

The Use of Team-Based Learning in an Experimental Physics Lab

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Team-Based Learning (TBL) is a teaching method which emphasizes learning through teamwork rather than from traditional lecturing methods. This paper describes the integration of TBL with the Physics Laboratory courses at New Mexico State University. Previous laboratory classes were run using an inquiry based method. Implementation of TBL was designed to enhance the willingness of the students to participate in the inquiry process by adding more structure to the assessment of student progress.

The change to TBL in the laboratory courses was designed to point students toward a hands-on, experimental approach to physics. The content portion of the TBL was the experiment itself. Students were asked to complete a RAT after working the experiment. The activity portion of the TBL was incorporated through a teamwork approach to the problems previously assigned for homework. Teaching assistants for each lab section made recorded observations of the students, both individually and as teams.

This observation and subsequent discussion with the teaching assistants and students revealed three interesting findings. First, the students in the TBL course were more likely to create and implement their own experiments to solve the problems expounded in the RATs. Second, the students in the college physics lab (biologists, chemists, and engineering technologists, as well as pre-med and pre-vet students) were the first to recognize the goal of the lab and engage in hands-on experimentation. Students in the engineering physics lab took twice as long to make the connection. Third, the teaching assistants' observations indicated an increase in understanding of the experimental process by the students. They also commented that student confidence was enhanced over that exhibited in the previous lab classes.

Introduction to Team-Based Learning

Team-Based Learning (TBL) is a teaching strategy that emphasizes learning from activities with peers rather than from lecture. TBL consists of Initial Acquisition of Content, Learning How to Apply Content and Assessment.

In a typical classroom, the Initial Acquisition of Content is provided by textbook reading assignments. The students are expected to read the textbook chapters, sections or pages assigned in order to prepare for Learning How to Apply the Content. This approach is similar to Just-in-Time Teaching (JITT). The instructor is able to focus on only the content not understood by the students through the Initial Acquisition of Content.

Learning How to Apply the Content is split into two parts: (1) A Readiness Assessment Test (RAT) and (2) In-class Activities. The RATs are simple concept tests given to students both as individuals and then in teams. The principle is to allow the students to first demonstrate their own proficiency in the content and then to work with a team of peers to find flaws in understanding and correct these flaws. The students

are then taken through a series of in-class activities with their team in order to gain deeper insight into the course content.

The Assessment is done in a traditional manner. Typically, the students are assigned homework that is done individually outside the classroom. They are also given an exam on the content when the homework and in-class activities are complete.

Why Did We Try Team-Based Learning?

Two goals are set for the lab courses. 1) Help the students learn physics through a hands-on approach. 2) Help the students become more independent of authority and rely more heavily on peers for understanding.

The traditional physics lab addresses the first goal by having students write lab reports about what was seen in the experiment. However, it does not address the second goal (unless students should choose on their own to work together with their peers).

The labs at NMSU use an Inquiry-Based Instruction approach. This method encourages students to ask questions of their peers but has no in-class assessment. The assessment is done through homework outside the lab and a final exam at the end of the semester. Taking the assessment outside the lab room and basing it only on individual response discourages team participation. Students gradually move away from an effort to understand the material in the lab. Instead they search for understanding from external sources. These include tutors, their physics class instructors and other textbooks.

We proposed the TBL approach as a way to incorporate an in-class assessment in the lab. The RATs are ideal as an feedback to the students of their comprehension both as individuals and as a team. The need to complete the group RAT with no errors gave the students incentive to continue learning with the team as their understanding of the material was enhanced.

Changes to the Labs

For the physics labs at NMSU, the TBL components were tailored to fit with the current structure of the lab course. The same textbook, labs and lab schedule were used. The only change in the lab was in the way the students were assessed. Below you will find a review of the changes that were made and their relationship to the TBL strategy.

Initial Acquisition of Content

A team of 3 to 5 students was expected to read the lab textbook and perform the experiments found there. Since the textbook used Inquiry Based Learning, the material contained therein was well suited for team-study. Only after the lab textbook chapter was complete were the students expected to proceed to the Reading Assessment Test (RAT).

Readiness Assessment Tests

The students were given both individual and team RATs. The individual RAT counted as a small part of the grade for the lab session, and required the students to work separate from the team. This prepared the student to participate in subsequent team discussions.

The individual RAT consisted of 5 multiple choice questions that required the students to analyze what they learned in the lab. The students were given 10 points which could be distributed among the answers for each question. In this way, a student was not forced to a single correct answer, but encouraged to view the relative merit of all of the answers.

The team RAT contained the same 5 multiple choice questions. The team started with 10 points for each question. As the team reached consensus on an answer, they revealed the answer to the instructor and were told of the correctness of their response. If the response was incorrect, the team lost 2 of the 10 points and they were told to review the question again. The same process continued until the team reached the correct answer. The students were not allowed to leave the lab room until they had found the correct answer to all 5 questions.

Homework

The homework problems were high level analysis type problems used to test the student's ability to reason through what they had learned in the lab. It was provided in a companion book to the textbook, and was initially used as an assessment tool. This was no different than the way it was done in previous semesters.

