PURDUE UNIVERSITY

Department of Chemistry Strategic Plan
2009-2014

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Preamble

This document presents the Department of Chemistry' strategic plan for 2009-2014, which builds on the strategic plan developed for 2002-2007. The plan begins with a clear, concise statement of the mission of the department that reflects our values and beliefs. It then outlines a vision for the future of the department as well as a plan for strengthening the Department's preeminence as a leader in the chemical sciences recognized at the state, national and international levels within the domains of discovery, learning and engagement.

The Department of Chemistry is poised to play a central role in the strategic plans developed by both Purdue University and the College of Science. Chemistry has been called the "central science" because it provides the foundation for students and researchers working throughout the fields of science, engineering and technology. At the undergraduate level, foundational courses in chemistry are required of virtually everyone pursuing degrees in the STEM disciplines of science, technology, engineering and/or mathematics. From nanotechnology to biotechnology, from the discovery learning center to biomedical engineering, from the Energy Center to the Burton Morgan Center for Entrepreneurship, faculty and staff in the Department of Chemistry have played, and will continue to play, important roles. From Launching Tomorrow's Leaders, to Discovery with Delivery, to Meeting Global Challenges, the Department of Chemistry has demonstrated not only a commitment to join Purdue's Strategic Plan Initiatives but also a track record of achievements and leadership in these areas.

The chemical sciences at Purdue can be viewed in terms of six core areas that include analytical, biological, chemical education, inorganic, organic and physical chemistry. But it can also be viewed as providing the foundation upon which the Department builds interdisciplinary research efforts targeted at university-wide thrust areas such as nanotechnology, proteomics, chemical biology, cancer, drug discovery and delivery, optics and photonics, advanced materials, the environment, alternative sources of energy, medical diagnostics and molecular imaging, soft materials such as membranes and DNA, and global change, among others. Each of these areas involves collaborative research from departments across the university, but they also require the atomic/molecular-scale understanding of matter that is characteristic of the chemical sciences. Furthermore, as the University increases its impact as the economic engine of the state of Indiana, there are ever-increasing opportunities for the Department for engagement with high-technology industries that positively impact the state's economy in the application of chemistry to the pharmaceutical, agricultural, and medical fields.

The department's strategic plan builds on its rich tradition of excellence in discovery with delivery. With 55 faculty (including individuals with joint or courtesy appointments), the department is one of the largest and most productive chemistry departments in the country. One of the significant features of our department has been the growth in the number of faculty with joint or courtesy appointments. Faculty based in the Department of Chemistry have *joint appointments* in Curriculum and Instruction, Earth and Atmospheric Science, Medicinal Chemistry, and Physics and *courtesy appointments* in Computer Science, Curriculum and Instruction, Earth and Atmospheric Science, and Engineering Education. Conversely, there are faculty with joint or courtesy appointments in chemistry whose primary appointment is in Biochemistry, Biomedical Engineering, Earth and Atmospheric Science, and Medicinal Chemistry.

Measures of the productivity of the Department of Chemistry have historically been found in metrics that include having faculty among the most cited chemists in the world; regularly appearing on the list of the top ten chemistry departments in terms of research expenditures; a graduate program that is among the largest in the country, often being ranked first among institutions that graduate the most Ph.D. chemists; surveys that have historically ranked the Department among the top 15 in the nation; an analytical chemistry division that is ranked second in the nation; and a chemical education program that is the largest in the world.

The unique strength of the Department in analytical chemistry has as its foundation a broad strength in the development of advanced chemical instrumentation that permeates every facet of the Department’s research program. Unique research infrastructure, such as the Jonathan Amy Facility for Chemical Instrumentation (JAFCI), makes possible the design and fabrication of next-generation instrumentation. Cutting-edge research programs in mass spectrometry, separation science, chemical imaging, nuclear magnetic resonance, laser-based detection, drug design, and atmospheric measurements all add to the strength of the department in the development of instrumentation. There is also a strong tradition of excellence in synthetic organic and inorganic chemistry that finds its roots in the Nobel-Prize winning work of H.C. Brown. The wide-ranging expertise in the department brings with it the ability to respond quickly and effectively to emerging interdisciplinary research opportunities. Recent years have seen key hires that add to our growing strengths in nanoscience, in drug design and delivery, and in theoretical chemistry. Several research groups have established themselves as campus-wide leaders in proteomics.

The Department's excellence in learning is a result of dedicated efforts by the faculty, and is enhanced by ongoing research in the discipline of chemical education. Research in chemical education as a defined discipline was founded in the department more than 25 years ago, and continues to flourish today. The vast majority of departmental courses at all levels are taught by tenure-track faculty, the teaching laboratories and equipment are regularly upgraded, a complete range of undergraduate and graduate course offerings (including undergraduate research) are provided, and undergraduate degrees with specialty emphasis (including B.S.-certification by the American Chemical Society, and ACS approved B.S. in Chemistry and Biochemistry) are a valued part of the curriculum. It is also an important feature of our Department that approximately 90% of student enrollment in chemistry courses (over 4,000 hrs/yr.) is represented by non-majors. The department remains committed to K-12 education through outreach activities that include the nationally-recognized Science Express program that brings research-grade instruments to high-school classrooms in Indiana.

At a time when an emphasis has been placed on bringing together the disparate groups needed to achieve discovery with delivery it should be noted that the Department of Chemistry has a long tradition in the area of technology transfer, bringing new knowledge and technologies generated from its research into a corporate structure that benefits the local, state, and national economies. In addition to the substantial impact arising from publication of research findings in the open literature, faculty and staff in the department have played key roles in the creation of start-up companies and in the development of intellectual property that the university has subsequently licensed to the commercial sector. Local companies with strong connections to the department at critical junctures in their development include Great Lakes Chemical, Bioanalytical Systems (BASi), Endocyte, Quadraspec, and Griffin Analytical Technologies. Members of the faculty have also engaged in new models for teaming universities with industry. For example, several of our faculty members are key contributors to an initiative that teams Purdue University, Indiana University, and Lilly Corporation in a new venture focused on the development of innovative technologies for proteomics. The department also encourages its students to engage in entrepreneurial activities, such as the Burton Morgan Competition, and offers fellowship support for graduate students to work on projects with high technology transfer potential. We plan to expand our connections with industrial science collaborators in this next strategic period. A major challenge to our continuing growth and leadership is the maintenance and acquisition of modern and high quality research and teaching space. Thus a key objective for the next few years is the construction of a new facility, aimed at strengthening our teaching, and promoting growth areas in research.

