

Activities in voluntary PLTL complement active-learning lectures and appeal to students with diverse attitudes towards learning

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ABSTRACT

Peer-Led Team Learning (PLTL) is a widely implemented academic support system that can have a positive impact on student grades and retention. For voluntary PLTL programs, determining the effect of the curricular context and understanding the factors that influence student attendance are critical considerations. We predicted that if active learning occurs during lecture, structured PLTL sessions may impart a negligible benefit for student learning because the activities in these sessions would be redundant with those occurring in lecture. We also predicted that students would be more likely to attend voluntary PLTL sessions if they had a growth mindset and positive attitude toward group work, because students with these attributes would be receptive to the frequent feedback and collaborative learning that are major components of PLTL. Furthermore, we predicted that students would shift to growth mindsets and view group work more positively after participating in PLTL. We found that, for an introductory biology course with an active learning curriculum, students who attended PLTL sessions with structured activities more frequently had a greater improvement in their performance than those who attended less frequently. This suggests that structured activities in voluntary PLTL are not redundant with those that occur in lecture. We also found that mindset and attitude toward group work did not explain frequency of attendance, nor did mindset or attitude toward group work change over the course of the study. Thus, fixed student mindset and negative attitudes toward group work do not appear hinder student participation. We conclude that the value of additional, voluntary practice in PLTL is not diminished in the context of active-learning lectures, and these sessions will be attended by students with a variety of mindsets and attitudes toward group work.

INTRODUCTION

Peer-Led Team Learning (PLTL) is an academic support system that encourages small group learning among peers or near-peers, which can take place during a class session or outside of normal class sessions (Woodward et al. 1993, Gafney & Varma-Nelson 2008). Outside of class, PLTL can take many forms, from highly-structured Supplemental Instruction (SI) sessions (<https://info.umkc.edu/si/>) to informal tutoring sessions. Structured activities in these outside of class PLTL sessions often include small group discussion, worksheets, problem-solving exercises, or mock exams (Gafney & Varma-Nelson 2008; Dawson et al. 2014). The critical components vital to PLTL programs include close integration with the course, active involvement of faculty with the workshops and peer leaders, peer leaders who have taken the course and are trained in facilitating collaborative learning in small groups, and activities that are appropriately challenging and designed for collaborative learning (Gosser et al. 2001).

PLTL sessions have been widely implemented in a variety of contexts (reviewed by Arendale 2004, Dawson et al. 2014), and have a demonstrated positive impact on student's grades, retention, and sense of belonging in a learning community. By taking part in PLTL activities, students are provided an opportunity for deliberate practice (Ericsson et al. 1993) with

course concepts, allowing them to identify and correct misconceptions, scaffold course content with prior knowledge, and articulate concepts with their peers (Dawson et al. 2014). In particular, when interacting with their peers and peer leader during a PLTL session, students engage in retrieval practice of concepts introduced earlier, such as in a reading assignment or during a class session. Retrieval of information during learning activities improves learning, particularly when feedback is received (Butler et al. 2008). The environment of PLTL is also thought to foster student learning because students are not negatively impacted by the performance anxiety that could accompany similar activities in a class setting with the professor observing and giving feedback on responses (Rath et al. 2007).

Active learning in regular class sessions increases student learning (Freeman et al. 2014), because it offers students the opportunity to work with course content and concepts. Activities in out-of-class PLTL sessions, such as small group discussion, worksheets, and problem sets, may be similar to those in regular class sessions with active learning and peer-instruction (Crouch and Mazur 2001). Therefore, the format of associated lecture curriculum is a design consideration for voluntary, adjunct PLTL. If active learning is implemented heavily during lecture, then structured learning activities in PLTL sessions may be redundant. Therefore, there may be diminishing returns in student learning when similar learning activities are repeated multiple times for the same intended learning outcomes. If so, structured PLTL sessions may only impart a negligible benefit for student learning. In other words, when the associated lecture implements active learning, we might expect similar performance gains from implementing unstructured PLTL sessions (i.e., question and answer/office hours format), compared to structured PLTL sessions (i.e., pre-planned activities that allow deliberate practice).

