Foundation and In-Depth Course and Laboratory Experiences

Introduction

The 2015 ACS Guidelines describe foundation and in-depth course work as the two categories of experiences (beyond the introductory experience) that approved programs must provide their students (see Sections 5.3 and 5.4). Foundation courses provide a breadth of exposure to the chemistry enterprise. Students who earn certified degrees must receive the equivalent of one semester of instruction in each of the five foundation areas: analytical chemistry, biochemistry, inorganic chemistry, organic chemistry and physical chemistry. The foundation course work provides the ground work for the in-depth course work. In-depth courses, by extension, build off of the students' foundation experience. A characteristic of all in-depth courses is that they have one or more of the foundation courses as a prerequisite.

This document briefly describes the number of courses students must take for a certified degree and the number and frequency of course offerings required of approved programs. It then discusses in more detail both the content and integration of foundation and in-depth courses.

Foundation and In-depth Course Requirements

There are two aspects to these requirements. The first involves the courses a student must take in order to receive a *certified degree*. The second focuses on the courses a department must teach to maintain *program approval*. To minimize confusion, these two aspects of the requirements are described separately.

Student certification

To earn an ACS certified degree, a student must receive instruction that is equivalent to a one-semester course of at least three semester credit hours in each of the five traditional subdisciplines of chemistry. For programs operating under the quarter system, this translates to eight quarters of instruction. As described in the following section, this can correspond to one course in each of the five subdisciplines of chemistry. Courses may also be integrated so long as students receive the equivalent of one semester of instruction in each of the five areas. In addition, students obtaining the certified degree must take the equivalent of four one-semester or six one-quarter in-depth courses corresponding to at least 12 semester or 18 quarter credit hours.

Program approval

To allow students to complete a certified degree in four years, the Guidelines also place requirements on the offerings of the foundation and in-depth courses. Specifically, programs must teach at least four foundation courses annually. These must cover at least four of the five foundation areas. Programs that operate under a quarter system are required to teach at least six of these courses each year. When all of the foundation courses are not taught annually, a schedule must be developed to ensure that foundation courses that are required for student certification are taught on a two-year cycle. In addition, programs must teach a minimum of four semester-long or six quarter-long in-depth courses annually, exclusive of research. While students may enroll in in-depth courses taught outside of the chemistry program, the chemistry program is still required to teach four in-depth courses each year.

Laboratories

Laboratory experiences also occur at both the foundation and in-depth levels. The certified graduate must have 400 hours of laboratory experience beyond the introductory chemistry laboratory. This laboratory experience must cover at least four of the five traditional chemistry subdisciplines and may be distributed between foundation and in-depth levels. The first laboratory exposure students have in a particular area is considered part of the foundation. Likewise, the laboratories associated with Organic I and other first-semester courses in a subdisciplinary area are part of the students' foundation experiences. While the experiments in these courses often consist of well-defined laboratory exercises, open-ended exploratory exercises are encouraged in foundation laboratories. Foundation laboratory experiences provide students with the preparation for open-ended activities that are the hallmark of in-depth laboratories and undergraduate research. Students can count in-depth laboratory experiences including undergraduate research toward their in-depth course requirements for certification. Likewise, programs can count these in-depth laboratory courses toward the in-depth courses that are taught annually. As stated above, undergraduate research cannot be counted toward the in-depth course offerings required for program approval.

All of the above requirements are minimum expectations for a program and certified degree. The faculty of different institutions may determine that proper preparation requires additional course and laboratory work as part of the required chemistry curriculum. These choices rest with the chemistry program.

Foundation Course Content and Structures

The purpose of the foundation course work is to provide breadth in chemistry by grounding students in the five subdisciplines: analytical chemistry, biochemistry, inorganic chemistry, organic chemistry, and physical chemistry. These courses build on the exposure students receive in general chemistry. In contrast to general chemistry, where a single textbook is typically used to cover all of the subdisciplines, foundation courses rely on specialized texts or other advanced materials.

The following sections describe examples of several approaches for structuring a curriculum around foundation and in-depth course work. As there are many effective ways to structure the foundation and in-depth courses, this discussion is not meant to be either exhaustive or prescriptive. The breadth of coverage in the foundation courses and coherence among the in-depth courses taken by the student are key to the approach described in the Guidelines.

Examples of Foundation/In-Depth Course Structures

Example 1. Two-semester subdisciplinary course sequence

In one approach to the foundation experience, the first semester of a traditional two-semester sequence is designated as the foundation course and the second semester as the in-depth course. The most familiar examples are organic chemistry and physical chemistry. Because the foundation and in-depth material is spread between the two courses, a student must take both courses to achieve the requisite experience. Designating the first semester as "foundation" and the second semester as "in-depth" is solely a bookkeeping device. This is particularly true in the case of physical chemistry, where some programs provide students flexibility in the order in which students take the two courses that make up the two-semester sequence.

An example of such a scheme is a curriculum with five one-semester *foundation* courses [Organic Chemistry I, Physical Chemistry I, Introduction to Analytical Chemistry, Inorganic Chemistry, and Biochemistry I] and four one-semester *in-depth* courses [Organic Chemistry II, Physical Chemistry II, and two other in-depth courses such as Advanced Analytical Chemistry, Advanced Inorganic Chemistry or Biochemistry II].