Based on this strong foundation, the Department of Chemistry looks forward to a future marked by innovative and important discoveries, excellence in learning, and mutually beneficial engagement with state, national, and international communities.

Mission Statement

The Department of Chemistry at Purdue University serves the state of Indiana and the nation by advancing and disseminating knowledge, by educating students, by catalyzing economic development, and by providing scientific leadership in the chemical sciences.

Discovery: The department consists of a community of scholars who seek a fundamental, atomic/molecular-scale understanding of chemical reactions and properties of matter, and who apply that understanding in innovative ways to solve problems and improve the human condition.

Learning: The department provides an innovative educational environment where students learn to be independent scientists and scientifically literate citizens. Its undergraduate and graduate programs are designed to help students understand how chemical knowledge is acquired and transmitted and to produce graduates with both a deep understanding of the world on the atomic/molecular scale, how that understanding connects to the macroscopic scale, and an enduring passion to learn more.

Engagement: By partnering with communities both inside and outside the university, the department supports the application of the chemical sciences to address societal needs, and seeks to be a driving force within the state and the nation in the area of technology transfer for discovery with delivery.

Vision Statement

The Department of Chemistry at Purdue University seeks to be nationally recognized as one of the top fifteen departments in the country, within the next 5-10 years.[1] It will be recognized worldwide for both the quality of its undergraduate and graduate instruction and its diverse, dynamic, and innovative research program. Preeminence in core areas will be strengthened in order to provide the foundation upon which chemistry faculty can contribute to interdisciplinary and multidisciplinary research that addresses societal problems. We will increase our connections with and recruitment of international students, faculty and research partners. The department will distinguish itself by its innovative and successful education of students in the chemical sciences within the setting of a major research institution, and by its strong cross-disciplinary, interdisciplinary, and multi-disciplinary collaborations both within and beyond the university.

[1] The most recent U.S. News and World Report ranking places Purdue among the top 25 departments, but no longer in the top 15.

Statement of Shared Beliefs and Values

A shared set of beliefs and values underlies our common sense of mission and provides a foundation for our vision for the future of the department.

We believe that:

- chemistry is a central science — uniquely positioned to address problems of great importance to our economy and public policy — that plays a crucial role in developing interdisciplinary and multidisciplinary research thrust areas;
- an understanding of matter at the atomic/molecular level is valuable and intellectually satisfying;
- a chemically literate society will be better able to make informed decisions about health, economic, environmental, and public policy issues.
- it is important for the community, state and the nation to provide high quality education for a broad range of students whose individual degree objectives may range from a BS, MS, and/or Ph D degree to K-12 teacher training.

We value:

- excellence in our research and teaching activities;
- independence of thought and academic freedom;
- creativity in generating new knowledge in the chemical sciences;
- a supportive, safe and healthy working environment for students, faculty, and staff;
- a work and learning environment in which each person is encouraged to reach his or her full potential;
- a work and learning environment that is collegial; where faculty, students and staff choose to work together in a cooperative and collaborative manner;
- a faculty with diverse research interests that uniquely positions the department to respond to changing research opportunities;
- diversity within our community, as characterized by a mutual respect among individuals having different points of view, cultural backgrounds, and interests;
- integrity in all aspects of the department’s activities; not only adhering to the highest standards of moral and ethical values but striving to build an understanding of ethical practice among our undergraduate and graduate students;
- accountability for policies, procedures and actions undertaken by faculty, students and/or administrators in the Department.

Overview of Strategic Plan Goals

The goals of the Department of Chemistry are aligned with both Purdue University's *New Synergies* plan and the College of Science's *Insight, Innovation, Impact* plan. The department will organize and implement its strategic plan around the four goals put forward by the College of Science, recognizing that these goals are interdependent and synergistic.

Launching tomorrow's leaders

- Develop new facilities for interaction with and educating our students.
- Provide an outstanding graduate experience in the chemical sciences.
- Improve and increase participation in opportunities for study abroad.
- Maintain an outstanding undergraduate experience for both chemistry majors and students in courses for non-majors.
- Provide mentoring and support for young faculty and researchers who will become leaders of their field.

Discovery with delivery

- Create advanced molecular sciences facilities for doing research in the chemical sciences and for the teaching and learning of chemistry.
- Achieve a ranking of the Department of Chemistry at Purdue University as one of the top fifteen departments in the country through world-class basic and translational research (in 5-10 yrs).

Meeting global challenges

- Strengthen the scientific, economic, and societal impact of the Department of Chemistry's discoveries, innovations, and achievements, and increase awareness of the contributions made by the department to issues of global importance and increase and improve global scale connections.

Building diverse communities of excellence

- Recruit and retain a distinguished and diverse faculty, staff and student body.
- Develop and maintain a vital, supportive and collegial work/study environment.

Goals and Strategies for:

Launching Tomorrow's Leaders

Goal: Provide an outstanding graduate experience in the chemical sciences.

Characteristics

- A department committed to the core mission of providing an exceptional education that prepares students to be tomorrow's leaders.
- National and international recognition as one of the best graduate programs in the chemical sciences in the U.S. as a result of the productive educational/working environment, the high quality of education, and innovative and successful research projects.
- Access to the state-of-the-art research facilities and the state-of-the-art infrastructure needed to perform research that is insightful, innovative and has significant impact on both the chemical sciences and societal problems.
- Globally aware graduates who understand the importance of working in an international community of scholars from diverse cultures.
- Graduates who have developed essential skills in problem solving and the communication of science.

