

## **A primer on Tutorials for CU faculty. (S.J. Pollock, Aug '04)**

### **What are tutorials?**

Tutorials are a research-based introductory physics curriculum, designed to change the way recitation sections work: from "teacher-centered" to "student centered". Students work in small groups, and the role of the TA becomes that of a learning coach or "guide on the side". The materials were developed at the University of Washington after years of research on student preconceptions, where students were tested and interviewed to see what common ideas they hold about basic physics concepts. Tutorials have since undergone many cycles of testing and implementation there. The goal of the Tutorial developers, often achieved, is for average post-test results on topics covered in tutorials to match or exceed the *pre*-test results of incoming physics TAs.

### **What is the pedagogical theory behind tutorials?**

Education research indicates that "passive" learning, in which students listen to an expert explain ideas, is not as effective as "active" learning, in which the responsibility for learning is shifted to the students. This is particularly true for non-expert learners, i.e. the majority of our introductory students. Tutorials are designed to completely shift the locus of learning to the students.

Tutorials frequently follow an "elicit-confront-resolve" cycle. Students are first asked to generate their ideas about a basic physical situation (e.g., if a car rolls up and back down a ramp, what is the acceleration at the topmost point?) A *pretest* is given in advance of tutorial to solicit student answers *and* explanations. The *Tutorial* guides them through logical steps, forcing them to utilize multiple representations, confront possible internal inconsistencies in their beliefs, and ultimately to make sense of the topic. A *tutorial homework* follows up with extensions and generalizations of the idea emphasized in tutorial.

Tutorials place a large emphasis on the *process* of problem solving - eliciting conflicting ideas, encouraging discussion and debate, requiring explanation and consistency rather than merely "answers". They tend to focus on a single, or limited number, of powerful and common pre-conceptions.

### **Why should I implement tutorials in my class?**

They work: There is considerable evidence that more traditional "problem solving" recitations rarely successfully confront students preconceptions, and have surprisingly little impact on students' ability to solve traditional homework problems. Students in Tutorials generally do not do any worse on end-of-chapter homework problems, despite the fact that Tutorials do NOT address that type of problem-solving directly. They *do* show considerable improvement in conceptual questions and long answer problems requiring explanations and discussion.

TA development: TA's learn a tremendous amount by running Tutorials. It changes the way they think about elementary physics, and requires them to develop Socratic Questioning skills. It often *increases* their personal contact time with students, since they no longer

lecture but work individually with small groups. Finally, it gives them excellent material for their teaching vita: the preparation sessions provide them with some understanding of the theory and philosophy behind the Tutorials, which will allow them to better communicate a deeper knowledge of pedagogy.

Improved student participation and engagement: There are important social components involved in tutorials - students working in groups feel collective responsibility, attendance in tutorials is generally much higher than traditional recitations where nobody is likely to notice or care about an absence. Our student surveys indicate that students are very receptive to group work - they find it fun and stimulating. (There is a flip side, which I discuss next.)

### **Why should I NOT implement tutorials in my class?**

Your Time: Tutorials will take up some of your time. I estimate 2+ hrs/week extra the first semester you run tutorials. You will want to work through tutorial materials in advance. You will need to administer pretests, run a weekly TA/LA training hour (or arrange for someone else to do so) and write exam problems that follow up on tutorial materials. You *may* choose to spend a bit of class time connecting what you do there with Tutorials, for consistency and motivational reasons. You will need to grade "tutorial-like" exam questions, which typically take more time to grade than conventional "end-of-chapter" problem solving questions.

Student Time: Students spend the *entire* recitation hour doing tutorials. Time is tight, many won't finish. If you want to do other things in recitation (e.g. extended question/answer or problem solving examples) there *won't* be enough time. Students with homework difficulties will have to go *separately* on their own time to the help room (or form study groups)

Resources: you will want a student/teacher ratio of roughly 16:1 or lower. (See below!)

