

Study of TA's ability to implement the *Tutorials in Introductory Physics* and student conceptual understanding

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Many students are not prepared for college physics and therefore perform poorly. This becomes a problem when students must pass physics as part of course requirements for their major. At the University of Cincinnati this problem is being addressed through the implementation of *Tutorials in Introductory Physics* [1] in the recitation sections of our calculus-based physics course. In recent years we have evidence that the *Tutorials* increase both students' conceptual understanding of physics as well as their success rate in the course. To make further improvements we have shifted our research focus to the training of the recitation TAs. This presentation will describe the training the TAs receive as well as the methodology and instruments used in the study to determine the effectiveness of each TA. Preliminary findings indicate that there is a relationship between the TA's ability to implement the *Tutorials* and student conceptual understanding.

Introduction

Many of us who teach physics are faced with a similar problem. Students can mathematically solve physics problems but can not answer simple related conceptual questions [2,3]. Alternative methods of instruction have been integrated into physics programs in an effort to address this problem. Some of these methods of instruction include cooperative learning, inquiry-based instructional materials, tutoring centers, use of computers in the laboratory to model difficult physics concepts, and more interaction between the lecture instructor and students. Evidence suggests that these alternative modes of instruction are effective at educating a wide variety of students [4,5]. However, because many of these innovations are being implemented in the laboratory and recitation parts of physics courses, it is the graduate teaching assistants (TAs) who take on this new duty. This raises the question of whether or not TAs have enough physics background knowledge and general teaching skills to effectively use alternative modes of instruction.

The *Tutorials in Introductory Physics* [1] is one example of an alternative method of instruction. These inquiry-based materials are typically implemented in the recitation sections of physics courses and incorporate a set of

conceptual activities designed to actively engage students in the learning process of physics. As the students work in groups under the guidance of their peers and the instructor (typically a TA), misconceptions are addressed enabling the development of a strong conceptual physics knowledge base. At various points in the *Tutorial* activities the students have their reasoning checked by the TA. During these "checkpoints", the TA uses directed questioning to determine the extent of student understanding of the material. If misconceptions arise, the TA guides the students to correct reasoning through additional directed questioning. This questioning process, frequently termed Socratic Dialogue, is a major step to the development of students' critical thinking skills.

Implementing the Tutorials at UC

At the University of Cincinnati (UC), students majoring in engineering or the hard sciences must pass a calculus-based physics course. In the early 1990's less than half of the roughly 500 students enrolled in the course were considered successful by earning an A, B, or C. In the late 1990's the success rate increased by over 20% after the introduction of a tutoring center and cooperative learning recitation classes. In an attempt to further

increase these rates, the *Tutorials in Introductory Physics* were implemented in several of the recitation sections on a trial basis. The success rate increased even more and larger conceptual gains were observed on the Force Concept Inventory (FCI) as well.

One of the difficulties with implementing the *Tutorials* is that TAs need more training than when teaching traditional recitation. At the University of Washington, an extensive *Tutorial* training program is in place. Their TAs meet weekly to work through the activities to be taught that week and to discuss misconceptions that may arise for each topic. Emphasis is placed upon the teaching process and first time TAs are paired with more experienced TAs, whenever possible, so that Socratic Dialogue and effective teaching can be modeled.

At UC, we designed our TA training program after the program at the University of Washington, but we had limitations. Our weekly meetings enabled TAs to work through the activities to be taught that week, but a lack of time usually did not allow us to discuss pedagogical content issues and misconceptions, except for a very brief period of time. Checkpoints and the use of Socratic Dialogue were modeled for the TAs during the weekly meetings but a lack of resources inhibited the pairing of first time TAs with more experienced TAs.

Method and Objective of Study

The purpose of this study is to evaluate our TA training program in regards to the relationship between the ability of the TA to implement the *Tutorials* (use of Socratic Dialogue) and student conceptual understanding. The outcome of the study will provide information on how to modify our current TA training program.