Strategies

- Recruit, retain and graduate outstanding candidates for advanced degrees in the chemical sciences, from both international and domestic sources.
- Recruit, retain and graduate a diverse pool of graduates on the basis of both gender and ethnicity.
- Provide graduate student mentors for incoming graduate students.
- Charge the Graduate Recruiting Committee with revamping the mechanisms by which we evaluate, recruit and support potentially outstanding graduate students from foreign countries. They are to be charged with revising both the evaluation and the admission process.
- Build an atmosphere of cooperation and collaboration among research groups that facilitates interdisciplinary research both within individual sub-disciplines in the chemical sciences and between sub-disciplines.
- Review the graduate program, in much the same way that the undergraduate program was recently reviewed, to make sure that it is appropriate in terms of foundational and advanced content that covers the broad field of chemistry.
- Ensure that graduate students have ample information about the expectations we have of them.
- Actively solicit and obtain fellowships and training grants to support more graduate students who are currently being supported as graduate instructors.
- Improve the ability of the graduate program to meet the needs of interdisciplinary students.

- Provide new opportunities for experiences that will inform and prepare students for their intended careers, including short courses, collaborations with the Burton Morgan Center for Entrepreneurship, courses at the Krannert School of Management, and college- and university-wide programs that enhance their knowledge of teaching.
- Develop other examples of interdisciplinary graduate programs, such as the Pulse program, that can attract top students into interdisciplinary thrust areas, and facilitate and enable cross-disciplinary graduate research experiences.
- Develop graduate course(s) and/or workshops that target the teaching of chemistry.

Goal: Maintain an outstanding undergraduate experience for both chemistry majors and students in courses for non-majors.

Characteristics

- Commitment to the core mission of providing an exceptional education that prepares students to be tomorrow's leaders.
- Chemistry faculty who are frequently recognized as recipients of awards such as the Outstanding Teacher in the College of Science, or the Outstanding Contributions to Undergraduate Teaching by an Assistant Professor award in the College of Science; chemistry faculty have received five out of the eleven awards given.
- Chemistry faculty who are routinely recognized as recipients of the Murphy Award, the University's highest undergraduate teaching honor, which has been won by eight chemistry faculty; the Helping Students Learn Award, which has been won by five chemistry faculty; and/or being elected to the Teaching Academy, which has seven chemistry faculty, and a teaching staff member.
- A department committed to providing students with access to high quality study abroad programs, co-op opportunities, and community-based service learning projects.
- Faculty and staff committed to fulfilling our goals as a learning community, treating all students equitably, adhering to the highest standards of moral and ethical values, and evaluating the learning achievements of our students based on clearly demonstrated academic performance.
- An undergraduate program that utilizes the strengths of a high-quality research environment to produce B.S. graduates ready to pursue careers in the chemical sciences.

Strategies

- Develop and enhance opportunities that give undergraduate students experience with the process of scientific research through participation in undergraduate research.
- Pursue funds for summer research fellowships for our students.

- Continue efforts to have virtually all undergraduate chemistry majors participate in undergraduate research.
- Make a coordinated effort to seek and advertise summer research opportunities for our undergraduate majors.
- Improve the facilities in Brown and Wetherill so that common high-quality interaction space is available.
- Implement the results of a recent self-study of the undergraduate program (see Appendix C, abridged version).
- Continue efforts to revitalize service courses to make sure that these courses match the needs of the student population being served.
- Continue efforts to bring innovative approaches to both the content and the pedagogy of undergraduate teaching and to work with the chemical education faculty to inform/educate/assist the faculty in developing and assessing “best practices.”
- Work to ensure that more than content knowledge is covered in our courses; that students also learn hypothesis development/testing, how to ask relevant questions, and how to find answers to these questions.
- Utilize undergraduate students as tutors and mentors in chemistry courses.
- Implement inquiry-based laboratories in more introductory courses.
- Charge the head of the department with ensuring that teaching is given an appropriate weighting in salary decisions.
- Identify appropriate equipment and technology to be integrated into the classrooms and seek resources for implementation.
- Continue efforts to update instructional equipment for both lower- and advanced-level laboratory courses.
- Evaluate the effectiveness of study abroad programs with the goal of doubling the number of student participants.
- Examine ways of revitalizing the chemistry co-op program.
- Provide resources in the form of summer funds or course release to assist faculty in making major curricular innovations and in revamping courses in ways that will improve learning.
- Continue to involve a high fraction of our faculty in lower-level classroom instruction.
- Conduct a resource assessment for a fully-integrated honors program.
- Charge the undergraduate committee with a re-examination of the undergraduate laboratory program.

Discovery with Delivery

Goal: Achieve a ranking of the Department of Chemistry at Purdue University as one of the top fifteen departments in the country through world-class basic and translational research.

Characteristics

- A continued ranking among the top ten chemistry departments in terms of research expenditures.
- State-of-the-art facilities for doing research in the chemical sciences.
- An approach to hiring that reflects the relative merits of hiring senior faculty and beginning assistant professors.
- An approach to hiring faculty and staff that recognizes the importance of hiring in both traditional core areas and in departmental thrust areas.
- A high-quality infrastructure for doing research that builds on efforts such as the Jonathan Amy Facility for Chemical Instrumentation (JAFCI) and shared facilities in chemical nanotechnology and combinational chemical biology.
- A high-quality infrastructure for shared instrumentation for doing research such as the laser laboratory and the interdepartmental NMR and mass spectrometry facilities.

Strategies

- Significantly increase the strength of our organic chemistry division and regain our #1 national ranking in analytical chemistry.
- Identify a small number of key strategic areas for growth based on our unique strengths that address problems of national importance.
- Draft white papers for development of centers of strength in signature areas such as drug discovery and disease detection, energy/catalysis, and soft materials such as membranes, DNA nanostructures, and peptide assemblies and composite materials.
- Make strategic faculty additions in both core areas and departmental thrust areas through a combination of focused and open searches.
- Maintain a hiring plan that involves recruiting an average of two to three new faculty members per year over the next five years, given the anticipated faculty retirements and the emergence of targets of opportunity.
- Ensure that mutually agreed upon mentors are given to all Assistant Professors.
- Pursue hires of opportunity that bring senior level leaders to the department.
- Leverage university resources to allow us to proactively seek out senior candidates, with particular emphasis on members of the National Academy of Science.
- Continue the policy of charging the executive committee with the responsibility of prioritizing hiring efforts annually.
- Proactively retain faculty who have exhibited superior performance; recognize and provides incentives for superior performance; define and embrace a

culture of commitment and contribution to achievement of these goals by all members of the faculty..

