

The following are examples of journal prompts developed by the authors that could provide a more thorough analysis of Leader journals using the Dreyfus model, particularly so as to more clearly see whether Leaders reached the Competence level, would be:

- In what ways did you have to make decisions about what to do or what to say in your Workshop? Describe the situation and the process of making that decision.
- How do you feel the decision(s) that you made affected outcomes within and outside of your Workshop?

Example prompts to assess group interaction approach and problem solving style as defined by the Pazos model would be:

- How would you describe the student interaction in your group this week? What do you think contributed to this level of interaction? (Adapted from Pazos' observation questions 1)
- Describe the group's response after they have solved a Workshop problem? Do they tend to see the problems more as a checklist to complete or more of a puzzle that spins off new problems for discussion?