Understanding the factors that might affect students' willingness to attend voluntary PLTL sessions is also a consideration (e.g., Arendale 2004, Batz et al. 2015), and thus important for designing effective PLTL programs. For example, because receiving feedback on one's performance is a key component of PLTL, a student's mindset (Dweck 2008) could influence their perception of how beneficial PLTL is for learning. Students with a growth mindset would be expected to buy-in to the PLTL learning environment, while students with a fixed mindset could feel threatened by constant corrections. Likewise, students who are willing to learn from peers may be more likely to participate in PLTL sessions. On the other hand, students who are wary of collaborative learning would be less likely to attend. Mindset and attitude toward group work could change, however, for students who choose to participate in voluntary PLTL sessions. For example, students could change from fixed to growth mindsets after the experience of participating in any type of PLTL session, because interacting with PLs and/or peers offers an opportunity to receive feedback on progress towards achieving learning outcomes. Likewise, students might perceive group work more favorably after participating in structured PLTL sessions that allow them an opportunity to solve problems with other students, rather than only with a PL.

In this study, we asked if the structure of PLTL sessions influences student performance when the associated course consists of an active-learning curriculum. We expected that unstructured PLTL will be effective for students who experience active learning in class, because structured PLTL could be redundant to activities already completed in class. We also asked if student mindset and attitude toward group work affects their voluntary PLTL session attendance. We predicted that students with growth mindsets and positive attitudes toward group work would be more likely to participate in PLTL sessions. Lastly, we expected that students would shift to

growth mindsets after attending PLTL sessions, and view group work more favorably after structured—but not unstructured—PLTL sessions.

METHODS

Context. This study took place at a medium-sized comprehensive university in a multi-section, multi-instructor Introductory Biology sequence (BIO 211 and 212). This study involved one instructor's lecture of BIO 211 (70 students) and BIO 212 (45 students). This instructor used an active, student-centered approach, in which substantial class time was devoted to active learning opportunities completed in small groups, with the instructor and peer leaders (PLs) facilitating small group discussion and problem solving. PLs were students who had previously been successful in the course and had demonstrated positive interactions with other students. PLs met weekly with the course instructor for discussion of course material and pedagogical training. To increase instructional support for students in these sections of BIO 211-212, we created Biology Education Achievement Resources: Peer-Assisted Workshops (BEAR PAWs), a voluntary, adjunct PLTL program headed by the same team of PLs. Some of the other instructors of these two courses (5 other instructors for BIO 211 and 4 other instructors for BIO 212) employ PLs in lecture, but they did not implement any form of voluntary PLTL sessions and these students were not included in the study.

Workshop design and assessment. In BIO 211, students were offered two types of BEAR PAWs sessions: weekly sessions and exam review sessions (Table 1). Weekly sessions were similar to faculty office hours, in that PLs were available to answer student questions and help them with course material. They were offered multiple times per week in various public locations on campus, as determined by each of the PLs in the course. These weekly sessions were unstructured, in that individual or small group discussion with and feedback from the PLs were based solely on questions that students brought to the session. Exam review sessions were offered prior to each of the four tests in the course. These were always structured sessions in which the PLs created a Jeopardy®-style game with questions similar to those on the upcoming exam. Attendance at exam review sessions generally consisted of larger groups (10+ students), so the opportunity for personalized feedback was more limited. In BIO 212, students were also offered these two types of BEAR PAWs sessions, but the weekly sessions were changed (based on the results gathered from BIO 211) to be structured, in that the PLs created oral and/or written practice quizzes for students to complete during the sessions. The PLs would then provide feedback to the student about their performance on the quiz. The exam review sessions in BIO 212 were unchanged compared to BIO 211 (Table 1).

Table 1. For BIO 211-212, each semester was divided into four segments, culminating in an exam. Each segment’s schedule of weekly and exam review BEAR PAWs sessions consisted of three weeks of weekly sessions and a fourth week of exam review. This pattern was followed for each of the 4 exams in the course.