- Enhance the instrument development activities of the Jonathan Amy Facility for Chemical Instrumentation (JAFCI) facility through the hiring of personnel, the acquisition of state-of-the-art equipment, improved project management, and improved collaboration between faculty and JAFCI staff.
- Implement the dual focus of disciplinary and multidisciplinary excellence called for in the College of Science strategic plan.
- Continue work begun in the previous strategic plan to examine the relationship between existing facilities and centers to department and college-wide interests, resources, and thrust areas.
- Continue work begun in the previous strategic plan to require existing or proposed centers and facilities to develop plans for long-term funding, space issues, and support staff.
- Improve department-wide mechanisms for promoting faculty and staff for external recognition in the form of national and international awards.
- Charge the head of the department to ensure that service and outreach are given an appropriate weighting in salary decisions.
- Invest in and support faculty/staff professional development.
- Provide enhanced opportunities for AP staff to increase technical skills and encourage AP staff to take advantage of intramural and extramural professional development opportunities.
- Facilitate the preparation of proposals to bring additional funds to the department.

Goal: Create advanced molecular sciences facilities for doing research in the chemical sciences and for the teaching and learning of chemistry.

Characteristics

- State-of-the-art facilities coupled with state-of-the-art infrastructure for doing research in the chemical sciences.
- State-of-the-art facilities for the teaching and learning of chemistry.

Strategies

- Make fund-raising and planning for a new molecular sciences research and education building that has chemistry at its core one of the highest priorities for the Department Head and the Department's Director of Development.
- Involve the Department's Advisory Committee in the fund-raising efforts and ensure they are informed of progress toward this goal at their meetings.
- Ensure that the Department maximally involves all potential industrial partners in the new building initiative, potentially using the fund-raising model developed by the School of Chemical Engineering during the construction of the addition to Forney Hall.
- Explore the potential for partnership in these fund-raising efforts with other Purdue colleges and departments that are likely to be co-residents of a new building, such as the Department of Medicinal Chemistry and Molecular Pharmacology.
- Sustain awareness within the administration of the acute need for the renovation of the Brown and Wetherill buildings during the period prior to the availability of a new building to accommodate current research programs and satisfactorily meet safety requirements, including the upgrading of essential utilities.
- When sufficient private and State funding is assured, create a faculty committee charged with seeking grant support from appropriate Federal agencies to support construction of new facilities.

Meeting Global Challenges

Goal: Strengthen the scientific, economic, and societal impact of the Department of Chemistry's discoveries, innovations, and achievements, and increase awareness of the contributions made by the department to issues of global importance.

Characteristics

- Collaborative interactions throughout the university, with collaborations with life sciences, agriculture, liberal arts, technology and engineering supported by multidisciplinary and interdisciplinary grants.
- Sustained efforts for technology transfer such as those that have resulted in the creation of successful companies in the Purdue Research Park.
- Commitment to being a hub of scientific inquiry, discovery, and development in the chemical sciences by providing expertise to serve the state of Indiana, the nation, and world.
- Commitment to increased discipline-based and multi-disciplinary research efforts based on global partnerships that reach beyond the boundaries of the institution.
- Commitment to inform the world of the contributions made by the department to issues of global importance

Strategies

- Bring together diverse groups within the Colleges of Science, Agriculture, and Engineering to develop new interdisciplinary and multidisciplinary initiatives.
- Increase involvement in multidisciplinary research programs within Discovery Park.
- Take advantage of administrative support to assist focus groups in responding rapidly to interdisciplinary research opportunities.
- Take advantage of the Department Advisory Committee to increase collaborations with industry.
- Better publicize the department's research results beyond peer-reviewed journals.

Building Diverse Communities of Excellence

Goal: Recruit and retain a distinguished and diverse faculty, staff and student body.

Characteristics

- A shared responsibility for recruiting and retaining a distinguished and diverse faculty and staff.
- A core belief in collegiality and respect that will continue the department's long-standing tradition of providing a work environment that promotes collaboration and creative interaction.
- A department that is ranked among the very top chemistry departments in the U.S. for number of underrepresented faculty, staff and students.
- A department committed to implementing the recommendations contained in the department diversity plan: "A Plan for Broadening Participation in Chemistry."

Strategies

- Increase faculty, staff and students' awareness of the benefits of diversity and commitment to practices based on the assumption that all faculty, staff and students are equally enabled to achieve success in a diversified, inclusive learning environment.
- Implement the diversity plan entitled "A Plan for Broadening Participation in Chemistry" that is included in the appendices.

Metrics: Monitoring Progress Toward Goals

Among the metrics collected to monitor progress toward the goals outlined in the strategic plan will be the following information the Department shares with research-oriented chemistry departments in the Midwest each year.

Faculty and Post-Docs

Number of tenured, tenure-track and non-tenure track faculty and lecturers with appropriate salary and total compensation data; number of under-represented minorities among the faculty; number of faculty holding joint or courtesy appointments with and without Chem. Dept salary; number of faculty searches authorized (both junior and senior hires); number of retirements anticipated; start-up funding for new faculty;

Faculty Achievements

Number of patents; number of nominations for external awards and external awards received; number of junior faculty awards received; number of Academy Memberships among department's current faculty.

Graduate Students

Number of M.S. and Ph.D. degrees awarded for both U.S. and foreign citizens; percent of students who left with no degree; average time to degree; number of graduate students supported as TA's, RA's or fellowship recipients; applications for graduate school received, number of offers made, number of students in entering class; graduate student salary and total compensation; average GRE and/or TOEFL scores; number of NSF fellowships.

