Chapter 6

Students' Perception of Lesson Objectives in Introductory Mathematics Courses Taught by Teaching Assistants

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We report on an investigation within calculus reform courses of the alignment of TAs' stated lesson objectives with perceived lesson objectives by students and external observers. We contrasted the objectives stated by TAs prior to the lesson, objectives as understood by observers viewing the lesson, and objectives reported by students immediately following the lesson. We found discrepancies between these objectives that point to a mismatch between TAs' intended objectives and what actually occurs in the classroom; students' objectives are aligned with classroom activities but not with TAs' stated objectives. We make suggestions to assist TAs in building lesson plans for reform-oriented classes.

Graduate student teaching assistants [TAs] who have full responsibilities for teaching (e.g., planning, teaching, and assessing students), play an important role in teaching introductory-level undergraduate mathematics courses in research universities. Often, however, TAs receive very limited training before entering the classroom as instructors; they have little opportunity to learn how to teach in ways they have not experienced and may very well have never experienced a calculus reform-type course. As such, the limited training can be especially problematic when the TAs are asked to teach classes with a significant focus on in-class group work and problem solving, as advocated by the calculus reform movement (Speer, Gutman, & Murphy, 2005).

Since the beginning of the calculus reform movement in the late 1980s, there have been numerous studies documenting and comparing student progress in reform and classically taught courses. Over the long term, the data support the claim that reform-type classroom activities are more effective in helping students realize their teachers' learning goals. In summarizing the results of 127 NSF projects at 110 institutions between 1988 and 1994, Susan Ganter remarks:

> Evaluations conducted as part of the curriculum development projects mostly concluded that students in reform courses had better conceptual understanding, higher retention rates, higher confidence levels, and greater levels of con-

> tinued involvement in mathematics than those in traditional courses. (Ganter, 1999, p. 234).

In this exploratory study, we investigated the alignment (or misalignment) of what a TA teaching a calculus reform class perceives to be the most important parts of a lesson with what his or her students perceive to be the instructor's goals for the lesson. We define "objectives" as what we want students "to learn as a result of our teaching" (Anderson, et al., 2001). We examined how students' perceptions of their TAs' objectives differed from the TAs' intended objectives. We considered the TAs' stated objectives (as obtained from pre-lesson interviews), objectives as understood by an observer viewing the lesson, and objectives as reported by students immediately following the lesson. Ideally, these objectives would be one and the same, but we found that this was not the case.

We used a now-classical model for studying curriculum that has been developed in the mathematics education literature (Travers & Westbury, 1989). This model posits that there are three different versions of curriculum. First, the *intended* curriculum refers to the aims, intentions, goals, and objectives for mathematics that are envisioned for learning at a national, regional, or local level. Guidelines in state standards, textbook content, or master syllabi outline the content, processes, and skills that we want students to learn. Second, the *enacted* curriculum is what results from enacting those guidelines in the classroom, via lectures, discussions, or activities that teachers plan so that their students learn the material in the classroom. Third, the *attained* curriculum describes what students learned, and it is usually measured via standardized tests or other forms of assessments, such as quizzes, homework, and examinations.

The model is represented in Figure 1. The arrows in the model indicate that each version of the curriculum affects the next version of the curriculum. The model is useful because it acknowledges that intentions, enactments, and learning might be different; that enactments of similar intentions can vary from classroom to classroom; and that what students learn depends on both the intended and the enacted curriculum.

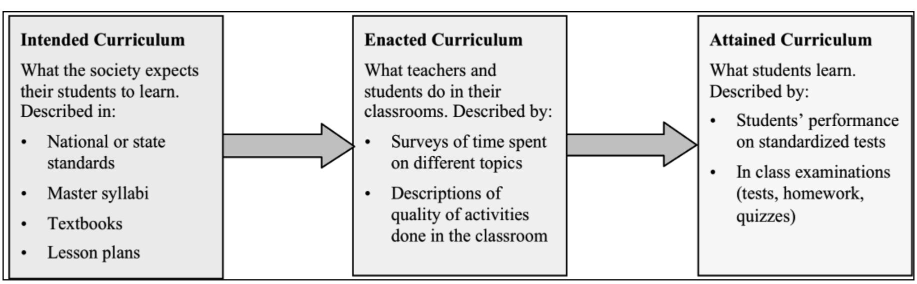

Figure 1: Model for describing different versions of curriculum. Adapted from Travers and Westbury (1989).