Example 2. One-semester foundation courses with topical in-depth courses

The essential concept of the foundation courses is that they provide the student with experience across the breadth of an area of chemistry. Providing that experience in a one-semester course requires a different structure than found in either semester of a traditional two-semester sequence. An ideal one-semester foundation course provides a portion of the content that appears in each of the semesters of such a two-semester sequence. The faculty should evaluate each foundation course, recognizing that it may be the only formal exposure of some students to that area. This type of foundation course is *not* simply the first semester of a traditional two-semester sequence. Examples of possible course content in one-semester organic and physical chemistry courses are described in the topical supplements. In this model, the in-depth courses are usually topical in nature and have one or more foundation courses as prerequisites.

Example 3. Integrated foundation and in-depth courses

Individual courses built around the traditional areas of chemistry are not the only means of providing the foundation or in-depth experiences. The goal of the foundation courses is to provide breadth in chemistry, and departments may want to integrate several aspects together in foundation courses. For example, the foundation experience in inorganic and organic chemistry could come in two courses devoted to synthesis without either being solely devoted to organic or inorganic chemistry. The essential goal is to provide the student with the breadth to appreciate the discipline and to pursue advanced work. Integrating various content areas into individual courses can help students make connections among topics earlier in their careers. Integrating courses requires careful attention from the faculty to ensure that the five courses cover all of the foundation areas of chemistry, as described above.

While integration of foundation lecture courses remains a relatively uncommon approach among approved programs, many programs use integrated laboratory experiences to provide coverage in some of the five foundation areas. When the foundation laboratory experiences are obtained through integrated laboratories, excellent programs will ensure that students obtain the equivalent of at least one semester of laboratory experience in at least four of the five foundation areas. As with the lecture course, general chemistry laboratories cannot be used to satisfy foundation laboratory requirements.

In-Depth Course Work

The purpose of in-depth course work is to build on and/or integrate the student's knowledge of one or more foundation areas. The in-depth experience builds technical expertise, provides a more sophisticated view of chemical concepts, fosters critical thinking, promotes skill development, and gives the student an opportunity for the intellectual growth and rigorous thinking that comes from engaging in topics at a high level. Research is a very useful component of the in-depth portion of the curriculum.

In-depth courses must have one or more foundation courses as prerequisites. Since there are many ways for a student obtaining a certified degree to meet the in-depth course requirement, programs have considerable flexibility in the way they structure their in-depth courses. The student could take a set of in-depth courses spanning all of the traditional areas of chemistry (see Example 1 above). Alternatively, the student could take a set of courses that concentrate on a defined chemistry subdiscipline. For example, a concentrated sequence of in-depth courses could focus on organic and inorganic chemistry for a student interested in synthetic chemistry. Similarly, advanced courses in physical and analytical chemistry could constitute an appropriate in-depth experience for a student interested in instrument-based techniques such as spectroscopy. A student interested in chemical biology or biochemistry could take in-depth courses in biochemistry, bioinorganic chemistry, and organic chemistry along with additional work in biology, while a student interested in chemical physics could take in-depth courses in physical chemistry along with additional work in physics. A student could take a series of in-depth courses with a topical focus such as materials. All of these might fall in the course sequences described in Example 2 above. Integrating chemistry content areas in the in-depth courses may also be desirable, with an obvious example being the combination of biochemistry and organic chemistry in an integrated in-depth course. (See Example 3 above.)

A student can use an in-depth laboratory or research experience to fulfill an in-depth course requirement. Courses from other disciplines could be counted toward the in-depth chemistry course requirements only if they have an appropriate chemistry prerequisite and contain sufficient chemistry content. Several scenarios for providing the in-depth course work experience are described in the "Degree Tracks" supplement.

The variety of sensible paths through the in-depth course work is large, and it is essential that the department carefully consider its choices in order to create a coherent plan for each degree track. The faculty should provide a clear rationale for the collection of in-depth courses that contribute to a degree track to themselves and their students. It is likely that most departments will offer a relatively small number of distinct tracks, depending on the size and interests of the faculty and the mission of the institution. Careful thought about the structure of the in-depth experience and plans to consistently offer the experience are crucial.

In-depth Laboratory Experiences

Laboratories used to satisfy in-depth course requirements should emphasize student skill development (see Section 7 of the Guidelines) in which students define problems, develop testable hypotheses, design and execute experiments, analyze data using appropriate statistical methods, understand the fundamental uncertainties in experimental measurements and draw appropriate conclusions. They should involve the use of the primary chemical literature, incorporate written and oral communication and promote teamwork and ethics.

In some cases, laboratory courses can be considered as in-depth courses both for student certification and the requirement that a program offer four in-depth courses a year. For example, advanced integrated laboratories are a common way of providing in-depth laboratory experiences, and an independent, integrated laboratory course that builds on the students' foundation laboratory experiences and requires a subset of them as prerequisites is suitable as an in-depth course. In general, the laboratory associated with a regular course (e.g., second semester organic) does not count toward the in-depth course requirement even if they have separate course numbers. The course and associated lab would count as a single in-depth experience for both student certification and course offerings of a program.

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