Undergraduate Students

Number of ACS versus non-ACS certified degrees; number of B.S. versus B.A. degrees; number of women and other under-represented groups receiving degrees; number of declared chemistry majors; data on the placement of B.S. students upon graduation.

Budget information

University support; special non-recurring funds; matching funds for individual PI grants; research support per faculty; research expenditures (direct and indirect) from various sources.

Data from the Office of Institutional Research will be used to compare the academic profiles of chemistry majors with other departments in the College of Science. The department will also track the percent of seniors who have participated in study abroad and co-op programs, as well as the percent of seniors who have been involved in undergraduate research. The department will also access the quantitative data collected as part of the College of Science strategic plan.

Metrics: Progress Measures

Launching Tomorrow's Leaders — Graduate Program

- Characteristics of entering graduate student classes that provide evidence we are recruiting the best possible graduate students.
- Evidence that we are successful in retaining and graduating students who begin our graduate program.
- Progress toward increased fellowships and training grants to support graduate students.
- Progress toward a new mechanism for evaluating, recruiting, mentoring, and supporting potentially outstanding graduate students from foreign countries.
- Progress toward a review of the graduate program.
- Progress toward improving the ability of the graduate program to meet the needs of interdisciplinary students.

Launching Tomorrow's Leaders — Undergraduate Program

- Data on incoming students, including test scores and class ranks.
- Changes in the rate at which chemistry majors are retained.
- Evidence of commitment to excellence in teaching in the form of awards at the departmental, college, university, and national levels.
- Progress toward dramatically increasing the number of students in study abroad and co-op programs.
- Evidence that virtually all undergraduate chemistry majors are involved in undergraduate research.
- Evidence of efforts to update instructional equipment for both classroom and laboratory courses.
- Evidence of the implementation of the results of the self-study of the undergraduate program.
- Improvements in the percentage of students earning grades of A, B, or C in service courses, as well as course evaluations and teaching awards.
- Evidence that our graduating students are successful in their pursuit of careers in the chemical sciences.

Discovery with Delivery

- Development of white papers that define thrust areas.
- Evidence of implementation of the hiring plan developed by the Executive Committee, including a proactive stance toward target of opportunity hires that strengthen the department.
- Evidence of efforts to promote faculty and staff for external recognition.
- Survey results that rank the department among the top 15 in the nation, and among the top ten departments in terms of research expenditures within the next 5 to 10 years.
- An analytical chemistry division ranked as first in the nation by 2011, increasing the strength of the organic division, and maintaining the reputation and strength of the chemical education program.

- Evidence of improvements in research infrastructure, including progress toward the creation of the proposed advanced molecular sciences facilities.
- Annual gift income from private philanthropy and corporations.
- Existence of a Department in which every faculty member is productive in research, teaching and service.

Meeting Global Challenges

- Evidence of mutually beneficial engagement with state, national and international communities .
- Progress toward increased cross-disciplinary, interdisciplinary, and multi-disciplinary collaborations within and beyond the university as shown by increased multidisciplinary and interdisciplinary grants, and collaborations between Departments and Colleges.
- Evidence of significant improvements in communication of the department's research beyond peer-reviewed journals.
- Evidence of increased commitment to discoveries, innovations and achievements that address economic and societal issues of global importance.
- Evidence of increased global interactions by faculty, students and staff in the department.

Building Diverse Communities of Excellence

- Evidence of progress toward building a diverse faculty, staff and student body.
- Evidence of the implementation of the diversity plan produced by the department.
- Faculty, staff and student retention rates, specifically targeting under-represented groups.
- Evidence from climate surveys that faculty, staff and students rate the overall climate as good or higher.

Appendix A

A Plan for Broadening Participation in Chemistry

Preamble

The Purdue University Chemistry Department is committed to the preparation of its students, staff and faculty to succeed in a workforce and global community that is becoming increasingly diverse. To do this successfully its climate must foster a culture of inclusion – one that is open, welcoming and nurturing to everyone, regardless of rank or position of authority. All academic departments strive for preeminence, but to be preeminent, a department must create and sustain an environment that is immersed in a rich culture of diversity. Only then can its members be successful, both at Purdue and in our evolving global society. Such a department will foster mutually supportive human relations as well as enable its members to not only identify, but also reject, stereotypical misconceptions and misperceptions. Addressing issues involving harassment and the abuse of authority will foster diversity as well as benefit all members of our departmental community.

In particular, the recruitment and retention of underrepresented students, staff and faculty is essential to creating and sustaining departmental diversity. Retention is enhanced by assuring that service on committees is equitably distributed, salary decisions are transparent and professional advancement is encouraged. Retention in all categories is adversely impacted by the relative isolation experienced by underrepresented groups, both within the department and within the larger academic community.

The goals of the Purdue University Chemistry Department's "Plan for Broadening Participation in Chemistry" are therefore to:

1. Enhance a culture of diversity by increasing the recruitment of students, faculty and staff that will be broadly representative of the people who make up our national and global societies.
2. Sustain this culture of diversity by ensuring that the department's environment is one of inclusivity – an environment which is truly the sum of its human parts and is marked by mutual respect, fairness and accountability regardless of ethnicity, gender, national origin, race, religion, sexual orientation, disability, age, rank or position of authority.
3. Capitalize on these successes of enhanced diversity to maximize the retention and graduation of undergraduate and graduate chemistry majors, categorically and collectively, in the department's programs.
4. Create focused programs that provide opportunities for all faculty and staff to develop and succeed professionally.

We are proud that our Department is dealing from strength as we strive towards these goals. Using the latest available date, we were first in the nation in the number of Hispanic Doctoral recipients in 2004-2005, first in the number of Ph.D degrees granted to members of underrepresented minorities between 2002 and 2006, and first among the top 50 chemistry research departments in the number of women faculty in 2007. We also note that the efforts outlined herein mesh well with analogous goals that are outlined within the Purdue College of Science's recently enacted strategic plan, and the University's plan for diversity entitled MOSAIC.