In this paper, we investigate how TAs' objectives (i.e., their intentions for the lesson) were realized in the classroom (i.e., the enacted lesson) and how the enactment related to what their students understood these intentions to be (i.e., a weak version of attained curriculum). This framework allows us to describe alignments and discrepancies that occur in teaching from the starting point of lesson objectives. Objectives are "explicit formulations of the ways in which students are expected to be changed by the educative process" (Anderson, et al., 2001, p. 1). There are numerous definitions of objectives in the field (Bloom et al., 1956; Gagné, et al., 2005; Gerlach & Ely, 1980) but all share a description of an "observable student behavior or action that will demonstrate learning, the conditions under which the behavior/action is to occur, and the standard against which the behavior/action will be evaluated" (Sleep, 2009, p. 29). Words such as "appreciate," "know," and "understand" are considered ambiguous because it is not clear what is meant by these verbs and they cannot be directly observed. Rather instructors are encouraged to determine what it would look like (e.g., what students would be able to do) if they appreciated, knew, or understood (Diamond, 2008, p. 148-149). That there are discrepancies between intended and enacted objectives is a common theme in the K-12 mathematics education literature, but the phenomenon has not been studied in higher education, where the literature indicates that what matters is the formulation of clear objectives. Although defining clear objectives is an important first step, we argue that aligning intended objectives with the objectives as enacted in the classroom is not a trivial process in teaching, especially for TAs who need to learn to teach using reform oriented techniques. Alignment seems to be a crucial goal, as it would support students' opportunities to learn.

"Opportunity to learn" describes the content students have been exposed to in class and allows researchers to make judgments about students' performance on tests relative to their in-class experiences. For example, students who were not given opportunities to learn about derivatives conceptually—either because the conceptual explanations were not in their textbooks or because their instructors did not teach derivatives conceptually in the classroom—are more likely to perform poorly on a test of the conceptual underpinnings of derivatives than students who were exposed to derivatives in a conceptual form. In K–12 educational research, "opportunity to learn" has become a general notion that includes not only content and instructors' enactment of the curriculum, but also school factors that most directly affect student learning (e.g., availability of graphing calculators, qualified teachers, or good textbooks). For a historical description of the evolution of this notion from a research to a policy tool, see McDonnell (1995) and Tate and Rousseau (2006).

Methods

Data were collected in Fall 2008. Our sample consisted of seven TAs, selected as a convenience sample from a pool of approximately fifty who had prior experience teaching introductory-level mathematics at a large research university. Five of the TAs were teaching Calculus I, one was teaching Pre-Calculus, and one was teaching an introductory Interest Theory class. All of the TAs were pursuing graduate studies in mathematics. Six had at least two semesters of college teaching experience and the seventh had two semesters of teaching experience in a high school mathematics scholars program affiliated with another university. None of the observed TAs spoke English as a second language. The seven classes included a total of 146 students.

At this university, Pre-Calculus and Calculus I are taught in small sections (32 students or less) rather than in large lectures. TAs teach the majority of these sections, with a few sections taught by faculty. The vast majority of sections meet three times a week in 80-minute blocks. Instructors are expected to make use of the small class sizes by offering a combination of short mini-lectures, classroom discussions, and individual and group work sessions during class. Homework assignments and exams are standardized across all sections to ensure comparability of all sections. The interest theory course is an introductory course on the mathematical concepts and techniques employed by financial institutions such as banks, insurance companies, and pension funds. It has one section per semester and is taught by a TA. These sections meet three times a week in 50-minute blocks and have enrollments of under 30 students. The TA determines how class time is spent and designs the homework and exams. Although the TAs teaching this class go through the same rigorous training, they are not bound by the need to use reform-oriented techniques in their teaching. This lesson served, in some ways, as a contrast for the reform oriented classes in our sample.

Seymour (2005) reports that it is common for TAs to attend a "generic one- or two-day workshop that is held before the start of the academic year and that provides a general orientation consisting largely of information on university policies and procedures," (p. 250) and that it is key for TAs to receive assistance in learning to use interactive methods (p. 275). All the TAs observed in this study participated in a rigorous weeklong professional development program immediately prior to their first semester of teaching. The program included practice teaching sessions (videotaped and discussed), sessions on administrative policies, and sessions geared towards techniques particular to reform-style calculus classes. For example, there were sessions titled "Planning and Managing an Interactive Classroom," "Cooperative Learning Techniques in the Classroom," and "Setting Up and Running Homework Teams." As the semester progresses, they also participate in ongoing training in the form of weekly course meetings where course information is shared and TAs can discuss issues arising in their sections. First-semester TAs are also observed at least twice during their first semester of teaching and receive feedback from students and the observer as an outcome of the observation. By all standards, this training gives students substantial support in learning to use the interactive teaching method that is required for the calculus program.

The first two authors contacted each TA and requested permission to (1) conduct an individual interview prior to one of his or her lessons, (2) observe that lesson, and (3) have his or her students respond to a questionnaire at the end of that lesson.