	BIO 211	BIO 212
Week 1-3	Unstructured Weekly Sessions ^a	Structured Weekly Sessions ^b
Week 4	Structured Exam Review Session ^c and Exam	Structured Exam Review Session ^c and Exam

^aOpen question and answer session similar to faculty office hours

^bPractice sessions with oral and/or written quizzes

^cJeopardy®-style game with questions similar to those on the upcoming exam

Students signed in to each BEAR PAWs session using a secret identifier that they created at the beginning of the course. For both courses, we assessed all students with a pre-/post-course assessment, given in lecture, that was aligned with course intended learning outcomes and contained questions similar to those on exams. This pre-/post-course assessment also included questions related to attitude towards group work and mindset. Using a Likert-type scale, we asked students to respond to “I think I will learn more in this course if I work by myself instead of working with a group” and “Some of my skills or abilities cannot be improved with practice.” Students used the same secret identifier to sign into BEAR PAWs sessions as well as on the pre-/post-course assessment, which allowed us to link attendance data and pre-/post-course performance on the assessments. All data collection was approved by the institution’s IRB (Approval Number H1801029_01). Two students in BIO 211 were not included in the data analysis because of mismatched pre- and post-course identifiers. One student in BIO 212 withdrew from the course, and was also excluded from the data analysis.

Data analysis. We first examined the relationship between session type and whether or not students answered questions correctly on our concept inventory by performing a logistic regression with a generalized linear mixed effects model (binomial errors) with test (pre-test or post-test), frequency of regular session attendance, and frequency of review session attendance as fixed effects, and student identifier as a random effect. We also asked if mindset and attitude toward group work at the beginning of each semester influenced the frequency of attending BEAR PAWs sessions. We tested for these relationships with a generalized linear mixed effects model (Poisson errors) with frequency of attendance as the response variable, attitude toward group work and mindset as the fixed effects, and student identifier as a random effect.

We also analyzed our survey questions on student mindset and attitude toward group work for any shifts in student responses over each semester. We used Fisher exact tests and G tests of independence between the frequency of responses (Strongly Agree, Agree, Neither, Disagree, Strongly Disagree) to each question and the time the survey was taken (pre- and post-course).

Each semester was analyzed separately using R (R Core Team 2019). The generalized linear mixed effect models were conducted using the *lme4* package (Bates et al. 2015). Tests of fixed effects were obtained using the *car* package (Fox and Weisberg 2011). The Fisher exact

tests and G tests of independence were implemented with the *RVAideMemoire* package (Hervé 2008).

RESULTS

In the first semester of the course (BIO 211), 50 of the 68 students (71.4%) attended at least one BEAR PAWs session. In the second semester of the course (BIO 212), 36 of the 45 students (80.0%) attended at least one BEAR PAWs session. BEAR PAWs attendance rates appear to be on the high end of the range reported for voluntary PLTL programs (15-55%; e.g., Arendale 2004, Preszler 2009, Stanger-Hall et al. 2010; but see Kudish et al. 2016).

Student performance was measured by examining whether or not students answered questions correctly on a concept inventory. Compared to the beginning of the course, students performed significantly better on the concept inventory at the end of the course for both BIO 211 ($\chi^2 = 100.5$, $df = 1$, $p < 0.0001$; Fig. 1A) and BIO 212 ($\chi^2 = 200.8$, $df = 1$, $p < 0.0001$; Fig. 1B). Considering that both of these courses implemented an active learning curriculum, we also asked if frequency of attendance and structure of BEAR PAWs sessions affected student performance on the concept inventory. We expected that if active learning in lecture provides sufficient opportunities for practice and feedback, structured BEAR PAWs sessions would not confer any additional benefit compared to unstructured BEAR PAWs sessions. In BIO 211, increased attendance at unstructured, weekly BEAR PAWs sessions did not lead to increased student performance on the concept inventory ($\chi^2 = 2.12$, $df = 1$, $p = 0.146$), but student performance did increase with increased attendance at structured exam review sessions ($\chi^2 = 6.86$, $df = 1$, $p = 0.009$). The odds of answering correctly on the post-test increased 1.15 times for each BEAR PAWs review session attended by a student. It appears that students continue to accumulate the benefits from additional opportunities for practice and feedback, beyond what is experienced in an active learning lecture course.