Strategies for Goal 1: Enhance a culture of diversity by actively recruiting students, faculty and staff that will be broadly representative of the people who make up our national and global societies

A. Faculty

1. Be proactive in soliciting applications from a diverse pool of candidates

a. Ensure that the department is regularly represented by a faculty member at meetings and workshops that primarily feature talks and posters by students and faculty from underrepresented groups. Examples include the Society for the Advancement of Chicanos and Native Americans in Science (SACNAS), National Organization of Black Chemists and Chemical Engineers (NOBCChE), Committee On the Advancement of Women Chemists (COACh) and the American Chemical Society Academic Employment Initiative (ACS AEI). (Implementation: Department Head)

b. Identify early-stage potential candidates, including those from Purdue, and make, as well as sustain, contact with them during their graduate and postdoctoral studies. (Implementation: Department Head Designate)

c. Annually obtain a list of Ph.Ds who are members of under-represented groups graduating from CIC Universities and assign a member of the faculty to identify and communicate with potential faculty candidates. (Implementation: Department Head Designate)

d. Use our alumni to help identify and maintain connectivity with potential candidates (Implementation: Department Head Designate)

e. Ensure that there are regularly held faculty searches that include all areas of chemistry so as to maximize the possibility of identifying underrepresented candidates and their inclusion on the search short list. (Implementation: Department Head)

f. Educate search committees about the need for, and the ways to obtain, a broad pool of candidates. (Implementation: Department Head Designate and Search Committee Chairs; Resource: several Purdue offices and staff)

2. Ensure that all candidates are given a fair and equitable evaluation.

a. Ensure that every search committee has at least one female faculty member. (Implementation: Department Head)

b. Educate the search committees about procedures that help ensure the fair and equitable evaluation of all candidates. (Implementation Department Head Designate and Search Committee Chairs; Resource: University of Illinois, Chicago Faculty Search Toolkit)

3. Seek out "targets of opportunity" for the hiring of members of underrepresented groups.

a. Maintain a list of potential faculty from among the underrepresented populations who are at colleges and universities with fewer resources than are available at Purdue, and actively solicit their application to our department. (Implementation: Department Head Designate)

b. Urge the various levels of the university administration to set aside funds to allow for the timely hire of a "target of opportunity" (Implementation: Department Head; Resource: the University of California program)

c. When a "target of opportunity" is identified, aggressively seek the resources needed to make that hire. (Implementation: Department Head)

B. Staff

a. Work with the University Office of Human Resources Services to ensure that ads for all staff openings are broadly placed in national venues likely to be seen by members of underrepresented groups. (Implementation: Department Head designate)

b. Work with the University Office of Human Resources Services to ensure that the departmental screening committees have available pools of candidates to choose potential staff. (Implementation: Department Head designate)

c. Educate the screening committees about procedures that help ensure the fair and equitable evaluation of all candidates. (Implementation: Department Head; Resource: several Purdue offices and staff)

d. Rationalize departmental hiring procedures to ensure consistent and best practices. (Implementation: Department Head)

C. Students

Undergraduate Students

a. Utilize the network of teachers and schools created by the Department's Science Express instrumentation van program to generate and maintain a list of potential science majors who are members of underrepresented groups and actively recruit them to enroll at Purdue. (Implementation: Outreach Coordinator and Department Head designate)

b. Develop visitation programs utilizing current students from underrepresented groups and their former high schools to enhance recruitment efforts at these schools. Place special emphasis on high schools located in major metropolitan areas of the state. (Implementation: Department Head designate)

c. Develop and hold annual high school chemistry teacher workshops in conjunction with one of the two semi-annual meeting of the Indiana Alliance of Chemistry Teachers. (Implementation: Outreach Coordinator and Department Head Designate)

d. Work with the Indiana Alliance of Chemistry Teachers to utilize that organization's web site to serve as a resource to teachers statewide. Include the opportunity for feedback from the teachers. (Implementation: Outreach Coordinator and Department Head designate)

e. Explore ways to increase the progression to the West Lafayette campus of students from underrepresented groups who have begun their higher education at one of the Purdue regional campuses or at one of the Indiana Vocational Technical Community Colleges. (Implementation: Department Head Designate)

Graduate students

a. Ensure that the department is regularly represented by a faculty member at meetings and workshops that primarily feature talks and posters by students and faculty from underrepresented groups. Examples include annual meetings of SACNAS and NOBChe. (Implementation: Department Head designate)

b. Work with the Campus' Multicultural Centers to enhance the visibility of the Purdue University Chemistry Department among college seniors from underrepresented groups (for example, the current Sloan-funded program for the recruitment of Native-American graduate students to Purdue) (Implementation: Department Head designate)

c. Build critical masses of underrepresented minority groups by working with others in the Colleges of Science and Engineering to develop ties to, and recruit from, institutions with large numbers of such undergraduates. For example, build on the existing departmental ties with Puerto Rico Chemistry Departments to create a critical mass of Puerto Rican graduate students. (Implementation: Department Head designate)

d. Increase our efforts to recruit top-level international students by expanding our successful International Graduate Students scholarship program.

e. Seek funding for the reinstitution of the Department's national "Chemistry Career Planning Workshop for Underrepresented Minorities." (Two were held at Purdue with NSF support in the1990's). (implementation: Associate Department Head)

Strategies for Goal 2: Sustain this culture of diversity by ensuring that the Department's environment is one of inclusivity – an environment which is truly the sum of its human parts and is marked by mutual respect, fairness and accountability regardless of ethnicity, gender, national origin, race, religion, sexual orientation, disability, age, rank or position of authority.

a. Ensure that all faculty, staff and graduate students are trained in recognizing, and sensitive to, incidents involving harassment. Ensure that all are knowledgeable about the appropriate responses to reports of bias or harassment consistent with Federal law and Purdue University Policies. These responses include specific prohibitions against any form of retaliation for reporting, or assisting in the investigation of, discrimination and/or harassment. (Implementation: Department Head or designate)

b. Conduct exit interviews with staff and graduate students before they leave Purdue, especially women and those from underrepresented groups, using a party from outside of the Department. (Implementation: Department Head or designate)

c. Create a team within the department, consisting of one male and one female full professor and one male and one female staff member, who have been trained in issues of harassment and discrimination consistent with Purdue University policies. The members of this team shall serve as resources for faculty, staff and students within the Department. Ensure that the existence of this team is publicized by the Department Head semi-annually and is prominently featured on the front page of the departmental website. (Implementation: Department Head only)

d . Conduct a departmental "climate" survey using expertise present in other parts of the University to define current issues and concerns. Regularly conduct such a survey every three years. (Implementation: Department Head or designate)

Strategies for Goal 3: Capitalize on these successes of enhanced diversity to maximize the retention and graduation of undergraduate and graduate chemistry majors, categorically and collectively, in the department's programs.