TA Interviews. Our goal was to learn about the TA's teaching experience as well as his or her specific objectives for the lesson that we would observe. The interviews were short (approximately 10 minutes) and informal. We asked them, "What are your objectives for the upcoming lesson?" If the TA had difficulty responding to this prompt, we rephrased the question to clarify our usage of "objective" or provided examples. An objective given by one Calculus I instructor was "for students to develop skill in computing implicit derivatives."

Observations. Our goal was to see the ways in which the TA communicated his or her objectives for the lesson to the students. To this end, either Matt Elsey or Jeff Meyer observed each lesson. We qualitatively recorded events in the lesson using a classroom observation protocol, a modified version of a protocol used in a study of mathematics instruction in community colleges (Mesa, 2009, in turn adapted from Grubb & Associates, 1999). This protocol allowed us to collect information on classroom activities, time spent on those activities, student engagement, and board work. Six lessons were 80 minutes long and the seventh lesson (from the interest theory course) was 50 minutes long.

Student Questionnaire. Our goal was to see what the students could recall at the end of the lesson. The questionnaire had two prompts: (1) "List the major ideas emphasized in today's class," and (2) "Suppose one of your teammates missed this class and they later asked you to tell them what they missed. How would you describe the major ideas emphasized in today's class and how they fit in the context of this course?" The purpose of this questionnaire was to determine what students perceived the objectives of the lesson to be without explicitly cueing them that we were after the objectives. We assumed that by using the term "emphasis," we would target the objectives of the lesson.

Data Analysis

In order to get a sense of the relative emphasis of conceptual versus procedural knowledge in the lessons, we classified the TAs' objectives as either pertaining to conceptual knowledge [C] or procedural knowledge [P] (see Table 1). This is an important categorization, because calculus reform is concerned with conceptual understanding, and at the same time, calculus requires substantial procedural work (Thompson, 1994; Thompson & Silverman, 2008). For example, we coded the objective "Students should understand the accuracy of linear approximations," as conceptual, using the key word "understand" as an indication of interest in deepening meaning, while we coded the objective "Developing skill and proficiency with the Fundamental Theorem of Calculus" as procedural, using the terms "skill" and "proficiency" as an indication of interest in developing methods and techniques.

Reform-oriented classes are designed to include a significant amount of group work and discussion between the instructor and students instead of the traditional lecture format. Because it was germane to our analysis, we parsed our class observation notes into events in which the role of the participants clearly changed; we had three categories, lecture (L), discussion between the TA and students (D), and group or individual work (G/I). We labeled a presentation by the TA that introduced new material to be a "lecture" when there were no questions, answers, or comments formulated by the students. We labeled the presentation as a "discussion" when there was substantial engagement in the form of questions and answers by both the TA and the students. Segments were labeled "group work" or "individual work" when the TA assigned problems to the students and he or she walked around asking or answering questions. We determined the general level of student engagement, which we classified as either "High," "Moderate," or "Low," depending on the number and type of instructor-student and student-student interactions. In particular, we referred to comments in the sections of our notes regarding the frequency and types of student-student interactions such as "students excited about

Table 1: Dimensions of Knowledge: Conceptual and Procedural (Anderson et al., 2001).

Conceptual Knowledge: The interrelationships among the basic elements within a larger structure that enable them to function together.	
Types of Conceptual Knowledge	Examples
C1. Knowledge of classifications and categories	Periods of geological time, forms of business ownership
C2. Knowledge of principles and generalizations	Pythagorean theorem, law of supply and demand
C3. Knowledge of theories, models, and structures	Theory of evolution, structure of Congress
Procedural Knowledge: How to do something, methods of inquiry, and criteria for using skills, algorithms, techniques, and methods.	
Types of Procedural Knowledge	Examples
P1. Knowledge of subject-specific skills and algorithms	Skills used in painting with watercolors, whole-number division algorithm
P2. Knowledge of subject-specific techniques and methods	Interviewing techniques, scientific method
P3. Knowledge of criteria for determining when to use appropriate procedures.	Criteria used to determine when to apply a procedure involving Newton's second law, criteria used to judge the feasibility of using a particular method to estimate business costs

group work" or "student texting" (indicating that a student was using their cellular phone during class rather than engaging with the discussion) to make decisions about level of engagement. We also recorded whether the TA ever explicitly wrote down the lesson objectives on the blackboard.

In Figure 2 we show an example of a summary of class events, recorded during the observation of TA2's class. The summary shows the type of objective formulated by the instructor and how the events in the class corresponded to each objective, from the observer's perspective. The summary also gives the time spent on each event.