The ability of the TA to implement the *Tutorials* was measured through the use of an observation rubric designed specifically for this study. Because Socratic Dialogue use by the TA was a large part of the implementation of the *Tutorials*, the rubric was designed to measure the percent of TA/student interactions that incorporated Socratic Dialogue. Each of the six TAs was observed and rated several times over the

quarter. Inter-rater reliability with two other observers was greater than 0.90.

The conceptual understanding of the students was measured through post-testing of concepts specifically taught in the *Tutorials*. The post-test questions were obtained from the Physics Education Group at the University of Washington (authors of the *Tutorials*). The questions were administered as part of four block exams.

Each TA was randomly assigned to a recitation section. Because it is possible that the students in each section were not equal in terms of academic background, the equality of the groups was investigated. Most students had taken an entrance math preparedness test and on comparison of average scores across recitation sections, it was found that the groups had similar ability ranges of math preparedness. As a second check, the Force Concept Inventory (FCI) was administered as a pre-test to half the recitation sections. The variance in the average scores from each section was small and did not seem to be significant in our final analysis.

The TAs were given the FCI and *Tutorial* pre-tests (designed by the Physics Education group at the University of Washington) before training began. This provided information about the conceptual knowledge of each TA.

Results

The use of Socratic Dialogue in TA/student interactions varied from 18% to 85% of total interactions depending on the TA. This large difference is interesting because all TAs went through the same weekly training (with the exception of TAs 1 and 4 who had taught using the *Tutorials* in at least one quarter previously). All other TAs had taught recitation or laboratory sessions before but had not used the *Tutorials*.

The students' average *Tutorial* post-test scores, depending on assigned TA, ranged from 55% to 66%. Although other factors such as lecture instructor or laboratory TA could have influenced these scores, the post-test questions were specific to material covered in the recitation sessions. This allowed for the measurement of concepts taught specifically during recitation under the guidance of the assigned TA.

A relationship between average *Tutorial* post-test scores for students of each TA and the percent of TA Socratic Dialogue use is shown in figure 1. Note the clustering of the TAs. This clustering is similar to both observed TA teaching performance and also the TAs' own pre-test scores (see table 1).

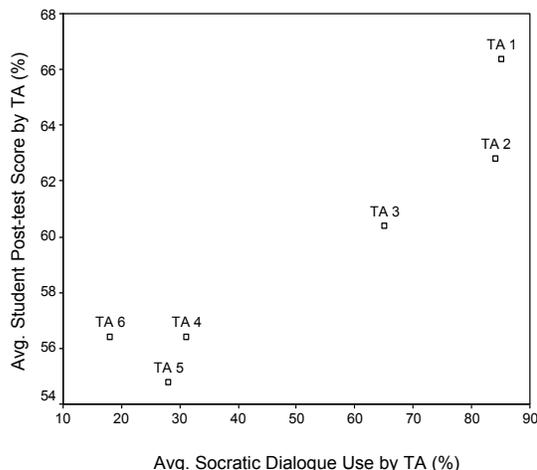


Fig. 1. Plot of TA's use of Socratic Dialogue compared to their students' average *Tutorial* post-test scores.

TA	TA FCI Score (%)	TA Pre-test Score Avg. (%)	TA Socratic Dialogue Use (%)
1	93	100	85
2	87	93	84
3	NA	58	65
4	80	83	31
5	67	78	28
6	NA	82	18

Table 1. FCI and *Tutorial* pre-test scores with average Socratic Dialogue use for each TA.

