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Laboratories and Demonstrations

A Practical Test of Organic Chemistry Laboratory Skills

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We have developed several alternative practical laboratory examinations for the beginning organic chemistry course and have field tested these laboratory exercises as a component of the final examination in the laboratory component of that course. Data correlating practicum scores with overall scores in the laboratory course show significant scatter, suggesting to us possible shortcomings in the traditional methods of evaluation of laboratory skills.

Traditional evaluation of performance in laboratory courses as currently taught may fail to measure effectively critical laboratory skills.

Despite the development of ever more sophisticated and reliable theory and the importance of computational chemistry [1], organic chemistry remains an experimental science, and the laboratory performance of students continues to be a most critical component of their success. Traditional evaluation of performance in laboratory courses as currently taught may fail to measure effectively critical laboratory skills. Students often conduct their carefully prescribed experiments in large laboratory classes with a minimum of close observation, and a large measure of the evaluation in this class is assigned to the laboratory report or notebook. Often that notebook is prepared or completed outside the class in order to maximize time for experimental work when the labora-

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tory is in session. In many universities and colleges experiments are not changed at all or are changed insignificantly from year to year, so that adroit students with access to experimental write-ups that received high scores in previous years can perceive quickly one unacceptable way to produce a good grade.

The perpetuation of high quality experimental write-ups that, in a few cases, may not be directly connected to the student's laboratory performance, is a condition that we would all wish to alleviate. It undermines the good efforts of a majority of students, and it also undermines the critical relationship between experimental observation and theoretical conclusions that we strive to teach. This effort dates back beyond the introduction of regularized laboratory practice [2]. We have, from time to time, varied conditions for certain experiments in order to interrupt the regularity of write-ups. Another source of reliable information regarding students' laboratory ability, certainly not novel with this writing [3], is the laboratory practicum. Professor Louis Fieser conducted such exercises during his teaching career, and many others have done the same.

We have experimented with the use of several laboratory practical examinations which are designed to constitute a significant part of the total grade (10–15%) and which are administered to students during their last class meeting. With a sufficient number of carefully tested examinations available, students cannot know in advance which examination they will encounter; therefore they cannot specifically prepare for one. The exams take a form that require students not only to carry out several common laboratory procedures correctly, but also to analyze the results of their experiment in order to discriminate among several possible initial conditions or outcomes. Critical thinking is accorded a premium in such an evaluation; however, students are not strongly guided to specific measurements.

While student anxiety level and glass breakage rate are notably higher during these examinations, we can see a correlation between performance on these examinations and a qualitative judgment of the instructor following extended observation of a student's laboratory ability. There is a less strong correlation between performance on these examinations and overall performance in the course, including the practicum score ($r = 0.70$). Although the correlation of data is good (Figure 1), the number of outlying points in the graph for students whose overall score in the course significantly exceeds their performance on the practicum is noteworthy. One possible implication is that the factors on which students have been traditionally evaluated, particularly the quality of their notebook write-up, may inadequately measure their intrinsic laboratory ability.

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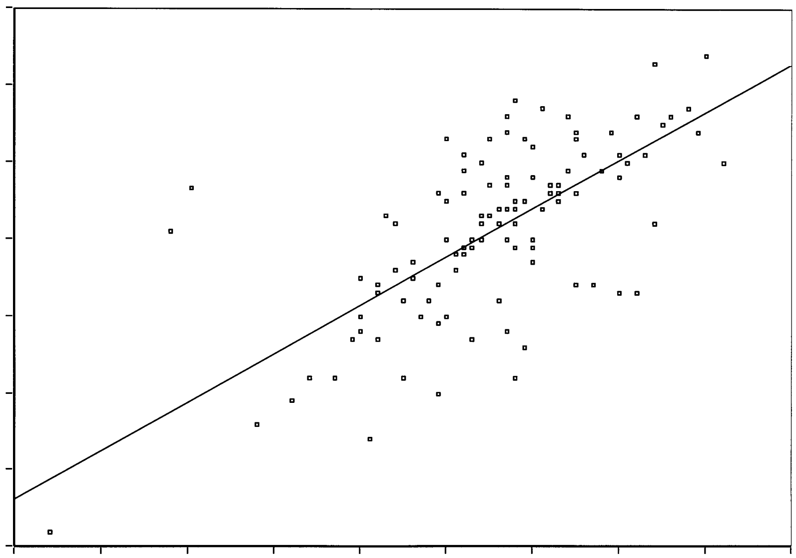

FIGURE 1. CORRELATION OF ORGANIC PRACTICUM LABORATORY GRADES WITH COURSE TOTAL SCORES.

To illustrate the use of the practicum, we have included one example—the preparation and characterization of one of the isomeric propyl acetates (see Appendix). Either 1-propanol (bp 97°C) or 2-propanol (bp 82.5°C) react well with acetyl chloride and may be used in this experiment. The techniques of reaction, reflux (special care must be exercised!), multiple extraction, drying and distillation are tested. The student can deduce from the boiling point of the product (a propyl acetate) the identity of the propyl alcohol which was supplied (1-propyl acetate, bp 102°C, 2-propyl acetate, bp 85°C). Identity of the alcohol also can be confirmed by a micro-boiling point measurement of the original alcohol, but only if the student understands the objective of the experiment before consuming all the starting material. Finally, students are asked to sketch out the ^{1}H NMR spectrum that might be expected, and to describe infrared cues supporting the structure of their product, based on a theoretical understanding of these spectroscopic methods.

We believe that the use of a practical in-class laboratory final examination of this type provides a reliable measure of a student's laboratory ability with minimum additional investment of time and energy from faculty and staff teaching the course. We are prepared to serve as a clearing house for the collection and dissemination of similar carefully designed and thoroughly tested practical final examinations in organic chemistry. Faculty who have designed and tested other experiments of this genre may submit them in a standard format. This format should contain a brief introduction that addresses the

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skills or concepts tested, sources of any difficulties in finding materials, unusual student problems, and noteworthy disposal problems. We would also welcome inquiries from organic instructors willing to test in their classes the experiments submitted by others. If the reader is interested in participating in the development of this idea, please e-mail comments or suggestions to jcasano@calstatela.edu.

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We thank the many students who unwittingly, and perhaps unwillingly, contributed a point to the data of Figure 1.

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