Each student response was classified in relation to his or her TA's objectives as Detailed, Nominal, Vague, or Unrelated. Consider the objective "Students should gain proficiency in computation of tangent line approximations" (formulated by TA2). A "detailed" response closely matched the instructor's statement, for example, *"We use linear approximation to approximate f(a) at a point a. This is done by finding the tangent line using the formula,* $y - f(a) = f'(a)(x - a)$." In a "nominal" response the student referred to the objective by name (e.g., *"linear approximation"*). A "vague" response was one that approached the objective but that either showed considerable confusion or was too general (e.g., *"We learned how to approximate functions with lines"*). A response was coded as "unrelated" to an objective if no mention was made of that particular objective. This coding was agreed upon by the observers then independently applied. To calibrate the coding, two tests of inter-rater reliability were conducted; first a full set of students' responses for one TA was coded by both of the first authors and the agreement established as a proportion of agreements to total items coded. This agreement was 66%. The review of the disagreements revealed that they were mostly with contiguous categories (for example, between Vague and Nominal). After discussing the disagreements, a better understanding of the coding categories was developed and agreed upon. Second, another full set of students' responses was recoded

Objective	Type	Events				
		1	2	3	4	5
Students should gain proficiency in computation of tangent line approximations	P		✓	✓	✓	
Students should understand the accuracy of such approximations	C		✓			

Events:
1. Discussion of homework regarding implicit differentiation. (23 min)
2. Lecture-based introduction to tangent line approximation with questioning of students. (10 min)
3. Group exercise: "Find tangent line to $\sqrt{x}$ at x = 1." (8 min)
4. Group exercise: Two book problems, "What is tangent line approximation to e^x near x = 0" and a problem using the local linearization to approximate derivatives. (20 min)
5. Group assignment: "Write a potential quiz question on the material from this and the previous section." (7 min)

Figure 2: Example of event coding for TA2's class.

independently and this time the agreement reached 73%. Given the complexity of the coding system and the nature of the data, we deemed this moderate level adequate for the purposes of this paper, and used the agreed upon definitions to code the remaining student data.

Results

We start with a general summary of the data that we collected, providing numerical information that is useful in characterizing the data; next, we present our three main claims and use data from different aspects of our study to substantiate them.

Summary and Characterization of Data

Table 2 shows a summary of the main characteristics of the lessons taught by the seven TAs. A total of 146 students responded to the questionnaires.

In general the classes observed followed the expected emphasis for the different types of events, with less time devoted to lecture than to discussion or group and individual work. The TAs indicated that the classes observed were representative of their teaching and that there were not unusual events occurring (e.g., exam review or an in-class quiz) on the day on which the observation took place.

Table 3 presents the synthesis of our data concerning the reported TA objectives, class events, and student responses. Eight observations can be derived from the table. First, as a group, the 7 instructors stated 17 objectives; more than half (9) were conceptually oriented. Second, with the exception of TA3, all the TAs stated at least one conceptual objective, and with the exception of TA6, all the TAs stated at least one procedural objective. Only one

Table 2: Characteristics of the Observed Lessons.

Lesson by	Class Size	Student Engagement	Time Allocation by Class Events (min)			Objectives Written on Board
			D	L	G/I	
TA 1	19	Moderate	25	35	15	No
TA 2	21	Moderate	40	10	25	No
TA 3	26	High	40	5	25	No
TA 4	20	Low	25	35	15	Yes
TA 5	22	High	24	28	16	No
TA 6	22	High	13	22	39	No
TA 7[a]	16	High	11	26	6	No
Average[b]	21	-	28	23	23	-

[a] This class was 50 minutes long. All other classes were 80 minutes long. Five to eight minutes were taken from each class to administer the student survey. Time devoted to administrative tasks (e.g., reporting change in office hours) was not included.
[b] Because the 7th observation was shorter, this average does not include it; the average is rounded to the nearest integer.

Table 3: Objectives, Class Events, and Students' Responses in the Seven Lessons Observed.

