

Diversity of Faculty Practice in Workshop Classrooms

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Abstract. We present a temporally fine-grained characterization of faculty practice in workshop-style introductory physics courses. Practice is binned in five minute intervals and coded through two complementary observational protocols: the Reform Teaching Observation Protocol provides a summative assessment of fidelity to reform-teaching principles, while the Teaching Dimensions Observation Protocol records direct practice. We find that the TDOP's direct coding of practice explains nuances in the holistic RTOP score, with higher RTOP scores corresponding to less lecture, but not necessarily more student-directed activities. Despite using similar materials, faculty show significant differences in practice that manifests in both TDOP and RTOP scores. We also find a significant dependence of practice on course subject reflected in both RTOP and TDOP scores, with Electricity & Magnetism using more instructor-centered practices (lecture, illustration, etc.) than Mechanics courses.

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INTRODUCTION

Successful active-engagement classrooms require more than just research-based and tested materials. Instructors make dozens of decisions that influence the classroom environment and impact student learning. [1] The extent to which instructors appreciate the underlying education research and curricular philosophy thus becomes important. Many faculty have been exposed to new methods through the American Physical Society's New Faculty Workshops, [2, 3, 4] others have attended meetings of the American Association of Physics Teachers, while still others have no formal exposure to the methods they are now asked to use in the classroom. It is thus unsurprising that faculty produce a range of classroom experiences, some inconsistent with the reform-based philosophies on which the classes are based. This study aims to capture the diversity of actual faculty practice so as to guide future dissemination efforts for maximum impact.

METHODS

Population

The study took place at a northeastern, large, four-year private university with high undergraduate enrollment and no graduate program in physics. The year is divided into three 10-week quarters, with ≈ 2400 students taking introductory calculus-based physics each year. The course is taught in a SCALE-UP format [10] that integrates lecture, experiment, and short group activities. Classes meet for three 2-hour sessions each week, with students working in small groups at tables of six. Faculty draw activities from a common "Activities Manual" and

attend weekly coordination meetings to synchronize the different sections. Engineering students make up $\approx 75\%$ of the students; a demographic analysis for the 2010-2011 academic year has been published elsewhere [11].

The introductory physics curriculum consists of three separate courses; most students begin the sequence in the winter of their freshman year. During the 2011-2012 academic year, we observed seven E&M instructors multiple times during the fall quarter and seven Mechanics instructors (multiple times) during the winter quarter.

Teaching Dimensions Observation Protocol

The Teaching Dimensions Observation Protocol (TDOP) was developed as part of the Culture, Cognition, and Evaluation of STEM Higher Reform project [12] and consists of 43 separate behaviors grouped into five categories: instructional techniques, questions and answers, cognitive demand, teaching artifacts, level of engagement, and miscellaneous. Observations are binned into five minute intervals; for the 90 minute classes observed each behavior can appear a maximum of 18 times. There is no limit to the number of practices that can be observed in a given 5-minute window. The survey was modified, with practices that never appeared (e.g. clicker questions) omitted.

Hora [12] reported lecture to occur in 93% of observed intervals in traditional physics classes, compared with 84% in biology intervals, 81% in chemistry, and 75% in math. Traditional physics courses also had a high frequency in which students were asked to receive or memorize information (93%) and a low frequency in which students were asked to solve problems themselves (28%) or make connections with the real world (24%).

Reformed Teaching Observational Protocol

The Reformed Teaching Observational Protocol (RTOP) was developed by Piburn et al. [13] to measure the degree to which a learning environment is student-centered [14]. Detailed field notes are used to rate the classroom along twenty-five 0-4 point Likert scale statements, grouped into three categories: Lesson Design & Implementation, Content (further differentiated into Propositional and Procedural knowledge), and Classroom Culture (also sub-divided into Communicative Interactions and Student/Teacher Relationships).

Sawada [15] interpreted RTOP scores as falling into three categories. He found that traditional lecture courses with minimal effort to engage students received scores of $RTOP < 30$. Lecture courses that incorporated active-engagement techniques — clickers, interactive lecture demonstrations, tutorials, etc. — scored between $30 < RTOP < 60$, with scores above $RTOP > 45$ representing significant student engagement with occasional hands-on activities. Scores above $RTOP > 60$ almost always corresponded to courses that took place in workshop-style environments that encouraged guided inquiry activities and critical reflection.

RESULTS

Practice in Workshop Environment

The six most frequent teaching techniques observed with TDOP are shown in Fig. 1. Lectures appear in 34% of observed intervals, far less often than in traditional classrooms. Three of the four most commonly observed practices, however, are faculty-centered — lectures, faculty-worked problems, and faculty illustrations. Despite a standard set of worksheets, student-worksheet activities are only 23% of the observations.

In traditional lecture courses students are asked (implicitly or explicitly) to receive or memorize information 93% of the time ([12]). In the workshops observed we find “receive/memorize information” in 33% of the intervals, most frequently in the same intervals as lecture. We found no instances of lecture accompanied by a more meaningful cognitive load, indicating the difficulty of lecturing in a manner that is cognitively engaging.