A. Undergraduate Students

a. Increase regular engagement activities that provide informal opportunities for undergraduate majors to interact with faculty and graduate students (Implementation: the Undergraduate Studies committee)

b. Increase communication and collaboration with the campus' Multicultural Centers. (Implementation: Department Head designate)

c. Provide regular opportunities for students to engage in smaller group experiences and active learning within the large gateway courses; for example, by adopting teaching strategies that are designed to actively engage students in collaborative group work during class time. (Implementation: Individual faculty and the General Chemistry and Undergraduate Studies Committees)

d. Utilize undergraduate students as tutors and mentors in chemistry courses. (Models that have been shown to increase performance in historically difficult courses, by providing regularly scheduled, voluntary, peer-facilitated sessions, are supplemental instruction (SI) and peer-led team learning (PLTL)). (Implementation: Undergraduate Studies Committee)

e. Increase collaboration with, and support of, current college and university diversity programs that are already active on campus. Examples include the Women in Science, Women in Engineering, NOBCChE and Gay, Lesbian, Bisexual, Transgender, Queer (GLBTQ) programs. (Implementation: Department Head designate)

f. Increase collaboration with, and support of, current university summer programs for members of underrepresented groups. Examples include the NSF- sponsored Louis Stokes Alliance for Minority Participation, the Summer Research Opportunities Program and the (partially) NSF-sponsored STEM Academic Boot Camp (for incoming freshmen). (Implementation: Department Head designate)

B. Graduate Students

a. Provide regular help sessions during the summer and the academic year to prepare students for the cumulative examinations. (Implementation: Division Heads)

b. Arrange for separate semi-annual meetings/socials for international students, members of underrepresented groups, and women during which issues and concerns can be shared. Reports from these meetings should be made directly to the Department Head if/when appropriate. (Implementation: the Team created for Strategy c of Goal 2)

c. Provide a graduate student mentor for each incoming graduate student. (Implementation: Department Head Designate).

d. Starting in a student's fourth year, require an annual report to be submitted by the student, and signed off by the professor, that outlines expectations for graduation and progress toward that goal. This report shall be distributed to the student's Advisory Committee. (Implementation: Graduate Studies Committee)

Strategies for Goal 4: Create focused programs that provide opportunities for all faculty and staff to develop and succeed professionally.

a. Identify faculty and staff development workshops and encourage/facilitate participation by all faculty and staff.

b. Conduct periodic performance reviews of all faculty and staff with the Head of the Department, Department Head designate or, when appropriate, a faculty member's Promotion Committee Chair. For faculty, the periodicity may vary depending on rank, but should be no less than annually for Assistant Professors. All reviews should be provided both orally and in writing.

c. Encourage the College of Science to adopt staff promotion policies as soon as they are authorized by the Provost.

d. Make available information about, and facilitate interaction with, Purdue organizations that may be of interest to faculty and staff from underrepresented groups.

e. Ensure that all Assistant Professors are assigned mentors.

f. Be judicious in the degree to which Assistant Professors are assigned to departmental committees.

g. Work with industry and foundations to develop seed funding programs for Assistant Professors.

Appendix B

Chemistry Department Faculty Hiring Plan

The chemical sciences are vast and bridge a number of administrative units at Purdue with homes in engineering, pharmacy, biology, and earth and atmospheric sciences among others. Our department's focus today is on Purdue's capabilities for approaching multidisciplinary problems of global import that require chemistry input. Likewise, we continue to reorganize our educational mission along these same lines to provide our students with the tools they will need to be tomorrow's leaders. We further recognize that we must be flexible and willing to share faculty with other units on campus. This we previously pursued for several years under the CoS program formally identified as Coalesce. We have also valued the pursuit of hires of opportunity that satisfy needs in diversity, spousal employment, and truly exceptional world-class individuals. Given this orientation toward flexibility, it is hard to predict where the next hires will come from and how they will be afforded. The strategic plan for 2009-2014, however, sets a series of goals that influence the direction in which faculty hiring must proceed. In this document we identify hiring priorities in the strategic thematic areas of drug discovery & disease detection, energy/catalysis, and soft matter chemistry. We pursue strength in those areas in concert with our commitment to having an analytical chemistry division ranked as first in the nation, increasing the strength of the organic division, maintaining the reputation and strength of the chemical education program, and continuing to identify emerging strategic areas for growth that address problems of national importance.

To fulfill this strategic plan, the department must average two-three hires per year. The following hiring plan summary for the Department of Chemistry is focused on strategic hiring in areas that represent significant national need, as well as those that maximally leverage our existing strengths and enhance our ability to conduct large scale collaborative research. The intent is to grow and pursue excellence in a few "signature areas," as agreed at the Department's retreat, held Feb. 28, 2009. We will also pursue hiring objectives consistent with those of the departmental Diversity Plan. When "open" hires can be made available, we will pursue them, to enable us to identify the best possible hires in emerging areas. The open hires will not target specific sub-disciplines, but call for applications from any area of chemistry. Such searches are particularly effective ways to identify talent with a minimum of filtering, and represent good opportunities for increasing our diversity. While we are not focused on a Division-based hiring strategy, the Department recognizes that it is important for us to strengthen our complement in analytical and organic chemistry (which will be accomplished in part via strategic hiring), and to maintain our strength in chemical education (which is particularly critical in the face of several upcoming retirements).