Class, Number of Stdents in Class, Type of Objective, Stated TA Objective	Event Type[a]	Time (%)[b]	Students' Responses[c]			
			Detailed	Nominal	Vague	Unrelated
TA1 (19 Students)						
1. **[C]** Reinforce the concept of inverse function with the example of inverse trigonometric functions.	D, L	14	11	5	0	3
2. **[P]** Develop skill/proficiency with computations related to inverse trigonometric functions.	D, G	34	7	1	2	9
3. **[C]** Introduce the concept of the tangent function.	D, G, L	13	8	9	0	2
TA2 (21 Students)						
4. **[P]** Students should gain proficiency in the computation of tangent line approximations.	D, G, L	40	9	12	0	0
5. **[C]** Students should understand the accuracy of such approximations.	D, I	7	0	0	2	19
TA3 (26 Students)						
6. **[P]** Demonstrate mathematical modeling of functions based on non-mathematical problem descriptions.	D, G	71	15	4	2	5
7. **[P]** Understanding/recalling/applying the procedure for solving optimization problems.	D, G	14	16	9	1	0
TA4 (20 Students)						
8. **[C]** Understand connection between area under velocity curve and final position.	G, L	13	4	3	4	9
9. **[P]** Proficiency with basic computations using graphs and tables of velocities.	D, G, L	49	11	3	5	1
10. **[P]** Familiarity with notation.	-	0	0	0	0	20
TA5 (22 Students)						
11. **[C]** Understand/Remember statement of Fundamental Theorem of Calculus	D, L	22	5	15	1	1
12. **[P]** Develop skill/proficiency with computations related to the Fundamental Theorem of Calculus.	L	7	0	2	6	14
TA6 (22 Students)						
13. **[C]** Understand the definite integral as a signed area under curve.	D, G, L	66	2	12	3	5
14. **[C]** Understand velocity $v(t)$, position $s(t)$ relationship extends to $f(x)$, $f(x)$ relationship.	-	0	0	0	1	21
15. Have fun	G	69	1	0	0	21
TA7 (16 Students)						
16. **[C]** Understand concept of IRR, in particular how it helps them decide if they should invest.	D, I, L	32	11	4	0	1
17. **[C-P]** Understand and be able to compute some basic probabilities.	D, L	47	11	5	0	0

[a] D: discussion, G: group work; I: individual work; L: lecture. [b] Percentage of minutes of the class devoted to the given events; [c] number of students who gave each type of response; in each row, the numbers add up to the number of students in the class

instructor (TA6) stated an objective that was not cognitively oriented ("15. Have fun"). Third, the majority of the TAs' objectives were addressed in a variety of formats throughout the lessons, but there were two objectives (stated by TA4 and TA6) that were not addressed during the observed classes. Fourth, excluding TA7's class, which was 50 minutes long, on average the TAs spent more time on procedural objectives (31 minutes) than on conceptual objectives (19 minutes); in addition, there was wider variation of time spent on the conceptual objectives (ranging from 7 minutes to 66 minutes).

Fifth, detailed responses about objectives were not very common. Only in the class taught by TA7 (the interest theory course) did a high percentage of the students (near 70%) provide a detailed response for both of the objectives that the TA stated. In TA3's class, about 60% of students provided detailed responses to both objectives. There were six objectives (all of TA6's, one each of TA2, TA4, and TA5's) that were described in detail by less than 10% of the students. It is difficult to determine whether this is a result of low extrinsic motivation for the students to answer the questions carefully (no grade was given and the response was anonymous), the students' difficulties in understanding the lessons, their lack of experience in answering these questions, or their TAs' lack of coherent lesson plans. The students were asked to write their responses immediately following the lessons, while the lessons were still fresh in memory; thus the students had no opportunity to review their notes or try problems on their own prior to responding. As a result, there was no additional opportunity for students to make sense of the material beyond what was provided by the TA during the lesson, which may explain why so few detailed responses were given to match the TAs' objectives. However, the large number of detailed responses provided for some objectives (particularly for TA3 and TA7) suggests that students did have the ability to answer the questionnaires.

Sixth, only 6 of the 17 objectives were identified with detailed or nominal responses by 85% or more of students (both of TA7's, and one each of TA1, TA2, TA3, and TA5's). However, in all classes, at least one student mentioned in detail at least one TA objective.

Seventh, the correlation between time spent on each objective and the number of detailed responses to the objective given by students, was positive ($r = .31$, $t(15) = 1.28$, $p < .10$), which suggests that the more time a TA spent on an objective, the more likely it was that the objective was recalled in detail (or vice versa, the more detailed responses were from objectives on which the TA spent the most time). Conversely, the correlation between unrelated responses and time spent on an objective was negative ($r = -.28$, $t(15) = -1.13$, n.s.), which suggests that the less time a TA spent on an objective, the more likely it was for students to provide an unrelated response for that objective. The sample size is too small for making definite claims, but the numbers do suggest an important trend in the data, namely that there is a positive correlation between in-class time spent on an objective and students' recognition of the objective.

In addition, some students described in their responses main ideas that were not stated by their TAs as objectives of the lesson. In Table 4 we list the ideas that at least 50% of the students shared in each class yet were not provided by TAs as objectives. The case of the lesson taught by TA6 is interesting. This TA listed two conceptual objectives, but about half of the students gave detailed or nominal responses about a procedural objective not stated by the TA, an objective that, according to our observation records, was addressed throughout the whole lesson (74 minutes). At the same time, in this class very few students provided detailed or nominal responses regarding the TA's stated objectives (compare with Table 3).