Student attitudes: Tutorials can be like telling kids to "eat their spinach". Although Tutorials are demonstrably effective learning tools, and surveys show students appreciate collaborative learning, the Tutorials are not particularly popular. Students often resent not being told "the answer". Some students find workbooks "childish", some find the tutorials too ambiguous (which is often intentional), some find them too time-consuming. Some complain that the materials are repetitive (which can be *true* for topics that are known to evoke robust and common misconceptions) Some find them confusing. Some don't understand why we care about explanations, as long as they get the answer right.

Our surveys this year showed that the majority of declared physics majors appreciated the tutorials, but a majority of the class overall do not *like* them (although they concede the tutorials are useful for learning physics).

Your pedagogical beliefs: If you believe that introductory physics *should* concentrate on formula manipulation, facts, and traditional (algorithmic, end-of-chapter style) problem solving then the tutorials are probably not for you! Similarly, if you despise the idea of group/collaborative work, I would avoid tutorials.

(If you fall into this last category, I might encourage you to study some education research literature to decide if your beliefs are grounded in evidence, and are serving your students well. See the end for some references)

## **What is the history of tutorials at CU?**

We first implemented tutorials in Phys 1110 in Fa '03, and repeated that in Sp '04. We have implemented Phys 1120 tutorials in Fa '04, and are preparing materials and resources for that. Student population was 500-600, we used a NSF teacher prep grant to provide additional learning assistants for all sections (see below). Measured learning gains on standardized conceptual exams were through the roof - higher than almost any reported gains in the literature. Results on tutorial-specific post-tests matched published results from the University of Washington, which has been refining tutorials for over a decade. Attendance in tutorials was required (and averaged over 90%).

## **What do I need to do to use tutorials?**

1. TA/LA training. Preparing TAs is *absolutely essential*, it is the single biggest responsibility the course instructor takes on when using Tutorials. (The remaining logistics below are all relatively simple.) I recommend scheduling a mandatory 1.5 hr/week TA meeting *every week, all semester*, a few days before each recitation (1110 recitations are traditionally all on Thursday, 1120 all on Tuesday) The TA's will get into groups and work through the tutorial on their own (with *you* playing the role of TA). I always start them off with the weekly pretest (see below), and then we discuss student responses/preconceptions, before they work through the tutorial themselves.

I usually bring snacks and hold it at 5 PM. This is the *only* preparation the TA's will need to do for their sections, so I have not found any resistance on their part to coming.

The role of the TA in Tutorial is to facilitate student collaboration, and to ask guiding "Socratic" questions to lead students to employ logic, common sense, and seek consistency in their arguments. TAs are encouraged not to "tell the answer", since it is the process, rather than the result, which is being emphasized. This is also probably the single biggest challenge for TA and student alike - our school system has trained students to believe that physics is mostly about rote, mechanical, or algorithmic problem solving. Some TA's do not understand how students can figure out physics without always being told how to do a "template problem" first. If you don't prepare the TA's, and they try to walk in and "wing" a tutorial, you will likely have total meltdown. The tutorials look deceptively simple, but many grad students do *not* immediately get the ideas correct, they learn a lot from the TA training hour!

2. Pretests: Each week, students need to do a pretest before coming in to tutorial. This is part of the "elicit" phase, and lets them articulate their ideas, shows them what we think are the important concepts for this week, guides them later in reflecting on what they learned. It is relatively important.

I will provide you with a complete set of word documents with weekly pretests, which you can administer in class, or let the students do on their own to hand in at tutorial.

I will also provide you with some "filled in" pretests, done by our students - these are useful to hand out in the TA training session so that they can look at student conceptions for themselves, and get a sense for the common ideas out there.

If you prefer to have students do pretests on the web (which is what we've done so far) at the moment we must rely on the University of Washington to "serve" them. You will need some login information, and can download results (if you want to give students credit for doing this - highly recommended) We are working on moving this to a local server, stay tuned. If you go this route, you will need to spend about 15 min/week dealing with this.

3. Postests: You should contact Prentice Hall and ask for a desk copy of the "Instructor's Guide", which contains sample exam questions. It is key that you have some exam questions which "look and feel" like tutorials, in order to motivate the tutorials. (I personally make these the "long answer question" on my exams, worth 1/4 of the exam.)

