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ABSTRACT

As part of an experiment, a three quarter sequence in organic chemistry was designed to be accompanied by laboratory experiments that reinforce the lecture material and encourage independent investigation by minimizing cookbook-style procedures. By having laboratory techniques explained in detail on video casettes, students were exposed to uniform instruction; they proceeded at their own pace, and they were encouraged to use an inquiry mode of investigation. An evaluation of the experiment based on a sample of students' written comments revealed that students overcame their initial resentment toward the extra time required in the laboratory, and they grew to appreciate the independence and dexterity they acquired by designing and performing their own experiments. An outline of the curriculum is included. (EMH)

SELF-PACED APPROACH TO THE ORGANIC CHEMISTRY LABORATORY

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During the last decade the composition of a typical science majors' organic chemistry course has changed from predominantly chemistry and chemical engineering majors to predominantly biological science and pre-medical majors. In our case this change in composition has dictated a reduction in the amount of time students spend in the laboratory as well as changes in the lecture material to reflect the changing interests of the students. The reduction in laboratory time forced a reevaluation of the purpose of the laboratory, and the following principles were affirmed.

1. The nature of the laboratory experiment should be related to the lecture material just recently covered. This served two purposes: (a) the lecture material was needed as background for the laboratory work, and (b) the laboratory served to reinforce the learning of the lecture material.
2. The primary purpose of the laboratory was for the students to gain skills in both classical and modern laboratory techniques. Were it otherwise (i.e., to carry out certain reactions), the reduction in laboratory time would frustrate the purpose of the laboratory.
3. It is better for students to learn some techniques well rather than a host of techniques and reactions so superficially that there are no long-term or short-term skills acquired.
4. A laboratory needs flexibility so that students who proceed at different rates will not hinder each other. Furthermore, avoidance of a rigid structure permits more than one experiment to be run at a time (a worthwhile goal) and allows students to miss laboratory periods because of family or personal emergencies without penalty.
5. Learning of laboratory skills and procedures will be enhanced if the student is forced to think about and understand what he is

doing. A cookbook approach is invaluable for all students in the initial stages of laboratory work, but a gradual change to an "honors" laboratory, where the student finds or develops his own procedures, is necessary if understanding is ever to be achieved. The following sequence of experiments therefore was devised.

Quarter 1 (3 hrs/week)

Experiment	Lecture Material Needed	New Techniques Introduced
Separation of a mixture of an acid, a base, and a neutral compound. (Flow diagram and recipe are provided.)	Acid-base theory	Extraction Quantitative transfers Filtration Simple distillation Fractional distillation Recrystallization Sublimation VPC TLC (IR)

In this sequence, the analogy of the separation procedures and techniques to the general approach used to work up a reaction was emphasized.

Quarter 2 (3 hrs/week)

Experiment	Lecture Material Needed	New Techniques Introduced
Preparation of an alkyl halide (Recipe provided; student makes changes due to changes in molecular weight - different alcohol used.	Reactions of alcohols; SN1 and SN2 mechanisms; infrared spectroscopy.	Steam distillation IR

Experiment	Lecture Material Needed	New Techniques Introduced
Grignard reactions (Recipes from Org. Syn. provided; student makes changes in scale, and substitutes benzophenone for methyl benzoate.	Preparations of alcohols	Column chromatography Anhydrous conditions Syringe techniques (Titration of Grignard reagent)

Quarter 3 (6 hrs/week)

Experiment	Lecture Material Needed	New Techniques Introduced
Esterification (General directions provided)	Derivatives of carboxylic acids	Kinetics Titration
Diphenic acid preparation (Original literature article provided.)	Reactions of alkenes and of fused aromatic hydrocarbons	Ozonolysis and/or Handling of hazardous substances (30-50% hydrogen peroxide.)
Friedel-Crafts acylation (Original literature article provided.)	Reactions of aromatic derivatives	Reactions in concentrated H_2SO_4 or PPA
Wolff-Kishner reduction (Recipe provided)	Reactions of aldehydes and ketones	Trapping of gaseous products over water
Sandmeyer reaction (Recipe provided)	Reactions of dizaonium salts	Micro-scale

The students making up the class represented the following academic areas:

Area	Number	%
Biological sciences	37	35
Chemical sciences	13	12
Medical sciences	53	49
Others	4	4

One of the problems with such a course is that, in general, the typical graduate teaching assistant cannot provide the necessary superior instruction in and demonstration of correct laboratory techniques. Experience has shown that, with a few exceptions, use of teaching assistants in this capacity results in presentations that lack uniformity and that are, in some cases, incorrect. This is due to a number of factors, the principal one being that teaching assistants generally are first- and second-year graduate students with insufficient research experience to be proficient in each of these techniques.

The solution that avoided this problem and permitted a self-paced program was the use of video cassettes in which a faculty member, presumably skilled in the arts, demonstrated each technique. These videotape facilities were available in our chemistry tutorial center, where they had been purchased previously for selected use in the general chemistry program. The following advantages accrued as a result of this arrangement.