Key Observations

The analysis of the qualitative data allows us to propose three major claims that would merit further investigation with a larger sample. First, and foremost, we found that students listed ideas and techniques related to activities done in the class as objectives of that class, regardless of those activities' relationship to the instructor's intended objectives. Second, student responses differed from TAs' responses in multiple ways. Third, students' engagement alone is not enough to determine how well the objectives perceived by students will match the TA's intended objectives.

Table 4: Main Ideas Described in Detail or Nominally by Students but Not Proposed as Objectives by Their TAs.

Objective	Event	Time (%)	# of Detailed or Nominal Responses
TA2 (21 Students)			
Review of implicit differentiation.	D	27	11 (52%)
TA4 (20 Students)			
Integration.	D	27	12 (60%)
TA5 (22 Students)			
Average of a function over an interval.	L	13	14 (64%)
Integration	D	27	15 (68%)
TA6 (22 Students)			
Develop skill/proficiency with approximating area with rectangles.	D, G	74	17 (77%)

Observation 1: Students listed ideas and techniques related to activities done in the class as objectives of that class, regardless of those activities' relationship to the instructor's intended objectives.

An interesting phenomenon was the wide range of main ideas that students listed in their questionnaires. Some ideas matched their TA's stated objectives very closely, others were slightly related, and many were not related at all (see Table 3). TA7 was the ideal case, with 69% of the students giving detailed responses matching TA7's objectives. The lesson was primarily lecture but punctuated frequently with short individual activities (primarily computation and problem solving) that matched the TA's objectives particularly well. The students were engaged during lecture and on-task during the individual activities. In the end, nearly all of the students' listed objectives matched TA7's. Student responses in TA3's class also matched well with TA3's pre-class interview; in this case, the class consisted primarily of (1) setting up and (2) solving optimization problems, both activities aligning well with the TA's objectives. In contrast, one of the three objectives named by TA6 was nominally matched by about two-thirds of the students, while the other two objectives received in total only one response coded as either "detailed" or "nominal." Time in this lesson was primarily spent on two long segments of group work. For each segment, TA6 assigned several problems out of the text from the same section; however, there was no obvious theme relating any of them. During the second long segment of group work, most groups lost focus within ten minutes and began discussing non-course related material; in spite of this, the segment continued for another eleven minutes. In the students' responses, 14 out of 22 were detailed or nominal matches for the first objective, the only cognitive objective that TA6 spent time on. In addition, the students' responses were mostly unfocused and referred to a wide variety of topics unrelated to TA6's stated objectives.

While TA6 was an extreme case, the students of other TAs provided a variety of responses as well. TA1, using lecture and discussion, introduced the new concept of the tangent function in the last eight minutes of class. TA1 indicated in the interview that this objective was secondary; however, nearly 90% of the students listed the introduction of the tangent function as one of the main ideas of the lesson. After completing a lecture on the Fundamental Theorem of Calculus, TA5 gave out a worksheet that required the use of conceptual knowledge about the integral. Many of the students (about 68%) then listed as an objective for that class "problem solving with the integral," as opposed to problem solving using "computations related to the Fundamental Theorem of Calculus," as had been intended by the instructor.

In summary, students consistently listed ideas and techniques related to activities they engaged in as objectives of that class. This is significant because TA1, TA2, TA5, and TA6 conducted activities requiring ideas and techniques not directly related to their intended objectives, and their students listed those ideas and techniques in their responses (refer to Figure 2 and Tables 3 and 4).

Observation 2: Students' responses differed from TAs' responses in multiple ways. In addition to the students' reporting ideas related to activities done in the class, we noticed three other discrepancies between students' responses and their TAs' intended objectives for their lessons. We list these three discrepancies below.

Focus on review material: In their responses, students consistently included concepts and techniques related to review material from past lessons. We observed that TAs generally spent the first part of the lesson going over past material. In particular, two of the seven classes observed spent 20 minutes or more of the lesson reviewing homework problems. TA2 spent 27% of the lesson reviewing implicit differentiation, and more than half the students in that class reported implicit differentiation as a main idea on their questionnaires.

Procedural vs. Conceptual Knowledge: We also found that the TA objectives most frequently matched by detailed student responses were those pertaining to procedural knowledge, such as TA2's, "Students should gain proficiency in the computation of tangent line approximations." Conversely, objectives pertaining to conceptual knowledge, such as TA2's, "Students should understand the accuracy of such approximations," had fewer detailed student responses (9 of 21 versus 0 of 21). One possible explanation is that, in this lesson, more class time was spent on the procedural objective than on the conceptual objective (30 minutes to 5 minutes). Another possibility is that the benefit of the computational process is immediately obvious to the student—in order to solve the basic problems in the associated section, one must be able to perform the computational procedure, and if students feel confident about those procedures they might be able to describe that confidence in procedural terms. Furthermore, we suspect students have more facility for recognizing and remembering procedures than concepts due to the nature of K–12 mathematical education. To pursue these explanations further interviews with individual students after both conceptual and procedural activities are given would be necessary.