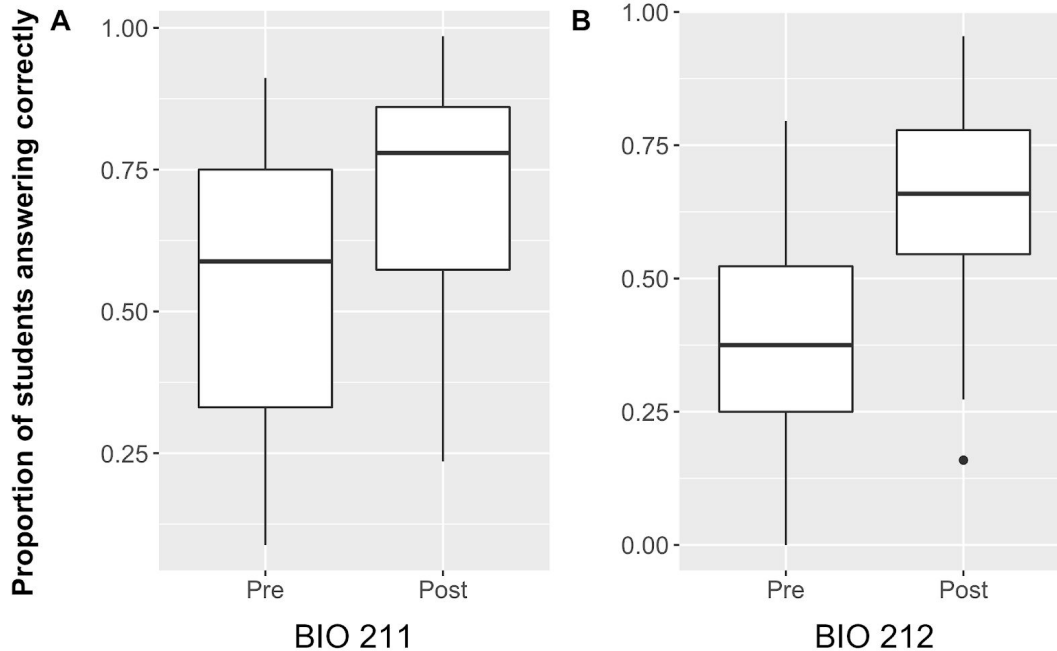


Figure 1. Proportion of students answering questions correctly on the pre-test vs. post-test in BIO 211 (A) and BIO 212 (B). Students are replicates ($n=68$ for BIO 211 and $n=44$ for BIO 212). Students perform significantly better at the end of the course (BIO 211: $\chi^2 = 100.46$, $df = 1$, $p < 0.0001$; BIO 212: $\chi^2 = 200.81$, $df = 1$, $p < 0.0001$). Students are 2.16 times more likely to answer a question correctly on the post-test compared to the pre-test in BIO 211 and 2.89 times more likely in BIO 212.

After BIO 211, we suspected that students did not benefit from unstructured weekly BEAR PAWs sessions because they may not have been able to identify critical questions to ask the PLs during this type of session. Given the success of the structured exam review sessions, we decided to revise the program to also include structured weekly BEAR PAWs sessions. In BIO 212, PLs created oral or written quizzes to be administered during weekly sessions. Implementing structured weekly BEAR PAWs sessions did indeed result in improving the efficacy of weekly sessions for student performance. We found that increased attendance at structured weekly BEAR PAWs sessions improved student ability to answer questions correctly ($\chi^2 = 19.81$, $df = 1$, $p < 0.0001$). The odds of answering questions correctly increased 1.18-fold for each time a student attended a BEAR PAWs structured weekly session. However, in contrast to BIO 211, BEAR PAWs structured exam review sessions lost efficacy. Increased attendance at BIO 212 BEAR PAWs exam review sessions had no effect on whether or not students answered questions correctly ($\chi^2 = 1.04$, $df = 1$, $p = 0.307$). Our results suggest that structured exam review sessions confer no additional benefit if active learning is occurring during lecture and in BEAR PAWs structured weekly sessions.

Given that attendance at structured sessions benefits student learning, we also asked how student mindset and attitude toward group work would affect attendance frequency. Although we predicted that growth mindset and positive attitude towards group work would increase the number of sessions that students participated in, we found that these factors were unrelated to the

attendance for both BIO 211 (Mindset: $\chi^2 = 1.41$, DF = 4, $p = 0.84$; Group: $\chi^2 = 3.23$, DF = 4, $p = 0.52$; Fig. 2A, B) and BIO 212 (Group: $\chi^2 = 3.37$, DF = 4, $p = 0.50$; Mindset: $\chi^2 = 1.31$, DF = 5, $p = 0.86$; Fig. 2C, D). In addition, we expected that the experience of participating in BEAR PAWs sessions would change fixed to growth mindsets and improve student attitudes toward group work. We were surprised to find that students did not change their mindset and attitude toward group work, whether they attended BEAR PAWs sessions or not, and regardless of the structure of sessions attended or course (all $p > 0.05$).