1. A student could prepare for each laboratory by viewing the appropriate videotape in the tutorial center.
2. Each student received the same correct instruction in techniques.
3. Slower learners could review the tapes as often as necessary, independent of classroom, laboratory, or office instruction.
4. Faster workers could progress as rapidly as they wished.
5. Cassette players could be student operated.

In the first year of the experiment, videotapes were made in black-and-white with a completely amateur crew (a student or my wife) under less than ideal conditions (ambient lighting, etc.). These included the following:

Extraction, filtration, and quantitative transfers

Distillation

Recrystallization

TLC

IR

Steam Distillation

Column chromatography, anhydrous conditions, and

syringe techniques

Furthermore, each tape was designed for the specific experiment being planned, and some lasted as long as 30 minutes. This year we are re-taking all of the videotapes in color with the aid of the university's Educational Television Center personnel and equipment. Additionally, only one technique is presented on any one tape, the length of each tape is being restricted to 10-15 minutes, the presentation is general in nature, and the tapes are edited and animation is included where appropriate.

What did we learn from the experiment? Under this system, students need more time to complete a given experiment. It seems crucial that they be given sufficient time for each experiment that they can make mistakes and repeat experiments without penalty. As a consequence, both their understanding and their skills are greatly enhanced. This has been verified by subsequent improved student performance in undergraduate research.

How did the students respond to the experiment? We heard gripes all year long about the amount of work and preparation required for the laboratory. Indeed, one might have been tempted to call it a failure were it not for the following unsolicited comments entered into their laboratory notebooks at the end of the year.

Ray M. (Pre-medicine): This quarter's Organic Chemistry labs have meant more to me than the previous two quarters' labs have. Although I learned alot in the first two quarters, I was sometimes rushed to finish the procedure and didn't have time to really think what I was doing, so the labs were often very tedious. But this quarter I had plenty of time to finish my procedures and to compare my results with others in the lab and to understand why I got the results I did. It's hard for me to believe, but I really enjoyed the

labs this quarter because I have never gotten any enjoyment out of chemistry labs previous to this. If it is in any way feasible, I think that the first two quarters of Organic Chemistry labs should have two labs a week instead of just one. Not only would it make it easier on the students, but it would stimulate interest in the labs and everyone would get much more out of them.

Dee E. (Pre-pharmacy): Now I am much more at ease in a lab than I was during the first quarter. Now when I go to a lab I have a good idea of what I will do, how it will work, and confidence in myself.

Robert R. (Pre-dentistry): I thoroughly enjoyed the experiment. I found this to be true the entire quarter. The first of this year I used to dread going to each lab but as I improved some of my techniques and learned a bit more about what I was doing, lab became more interesting, and even became fun this last quarter.

Chris C. (Computer Science): This experiment was very easy but this is due to the fact that Dr. Krubsack's handout of the procedure eliminates the pre-lab preparation time. I find the experiments easier to complete but I don't really know what I am doing. This procedoe (sic) "cookbook chemistry" eliminate the requirements for me to do the experiment procedure work up and thus my knowledge of what is actually occurring is reduced.

Mike H. (Polymer Science): This last quarter helped me the most. This lab has also taught me better procedure and also to be creative in my apparatus structure (especially if you have to make a three-necked flask out of a one-neck flask). I feel that making us look the procedure up ourselves is good. It makes us understand the proceedings (what to do and when to do it) of the reaction.

Gary F. (Pre-medicine): As a whole this whole quarter was a lot better because I had more time and I wasn't rushed so I could take my time and do a better job like I like to do. I feel I learned alot more this quarter by having to look up the procedures myself, and I felt like I knew what I was doing in lab and I felt I was doing the lab well because I could take my time and make sure what I was doing was right. On the whole I enjoyed this quarter's lab more and I believed I learned alot more mainly because of the extra time.

Stephen C. (Pre-medicine): The third quarter of lab has been the most enjoyable of all and bordered on being fun. I believe that this is due to the fact that one knows the basic now and can apply these skills in actual experiments and receive positive reinforcement. Knowledge of these skills also affords the student with more time to satiate his own curiosity concerning the experiments and to carry them out with efficiency. I finished early and would have enjoyed an additional experiment that would have been simple and counted little point-wise. In retrospect, of course, the first quarter was the easiest as far as the tasks involved but at the time was surely the worst for me. Insecurity and little confidence marked my work the first quarter. The videotapes helped. I was gradually weaned over into the realm of knowing what one is doing. I now feel more confident and less apprehensive concerning laboratory work in organic chemistry. It is ironic that now, when I finally begin to feel confident about and enjoy lab that

the course ends and I must put these skills and knowledge in some compartment in my mind, hopefully to dig it up one day with little stagnation of the basic skills. Thus, I have gained knowledge in organic chemistry but lost my innocence (Wordsworth told me it would happen).