Name of Topic as an Objective: Students uniformly reported the topic of the lesson or the name of the related section in the textbook as a major idea of the day's lesson. In contrast, the TAs reported objectives that were more specific. Consider TA2's first objective: "Students should gain proficiency in the computation of tangent line approximations." All twenty-one students reported "linear approximation," yet only nine of them reported something related to the "computation" of linear approximations as an objective of the lesson.

These discrepancies may be due in part to the differences in the ways in which we asked TAs and students about the objectives of the lesson. The TAs gave their intended objectives in an interview while the students answered preprinted questionnaires, thus while TAs had the opportunity to clarify their objectives, the students did not. While a different method may have been useful, it is unclear that it would have reduced the wide range of responses students gave. The impact of the method for collecting data could be investigated in a follow-up study, but we anticipate that unless the objectives match the activities in the classroom there would still be great variation in student responses.

Observation 3: Student engagement alone is not sufficient to determine how well the objectives perceived by students will match the TA's intended objectives.

Even if the class events emphasized the TA's objectives, low student engagement may prevent the objectives from being internalized by the students. The responses provided by the students of TA4 (the only TA observed with student engagement coded as "low") varied greatly and did not match their TA's stated objectives. Most notably, TA4 concluded class by writing the major objective of the lesson on the board ("Conclude: The area under the curve = distance traveled"). It remained on the board during the time the students filled out their questionnaires. Yet only 55% of TA4's students mentioned this objective in any form in their responses.

At the same time, student responses in classes with high student engagement still may not match the objectives of their TA. For example, the student engagement in TA5's class was coded as "high," yet, as mentioned in Observation 1, there was a significant misalignment between the objectives described by the TA in the interview and the objectives described in the student responses. Thus low engagement can naturally prevent students from learning in class, but high engagement in activities that are unrelated to the class objectives can be also problematic.

Discussion

Few would dispute that in order to be an effective teacher of a calculus reform class, a TA must come to each lesson with a lesson plan that includes activities reflecting the objectives chosen for that lesson. However, our findings suggest that there is more subtlety than one might have originally thought in the relationship between what TAs would like their students to get out of a lesson and what students say were its main points in these reform oriented classes. Each of the TAs observed came to class with a clear idea of what he or she wanted the students to learn, as well as a lesson plan that he or she thought reflected those goals; that is, they had a clear idea of their 'intended curriculum' for the lesson. However, immediately following the lesson, students generally did not share with their TAs the same ideas about the main mathematical ideas of the lesson, which points to discrepancies in the 'attained curriculum.' As suggested by the Travers and Westbury (1989) model, implementation of the TA's goals in teaching (the 'enacted curriculum') determines the attained curriculum in important ways.

Our first observation is a corroboration of the curriculum model; students reported more frequently what they had the opportunity to learn as the important points of the lesson, independently of what instructors had in mind. This idea appears obvious, in hindsight. But it is important to be aware of, as these TAs clearly had good intentions and a clear idea of what was key for the lessons they were teaching. Yet we observed that the enactments of their plans were not well tied with those objectives. We see here important opportunities for TA development, in terms of assisting TAs in developing activities that match the objectives they have for a particular lesson. TAs need to be exposed to explicit descriptions of the relationship between intentions, enactment, and students' learning, and to the importance of designing objectives that are observable and attainable (Anderson, et al., 2001; Diamond, 2008). A complementary activity to this training is to repeat the process outlined in this paper with TAs, that is, ask them to formulate objectives; observe their lesson, taking notes on how time is used and spent; ask the students for input on main points of the lesson; and then contrast the three pieces of evidence in a mutual discussion. Planning and enacting lessons that fit a given set of purposes are not straightforward activities; TAs must have practice and feedback in order to improve in these skills.

Although TAs were aware that they were going to spend some of their lesson time reviewing past lessons, they did not report ideas in the review as objectives of that day's lesson. It seems that the time spent reviewing was more important in shaping students' understanding of the lesson than instructors recognized. This suggests that TAs might need to spend more time preparing this segment of the lesson and incorporate the ideas treated in the review into their objectives for the lesson.

Often TAs are told that a major key to successful teaching is keeping students engaged in the classroom activities. They are given a wide variety of techniques and suggestions aimed at achieving and maintaining high student engagement. However, it seems that student engagement alone does not necessarily ensure that students will have a clearer idea of what their TA wants them to know at the end of the lesson. While disengaged students are unlikely to learn much from even a well-planned lesson, it is necessary to ensure that the class events that students engage in are also specifically geared toward the TAs' objectives.