The reduction in lecture has a significant impact on student engagement. As part of the TDOP protocol, the researcher counts the number of students actively engaged or “on task.” The percentage of students engaged was “High” (>90%) or “Medium” (>67%) in 95% of the observed intervals. This is consistent with the anecdotal observation of increased student attendance, indicating that students do find the classes engaging and valuable.

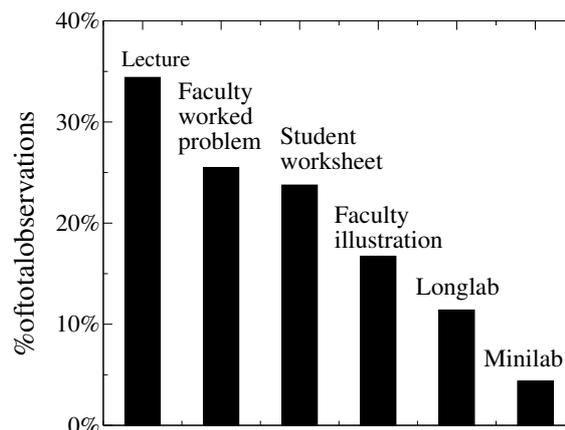


FIGURE 1. Seven teaching techniques most commonly observed in the introductory physics classes. Faculty-centered practices — lecture, faculty-worked problems, and illustrations — are three of the four most prevalent techniques.

RTOP/TDOP Correlations

RTOP scores of all instructors observed, sorted from low score to high, is shown in Fig. 2. All instructors were observed at least twice in a given course; error bars correspond to the standard deviation between the observations. Two instructors (#3 and #9) were observed in both the Fall (E&M) and Winter (Mechanics) quarters; they are represented by two dots, one per course. The difference between the subject areas is seen in the grouping of E&M instructors toward the left (lower RTOP score) half of the figure. The average score across E&M faculty was $\langle E\&M \rangle = 44$, with the average across all Mechanics faculty $\langle Mech \rangle = 56$. This difference is statistically significant ($p = 0.04$).

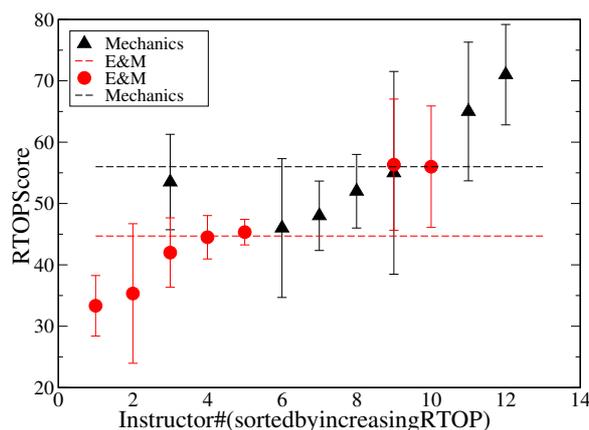


FIGURE 2. RTOP scores from introductory physics I & III classes. Scores range from 30-65, indicating significant variation of engagement across the different classes.

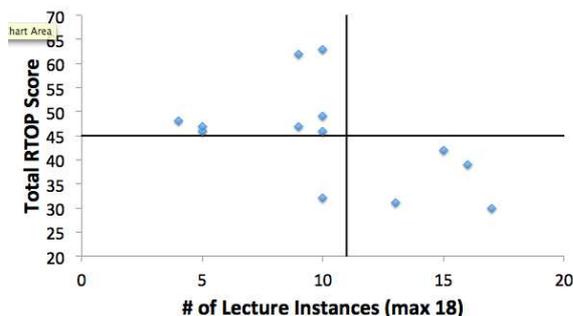


FIGURE 3. Total RTOP score vs. number of lecture instances observed (maximum 18). The solid lines divide the space into four quadrants, and it is notable that no observation with an RTOP score above 45 had more than 10 lecture instances.

The average RTOP scores (30-60) place the observed courses firmly in the category Sawada [15] observed to correspond to traditional lectures that incorporate elements of activity-based or reform practice. We find evidence that the lower RTOP scores are directly due to two features: (1) a preponderance of lecture and (2) activities that do not engage students in prediction, reflection, or a diversity of thought processes.

The evidence for the impact of excess lecturing is found by plotting the RTOP score vs. the number of lecture instances that are observed in TDOP analysis (maximum: 18), shown in Fig. 3. With one exception, all courses with fewer than ten observed instances of lecture have high RTOP scores (> 45), consistent with the idea that lecture is being replaced by more active, reform-based practices. No classes with more than ten observed instances of lecture receive an RTOP score above 45. Thus, 50% seems to be a critical fraction of the course in which lecture can occur while still maintaining a reasonable RTOP score.