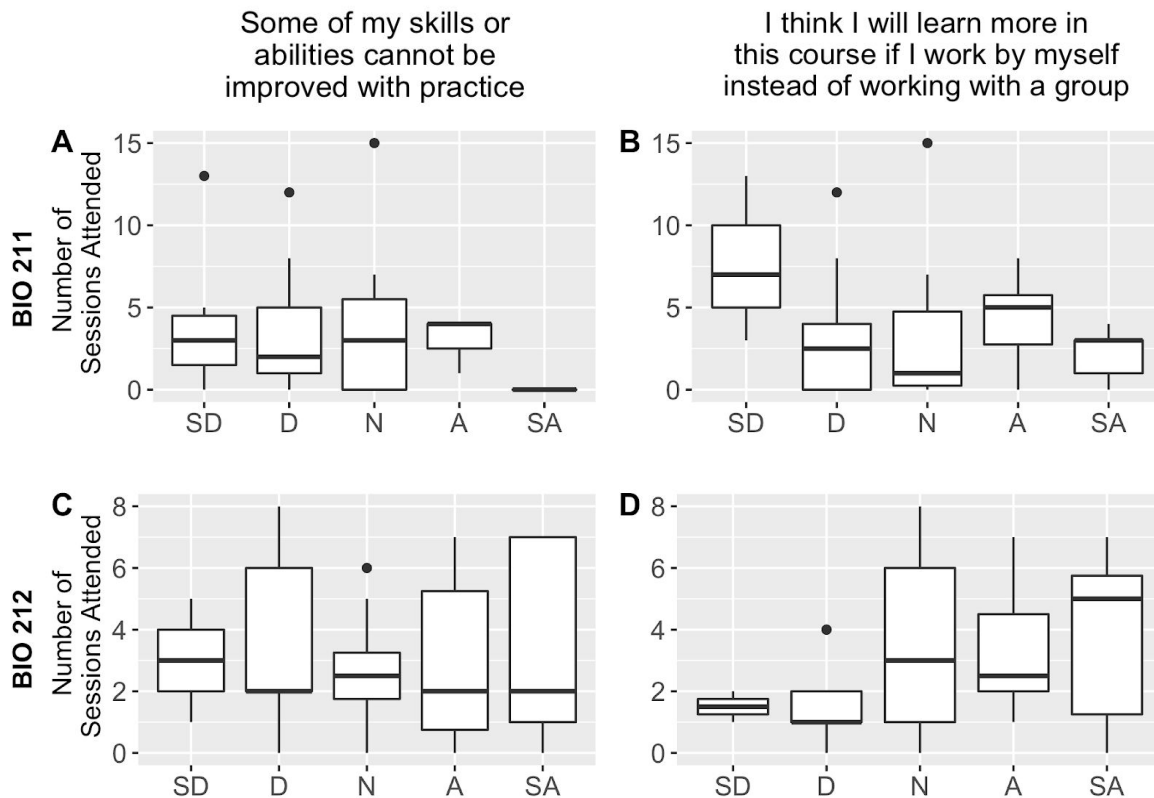


Figure 2. For BIO 211 (A, B) and BIO 212 (C, D) attendance at BEAR PAWs sessions was unrelated to mindset (A, C) and attitude toward group work (B, D). SD = Strongly Disagree, D = Disagree, N = Neither Agree or Disagree, A = Agree, SA = Strongly Agree

DISCUSSION

We found that student performance improved with increased attendance at structured PLTL sessions for an introductory biology course with an active learning curriculum. This finding shows that PLTL programs are useful as a supplement for not only passive instruction lecture courses (e.g., Batz et al. 2015, Snyder et al. 2015, Kudish et al. 2016), but also for courses designed with active learning pedagogy. Moreover, it appears that higher frequency of structured sessions can confer greater learning gains. There were 84 structured sessions (6 per week x 14 weeks) in BIO 212 compared to BIO 211, which only had 4 structured exam review sessions. We believe that the considerable increase in per session attendance benefit for BIO 212 compared to BIO 211 was a result of the much higher availability of sessions for BIO 212, i.e., frequent opportunity for retrieval practice was more beneficial than rare opportunity. Because

self-testing is not a study strategy that many students employ on their own (Karpicke et al 2009), structured PLTL provides the repeated retrieval practice through testing that improves knowledge retention (Roediger & Karpicke 2006).