4. Human resources: You need a better student:teacher ratio than the departmentally provided 30:1. Tutorials are student-centered, but they are tougher than they look, and students need a fair amount of guidance. TA's need to check that students are on the right track, working on the materials, and explaining themselves. Using groups of 4, a 16:1 teacher:student ratio means that each group is in contact with a TA for 1/4 of the tutorial, which seems to be (marginally) sufficient. Since we presently have sections of 28-32 with 1 grad student, tutorials will NOT work well without extra human resources.

Our solution has been to use "Learning Assistants" - undergraduates who train along with the grad TAs at the weekly meetings, and play the same role in recitation (except they don't have any homeworks to grade!) . We have paid for these with an NSF teacher preparation grant that provides \$10/hr\*10 hrs/week\* 15 weeks = \$1500/Learning Assistant/semester. This funding will be available through Sp. 2006.

Contact Steve Pollock to learn how to get a cadre of LA's. You will need to get involved to some extent with the "STEM-TP" group, which may take another 1 hr /week or so of your time. The payback is enormous - 6-8 LA's at your disposal, who get trained separately by STEM-TP in pedagogy theory, and are available to you for help room hours, exam grading, classroom assistance, and more!

Another solution is to hook in with our Phys 4810/7810 "Teaching and Learning Physics" class, which will train physics majors in teaching theory, and expects them to function as a Learning Assistant as part of their "practicum" in that course. Contact Steve Pollock or Noah Finkelstein for more information on getting these students into your tutorial sections.

5. Classroom and materials: Tutorials are designed as collaborative group efforts. 1110 tutorials do not involve many materials except for a large piece of paper (11x17 is fine) to encourage easy student "back of the envelope" scribbles/shared work. 1120 tutorials often have very small and simple labs (circuits, motors, etc) built in. Jerry Leigh/Mike Dubson will provide all those materials. When possible, we have switched our students *out* of their assigned recitation rooms and into a new, temporary tutorial area, G2B77, in the basement labs across from Jerry Leigh's office. There are good tables there and whiteboards, and materials are stored in boxes in the bay behind this space. It is slightly noisy/busy, but works well. (TAs must be told to respect the needs of neighboring labs and recitations.)

You *can* run 1110 tutorials in regular classrooms, moving desks into circles. This requires more TA facilitation to get groups working well - it's not optimal. For 1120, it will be worse, as classroom desks are poor for sharing equipment, and materials have to be moved in and out of the classroom every week. At present we have room for two simultaneous sections/hr.

6. Modify your syllabus You need to order tutorial books for your students at the bookstore along with your regular textbook. You will want to include information about the tutorial in your syllabus/web page, and decide how much credit to assign to the various portions. ([www.colorado.edu/physics/phys1110/phys1110\\_fa03](http://www.colorado.edu/physics/phys1110/phys1110_fa03), or [\\_sp04](http://www.colorado.edu/physics/phys1110/phys1110_sp04), or [www.colorado.edu/physics/phys1120/phys1120\\_fa04](http://www.colorado.edu/physics/phys1120/phys1120_fa04) for examples)

You also need to change your homeworks, since Tutorial hw takes considerable time and effort. I reduced the number of conventional end of chapter problems by a factor of two each week. I still required a long answer writeup of one conventional problem each week as well.

### **What else do I need to know?**

A little "classroom propaganda", explaining the value and benefits of Tutorial will go a *long* way in improving student satisfaction and buy-in. Steve Pollock will be happy to work with you the first TA meeting (or two) of the semester. After you've done one, you'll find them *\*extremely\** easy to run, they require little or no preparation beyond having worked the tutorial yourself, and photocopying pretests (described above).

### **Where can I go to learn more?**

Tutorials in Introductory Physics: Prentice Hall.  
(Look at the tutorial book, the tutorial homework book, and the Instructor's Guide)

Redish: Teaching Physics with the Physics Suite.

Lillian McDermott's Millikan Lecture: "How We Teach and How Students Learn - A mismatch?" AJP 61(4), (1993), p295