To us, the most striking finding was that students consistently listed ideas and techniques related to activities they did individually or in groups as objectives of that class, regardless of their relationship to the instructor's intended objectives. When students were given activities whose completion required auxiliary concepts other than the one being emphasized, the students were later unable to distinguish the primary concept from these auxiliary concepts. For example, TA6's conceptual objective (Table 3) was to "Understand the definite integral as a signed area under curve." Immediately after presenting the concept of signed area and the example $\int_0^{2\pi} \sin(x)dx = 0$, TA6 gave the students five problems to do in groups. The first of these problems asked the students to use a table of data representing the (monotonically decreasing) rate that a chemical is leaking out of a vat to approximate the amount that had leaked out of the vat over several time intervals. In Table 4, we see that 77% of students in this class listed "Develop skill/proficiency with approximating area with rectangles" as an objective of the class, which reflects the techniques associated with completing this activity. Although related, these objectives are mismatched: whereas the students focused on the process of finding the areas, the TA expected them to focus on the nature of that area. This finding is important because the reform movement in calculus places substantial emphasis on peer-to-peer interaction in the classroom; thus this finding makes the need to plan lessons with activities that reflect and emphasize the desired objectives more salient. With this in mind, it appears to be warranted to suggest that for each lesson, TAs choose activities whose completion depends primarily on the application of the concept or skill just introduced.

Finally, and connected to this last point, we see the potential for focused training in designing activities that emphasize students' conceptual development; our observations point to little emphasis in this area in the enacted lessons, and in the students' reports. This area is key, as one of the most important goals of the reform in calculus was to attend to conceptual development.

Limitations

We mention two limitations of the study. First, this is an exploratory study conducted with a convenience sample of seven willing TAs who were aware that we were observing their lesson in advance, and therefore the results are to be interpreted cautiously. These TAs are probably more confident than others about their teaching because they were willing to have others observe and scrutinize their practice. However, the large proportion of students in several of the classes who stated objectives that differed from those of their TAs, suggests that this difference is likely to also be present in a more carefully chosen sample. The TAs were told that we were observing the alignment of objectives between the instructor, classroom events, and students. This knowledge might have affected the lessons, as TAs would have been more purposeful in making the lesson align to their objectives; yet we still observed a significant misalignment between lesson objectives and enactment. If there were such an effect, it would just show that the misalignment would be larger in standard conditions.

Second, students had a short time period to respond to the questionnaire (five to ten minutes at the end of class) and lacked familiarity with the format. This could have had an impact on the quality of the responses they produced, some of which were very short and unelaborated. In addition, there were no tangible incentives for the students to respond with attention and detail, because their participation was anonymous, voluntary, and had no implications for their own standing, we suspect that some students might not have taken the questionnaire seriously. At the same time, we think that for these reasons students gave us a more valid and candid account of what they perceived had happened in the lesson. This format also can be systematically used by instructors to assess the extent to which their lesson objectives match students' perceptions of those objectives, and thus, we felt satisfied with this choice of format.

Conclusion

In spite of the limitations of our exploratory study, our findings reflect an important discrepancy between the objectives conceived by the TA and the objectives perceived by the students in reform-oriented classes. The objectives perceived by students were directly related to what was enacted in the lesson and not with the TAs' intentions for that lesson. Thus when TAs' objectives aligned well with their class enactment, the students had more opportunities to engage with the intended content of the lesson. Although this result appears obvious, there is more we need to understand about *how* exactly the process of stating objectives and aligning instruction takes place; as our results point out, not all the TAs manage to align lesson objectives and enactment despite the rigorous training they received.

Our study suggests that TA training programs need to emphasize not only the importance of setting objectives for lessons but also to reflect on the process of choosing activities that adequately address those objectives. Workshops that illustrate why certain activities might be more appropriate than others in meeting lesson objectives would be fundamental; this kind of work requires expertise in the discipline and knowledge of students' learning processes (Speer, Strickland, Johnson, & Gucler, 2006) which underscores the importance of content-based TA and faculty development.

Besides this emphasis on planning, TAs can be encouraged to ask students at the end of some classes questions similar to the ones we asked in order to determine the extent to which their students agree with the goals they have set for the lesson. This feedback can be productive in helping TAs to create lessons that are more coherent—from intended, to enacted, to attained objectives. Doing so may increase the number of opportunities students have to learn the content of the course and potentially result in greater student achievement.

Authors' Note

This paper is a part of a research study conducted by the first two authors while taking a class on college teaching across science, technology, mathematics, and engineering taught by the third author. Preliminary reports on this work were presented at the *Mathematics Teaching Seminar* at the University of Michigan, February, 2009.

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