However, our results suggest the possibility of constraints on efficacy, because structured exam review sessions were only beneficial for BIO 211—when weekly sessions were unstructured. Structured exam review sessions did not confer an additional benefit to student performance for BIO 212 students, who had the opportunity for structured learning activities during both weekly and exam review PLTL sessions. Exam review session efficacy also may have differed between semesters because of the context in which active learning took place. In BIO 211's BEAR PAWs program, the only opportunity for students to practice and receive feedback was during exam review sessions. However, in the following semester, both weekly and exam review sessions were structured with these opportunities. These structured sessions did differ in one major aspect: size of peer groups. The structured weekly sessions typically had individual or small groups (2-3 students) interacting with the PL, whereas the structured exam review sessions were attended by much larger numbers of students (10+). We believe that the decreased opportunity to receive personalized feedback from a PL in the exam review session reduced the effectiveness of those sessions when compared to structured weekly sessions. Unfortunately, our unbalanced study design reduces our ability to examine the interaction of structure and group size in this study explicitly. Note that altering the study design by including structured weekly sessions in BIO 212 was not intentional, but was a curricular adjustment made with the goal of responding to the outcomes of the BIO 211 BEAR PAWs program in a way that would benefit the students. Future studies are needed to tease out the separate effects of session structure and group size, as has been suggested by Dawson et al. (2014).

Because we found that student mindset and attitude toward group work are unrelated to attendance frequency in our voluntary PLTL program, there are clearly other factors that influence students' likelihood of participating. Other demands on students' time, including course schedule, work, or family responsibilities are a possible factor, as described by Batz et al (2015) and Stanger-Hall et al (2010). It is unlikely that issues related to transitioning to college are responsible for lack of attendance, as these students are in their second and third semesters (BIO 211 and 212 respectively), and have already experienced college-level science courses in their first semester (e.g., chemistry). Our results underscore the importance of offering PLTL sessions multiple times per week, to be inclusive of as many students as possible.

We also suggest incorporating activities into PLTL sessions to deliberately promote self-reflection, because these sessions will be attended by students with a variety of mindsets and attitudes toward collaboration. This may also lead to students changing from fixed to growth mindsets and from negative to positive attitudes toward group work. The lack of change for mindset and attitude toward group work that we observed does reflect the focus of BEAR PAWs sessions: practice with and feedback on content. Working with peers and receiving feedback from PLs may improve self-efficacy (Stanger-Hall et al. 2010, Batz et al. 2015), which is only one component of self-regulated learning (Zimmerman 2013) and mindset (Dweck 2008). Therefore, if one of the goals of PLTL sessions is to shift students towards a growth mindset or to improve their attitude toward working collaboratively with other students, we encourage the inclusion of deliberate self-reflective and metacognitive activities as part of each session. However, if these student attributes are not a learning outcome for a curriculum, then our results

suggest that a lack of improvement will not have an impact on the likelihood of attendance at future PLTL sessions.

CONCLUSION

Student retention in first-year and gateway courses are a major challenge for many undergraduate institutions. Our work has implications for biology and other science programs who are considering, establishing, or revising voluntary and outside-of-class academic support resources. Our study identifies the value of voluntary PLTL sessions to supplement active learning that is occurring during class. The efficacy of active PLTL sessions that supplement a class composed primarily of passive lecture delivery has been established (e.g., Batz et al. 2015; Snyder et al. 2015; Kudish et al. 2016). We found that even if structured active-learning experiences are a principal component of regular class meetings, students still benefit from similar opportunities in out-of-class PLTL sessions. Thus, creating a PLTL program to accompany an active-learning curriculum is a worthwhile investment of resources—both time spent preparing weekly retrieval practice materials and stipends for PLs.

Our study highlights some important considerations for designing PLTL sessions. Structured PLTL sessions confer benefits that unstructured sessions do not impart to students. The benefit of structured PLTL sessions appears greatest when the sessions occur in individual or small group settings, as they offer the opportunity for more personalized feedback. To encourage continued attendance by students with a variety of mindsets and attitudes, activities in PLTL sessions should help students connect their perceived learning gains with the feedback and collaboration inherent with PLTL.

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