

the experiments described in the article have known results, and students could be, and apparently are, given guidance that helps them discover what the professors hope they will conclude. There is only one brief mention—without an example—of students doing experiments in which the result is unknown.

Physics tends to simplify systems under investigation in order to seek results that apply with great generality. Conversely, it seems to me that teaching students to think like physicists can be served better by having them work on messy projects with unknown answers.

One way to achieve that is to have every student or student group do an experiment that is different from those done by previous students or groups. That sounds impractical, but when I addressed the problem in physics laboratories I was running in Chile 50 years ago, I concluded that it is not difficult. Link the measurements to a local environment. Every simple pendulum behaves like every other simple pendulum, but each person, each pickle, and each piece of popcorn behaves differently from every other person, pickle, and piece of popcorn. So it is not hard to devise experiments to measure the properties or behavior of things in which every case can lead to a different result.

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► **Holmes and Wieman reply:** We are pleased to hear of other instructors working to provide students with authentic experimental physics experiences. We agree with Alwyn Eades that “confirmatory” or “verification” labs, an area we have studied, can be particularly problematic. Preliminary research results indicate that, unsurprisingly, students engage in more scientific behaviors in evaluation labs than in verification labs. However, it is not clear whether the outcome of an experiment needs to be unknown in general or simply unknown to the students. That is a subject for future study.

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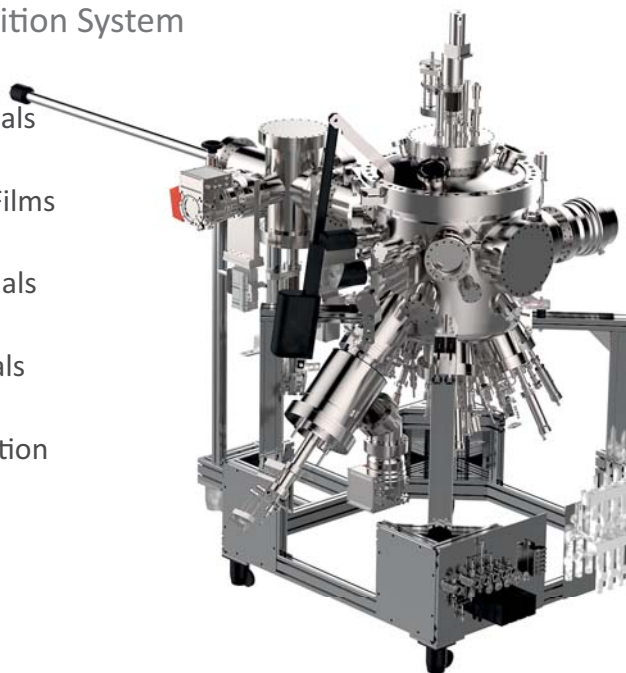
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