The TAs with the highest Socratic Dialogue use (TAs 1 and 2) scored higher than the other TAs on both the FCI and *Tutorial* pre-tests. In terms of classroom performance, they generated more discussion amongst their students than the other TAs and consequently their classrooms were noisier as more students participated in the activities. These two TAs were very good at questioning student understanding and seemed at ease with the Socratic method of teaching. Both were extremely confident in their physics content knowledge and it wasn't until the mechanics topics became more unfamiliar to them that they resorted to more traditional modes of teaching and

less questioning. For example, the Socratic Dialogue use for TAs 1 and 2 dropped to 76% and 64% of total interactions for the topic of rotational motion; a topic that appeared conceptually difficult for both the TAs and students. Although both were able to identify student misconceptions, they occasionally had difficulty leading students to correct reasoning through questioning for the more difficult topics. At these times they resorted to giving students the correct answers rather than engaging in Socratic Dialogue.

TA 3 was a unique case. Although he used Socratic Dialogue in over 60% of interactions with students, he had difficulty asking appropriate questions. When he tried to elicit information from students, his questions were frequently misinterpreted. When leading students to correct reasoning, his students often became frustrated with his questioning and the checkpoints became time-consuming and inefficient. Occasionally he did not recognize misconceptions that surfaced in his conversations with students. Although he tried hard, it was obvious that he was not at ease with this teaching method. His teaching performance could be attributed to his weak conceptual knowledge of physics as indicated by his low average score on the *Tutorial* pre-tests.

The TAs with the least Socratic Dialogue use (TAs 4, 5, and 6) had similar teaching styles to each other. All three checked students' answers by reading from student notebooks instead of asking for oral responses. They tended to give students correct answers when mistakes were evident instead of leading students to correct reasoning through directed questioning. TA 4 went so far as to actually write correct answers into student notebooks instead of letting them do it themselves. All three TAs did not have a strong conceptual physics background, as indicated by FCI and *Tutorial* concept pre-test scores, and they relied heavily on formulas to explain the concepts misunderstood by their students. Occasionally these TAs would end a checkpoint with a question that indicated an attempt at probing for student understanding, but the question was too superficial to uncover misconceptions. Whereas TAs 1, 2, and 3 made an effort to check the reasoning of all students in the group, TAs 4, 5 and 6 typically checked only the student closest to them and made

the unjustified assumption that others in the group had similar answers.

Four of the six TAs in the study were foreign graduate students. Two fell in the cluster of high Socratic Dialogue use and two in the low. The two American graduate students fell into opposite clusters from each other. The limited statistics in this study show no evidence that native language affected TA's ability to use Socratic Dialogue.

Conclusion

The results indicate that the ability of the TA to implement the *Tutorials* does impact student conceptual understanding. Although TAs 1 and 2 performed significantly better in the classroom, all six TAs could benefit from additional instruction in both content knowledge and the pedagogy of teaching specific topics.

All TAs lacked knowledge of at least some of the concepts taught as indicated by the *Tutorial* pre-test and class observations. Without this conceptual knowledge, the TAs appeared unable to generate appropriate questions that led students to correct reasoning. Instead they resorted to mathematical explanations that in many cases further confused the students. Also, the TAs need to be aware of the common misconceptions for each topic being taught. When this information was lacking, the TAs' probing questions were not direct enough to uncover and address the students' conceptual difficulties. And finally, TAs need to practice Socratic Dialogue outside the classroom. Although it was modeled for them during training sessions, many did not learn the fine details of the technique nor did they gain confidence in their ability to use this method of questioning.

The use of the *Tutorials* requires additional TA training, but we are encouraged by the success rate in the course and increased FCI gain. Even the students of TAs who ranked low in terms of teaching performance had higher average FCI gains than students in other sections that did not use the *Tutorials* (see table 2). Therefore, a modified TA training program will be implemented and a future study will focus on its effectiveness.

		FCI Gain*	No. students (pre/post)
Tutorials Used	TA1	60%	49/42
	TA2	32%	47/36
	TA3	49%	47/33
	TA4	42%	74/54
	TA5	no data	no data
	TA6	no data	no data
No Tutorials	Honors	25%	47/44
	Regular	21%	92/58

*students are from different lecture sections

Table 2. FCI gain for students of TAs in this study versus those scores of students not using the *Tutorials* in recitation.

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