An analysis of the RTOP subcategories supports the idea that the activities developed are more traditional in style, even when the students are “active.” The average RTOP score across the five sub-categories is shown in Fig. 4. The workshops score highest (70%) on the propositional knowledge sub-category, which centers on the coherence and fundamental nature of the lesson (i.e. does the lesson involve fundamental concepts), as well as the instructor’s grasp of the subject. As these are all characteristics valued in even traditional classes, it is not surprising to find a high score in this sub-category.

The lowest scoring categories are those that directly measure the reform-based nature of the activities “Lesson Design and Implementation” (LD&I, 30%) and “Procedural Knowledge” (25%). LD&I assesses whether/how the lesson elicits prior knowledge, encour-

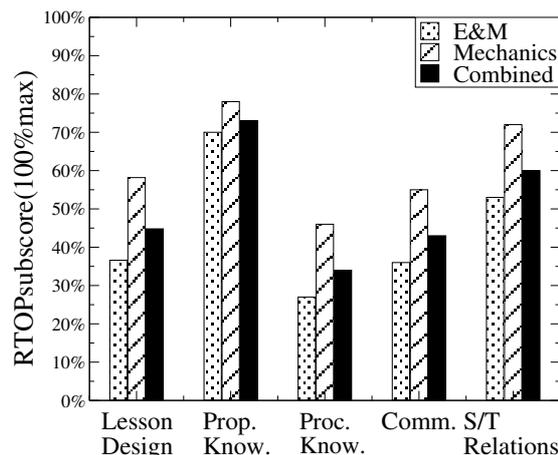


FIGURE 4. Average RTOP subscore across all observations. Classes score highest in the subcategory that assess the instructor’s knowledge, and lowest those that directly measure active-engagement techniques.

ages students to seek alternative modes of investigation, and allows students to determine the lesson’s direction. Procedural Knowledge rates the extent to which students make predictions, use a variety of representations, and/or reflect upon their learning.

Subject dependence

Figure 2 indicates that faculty in the Electricity & Magnetism receive lower RTOP scores than their colleagues in Mechanics. Clues to the origin of this are found in the Teaching Techniques sub-category of the TDOP. Figure 5 shows scores in three instructor-centered activities (Lecture, Faculty-worked problems, and Faculty Illustrations) and one student centered activity (Student worksheets). Lecture appears in half of all observed Electricity & Magnetism intervals compared with 20% of Mechanics intervals. While Mechanics faculty spend more time working problems in front of the class (32% vs. 17%), E&M instructors spend more time giving illustrations (21% vs 12%). The average frequency of these three instructor-centered techniques for Mechanics courses is 29%; for Mechanics courses the average is only 21%. The most prevalent student-centered activity is student worksheets. Figure 5 shows that Mechanics courses spend 40% more time on these activities than do the E&M courses. All of these differences are significant at the $p < 0.05$ level.

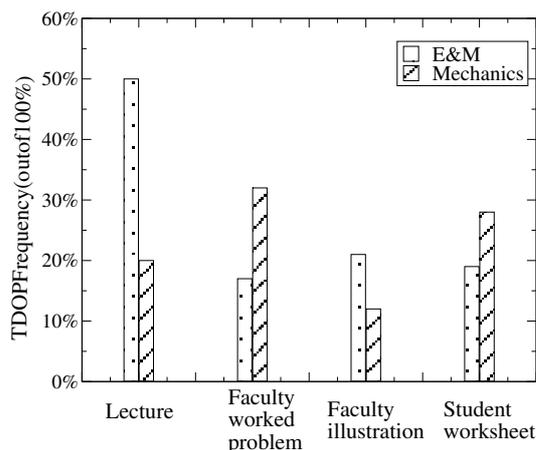


FIGURE 5. Frequency of instructor (left grouping) and student centered (right) practice in Mechanics and Electricity & Magnetism courses. E&M instructors lecture 2.5 times as often as Mechanics instructors and have students working on problems far less often (19% vs. 28%). All of these differences are statistically significant ($p < 0.05$).

CONCLUSIONS

We present the first fine-structured characterization of faculty practice in workshop-style introductory physics courses, and compare the practice as recorded by the TDOP with the more summative evaluation of the RTOP. This analysis reveals a drop in the frequency of lecture and instructor-centered practice compared with traditional classrooms, as expected, but with lower RTOP scores than might be expected given the radical change in environment. This surprising result can be explained by the fairly high prevalence of instructor-centered activities (including, but not limited to lecture) and the scarcity of student activity that encourage prediction, reflection, or higher-order cognitive effort.

We also find a statistically significant difference between practice in Mechanics and E&M courses, with faculty in the former courses lecturing less, using more student-centered activities, and receiving correspondingly higher RTOP scores.

This difference in practice has several possible origins. Much early physics education research dealt with mechanics concepts. Faculty may be more familiar with this work, and thus more likely to incorporate the activities into the classroom. Casual interviews with faculty revealed the belief that E&M is more mathematical and difficult, with students more in need of didactic instruction. While we take great issue with this viewpoint, it does explain why faculty feel compelled to assume a more explanatory role in the classroom, and indicates another obstacle to dissemination of pedagogical reforms.

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