About three weeks into the semester, the homework was changed to an in-class activity. It was then completed at the beginning of the lab on the following week. The students were encouraged to work together with both their team and other teams in the lab section to complete as much of the homework as possible. The grade was assigned by the instructor using three guidelines: accuracy, creativity and interaction.

Accuracy was assessed in the typical manner and counted for about 70% of the homework grade. However, since the effort was a team effort, creativity also came into play. The instructors were asked to rate the students based on how well they explained their answer and on whether that explanation was unique. This was worth about another 20% of the homework grade. As an example of a unique solution, one lab section described the answers to series and parallel circuit questions using a water-based analogy.

Finally, the instructors were asked to observe the student interaction with other students and the instructor. This was worth 10% of the homework grade. If the instructor saw any sign that individual students were not participating, they were told not to give any points toward this part of the grade.

Results

No direct measurement of success for the TBL strategy can be provided. Use of TBL in the physics labs at NMSU lasted for only one semester and was implemented in only the Physics 212 and 216 labs. This provided only minimal direct data. Nevertheless, observations of both individual students and teams were made by the instructors in each section. These observations and subsequent discussions revealed three interesting findings. It was agreed by all instructors and the lab coordinator that all of these findings have merit.

First, the students in the TBL course were more likely to create and implement their own experiments. Many of the students, especially in the college physics sections (biologists, chemists, and engineering technologists, as well as pre-med and pre-vet students) even went so far as to ask for additional material, such as paperclips, extra light bulbs, batteries, and different kinds of magnets. The majority of these

additional experiments were used to directly measure the answers to the RATs. In at least one instance, however, students actually went beyond the requirements of the initial lab and began to prepare for the homework that they would complete the next week.

Second, the students in the college physics lab were the first to recognize the goal of the lab and engage in hands-on experimentation. Students in the engineering physics lab took twice as long to make the connection. The college physics students made this connection in about two weeks with no prompting from the instructor or coordinator. The students were simply told that completing the RATs was the goal of the lab.

The engineering students complained that they did not have the content necessary to complete the RATs. Intervention by the lab coordinator on the fourth week included telling them that the experiment was the content. Even then, many students in the engineering sections did not understand that they were to be learning from the experiment. Most engineering students even made comments about this on the final instructor evaluations. Some of the comments were “the class was behind the lab and we did not know how to do the RATs” and “the textbook did not give us enough information.” We should point out here that the class and the lab are separate. Students need not take them together and some take one without taking the other. Also, the students who complained about the textbook were reading it without performing the experiments found there, and without participating in the discussions that the textbook requires.

The third finding by the instructors was an increase in understanding of the experimental process by the students. Students in the previous lab semesters were dealing with the experiments and questions in a different way than the TBL sections. Basically the previous students tried to recall and fit equations to the experiment in order to complete the assigned homework questions. On the other hand, The TBL students were more likely to develop physics concepts by using experiment.

This trend was seen even between sections of the TBL labs. Students in the engineering section were more likely to revert to the equation method. These students typically had already completed several physics or engineering classes that were based on using equations to solve problems. Whereas, the students in the college physics sections of the TBL labs were less likely to have been taught the equation method and were more open to application of experiment to this type of problem solving.

Finally, comments were made by those instructors and students who had participated in both TBL and non-TBL sections that the students felt more confident in their understanding of physics. This was especially prevalent among students who were not previously exposed to equation based problem solving.

Future Changes

Several changes are recommended for future physics labs that use TBL. Most of these changes are based on difficulties experienced by the students or instructors during the semester when TBL was in place.

First, a final assessment needs to be made for each lab. The current TBL labs use only the RATs and homework as assessment. Both of these are, in large part, team based. The individual RAT was given as part of the learning process and is not a good measure of individual comprehension. A post-quiz should be added after the homework (in-class team activity) is completed. This final individual measure would enable the instructor to better assess the students comprehension. It could also be implemented in lab sections that are not TBL in order to gain insight into the effectiveness of the strategy. Also, students would have additional incentive to gain understanding through participation in the team.

As another change, observational questions could be added to the analysis question in the RAT. Questions such as “What is the frequency of the pendulum you have built?” (observational) in addition to “How is that frequency related to the pendulum length?” (analytical) would direct students more quickly to the need for experimentation.

Finally, students should be reminded explicitly and repeatedly about the goals of the lab through the following statement at the beginning of each RAT. “The goal of this lab is to gain understanding of _____ principle through the application of experiments involving _____. Students should complete pages ____ through ____ in the lab textbook before completing this quiz.” This would avoid confusion about where the Initial Content for the lab is to be found.

Conclusion

In general, the use of TBL in the physics labs as a strategy for enhancement of peer activity through assessment was a success. Students still tried to solve problems on their own and still tried to use equation based problem solving. Still, they were more likely to participate in the experiment and to work with peers as they moved toward comprehension of the physics concepts. Further improvements to the strategy are needed. Nevertheless, the additional benefits of TBL seem to warrant its inclusion in the current inquiry-based physics labs at NMSU.

References

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