Our hiring plan reflects a strategy of mixed hires in "core" areas of chemistry, targeted hires in key strategic areas for growth, and open hires that will not target specific sub-disciplines, but call for applications from any area of chemistry. Core needs for the 09/10-13/14 hiring period include anticipated requests for one junior position in analytical chemistry, two senior and a junior position in organic chemistry ("molecular synthesis"), and two positions in chemical education. Needs for core hires in other divisions are likely to be filled by the open hiring or targeted hiring processes, but will be pursued as needed.

The following areas will represent hiring priorities with respect to development and pursuit of strategic areas for growth:

1. Drug Discovery and Disease Detection
   In sub areas, such as:

   - Natural product synthesis
   - Chemical biology
   - Human trials
   - Target selection and validation
   - Biomarker identification and detection
   - Drug delivery
   - Structure-based drug design
   - Chemical sensing and imaging

2. Energy/Catalysis

   - Solar/hydrogen
   - Biofuels
   - Organometallic synthesis
   - Battery research
   - Fuel cells
   - Hydrogen storage

3. Soft Materials

   - Membranes
   - DNA nanostructures
   - Peptide assemblies and composite materials
   - Carbohydrates
   - Chemical sensing and imaging

A prioritized hiring schedule, which reflects the priorities listed above, is provided below. The order of hiring, particularly in the out-years, is subject to annual review.

<table>
<tr><th>Year of search</th><th><u>Targeted Hire Area</u></th><th><u>Flexible Strategy Hire</u></th></tr>
<tr><td>2009/2010</td><td>Drug Discovery Senior Hire</td><td rowspan="5">On average the department expects to hire two new faculty per year meeting our strategic initiatives in energy, drug discovery, and soft materials. We will take into account losses by attrition and changing conditions to annually decide our priorities among these areas, in the spring of the previous academic year. Each year, we will pursue the goal of making "Leadership hires" of preeminent scientists, and also meet our charge to diversify our faculty. Whenever possible, we will conduct searches that are open to prospective faculty in any of our strategic areas:

Energy, Drug Discovery, and Soft Materials.</td></tr>
<tr><td>2010/2011</td><td>Chem. Ed.; Drug Discovery Sr. Hire</td></tr>
<tr><td>2011/2012</td><td>Asst. Prof., Mol. Synthesis
Asst. Prof., Analytical Chemistry/Chemical Imaging</td></tr>
<tr><td>2012/2013</td><td>Chem. Ed. Asst. Prof.</td></tr>
<tr><td>2013/2014</td><td>Energy or Biochemistry/Soft Materials?</td></tr>
</table>

Appendix C

ABRIDGED REVIEW OF CHEMISTRY MAJORS' CURRICULUM

Report and Recommendations to the Faculty of the Department of Chemistry

Chemistry Undergraduate Committee
Fall 2006

(Abridged version for inclusion in Chemistry Strategic Plan, 2009)

Gabriela Weaver (chair)
Beatriz Cisneros
John Grutzner
Anne Guentert
Christine Hrycyna
Kami Larson*
Fred Lytle
John Nash
Jon Wilker

Previous Undergraduate Committee Members Contributing to this Report

Evonne Baldauff
Andrew Gordon*
Jennifer Hovis
Olivia Johnson*
David Kissick*
Mark Robbins*
Alex Wei

* undergraduate student representative

Table of Contents

I. Outcomes for a Chemistry Degree

As described in section II, this report builds outward toward recommendations by starting with a list of outcomes that are desired for a student receiving a B.S. degree from this chemistry department.

> It must be kept in mind that this list of outcomes is being used as a working framework for our recommendations. While there may be numerous variations, the list provided here is the one that our committee settled on after a great deal of data collection and discussion. The purpose is to allow us to build a set of recommendations. While there may be many individual opinions on the exact ordering or wording on this list, we believe that slight perturbations of this list would still result in the same overall recommendations.

The list is organized by levels of importance, and by sublevels that describe categories of learning or skills. The outcomes that are listed below are consistent with the requirements and the intent of both the ACS Guidelines [3] and the North Central Association's institutional accreditation guidelines [7]. Criterion Three of the NCA document addresses student learning directly: "the organization provides evidence of student learning and teaching effectiveness that demonstrates it is fulfilling its educational mission." The issue of providing evidence will be addressed in section VI of this report, but is based on the use of the outcomes listed here. The NCA document also makes reference to education in Criterion Four on Acquisition, Discovery and Application: "the organization demonstrates that acquisition of a breadth of knowledge and skills and the exercise of intellectual inquiry are integral to its educational programs." The criteria for the North Central accreditation are given in Appendix B.

Part A. Descriptions and Implications of Levels

A master list of outcomes has been organized into three levels of importance (critical, important, and desirable), with each level having three subdivisions (skill-based competencies, knowledge-based competencies, and critical/analytical thinking). A brief description of each level and subdivision is provided below:

Level 1: Critical. These outcomes are considered vital and of fundamental importance to the professional chemist. These represent items where an enduring understanding is needed, such that students will remember these even after the details have been forgotten.

Level 2: Important. These outcomes are more specific and determine the quality of training in chemically relevant topics and activities. Student learning is incomplete without mastery of these essentials.

Level 3: Desirable. These outcomes have an indirect impact on the quality of chemical education and training, but are recognized as worth knowing. They are items that students should be exposed to, but mastery is not necessary.

Subdivisions for each level:

A. Technical Competency: Operational Skills. These outcomes encompass the skills expected of the practicing chemist, including experimental design and execution, data collection and documentation, and dissemination of knowledge.

B. Technical Competency: Knowledge Based. These outcomes encompass the mastery of chemical principles and theories, and an understanding of their roles in chemistry-related issues.

C. Critical/Analytical Thinking Skills. These outcomes encompass a broader set of skills, including appreciation for the scientific process, the ability to solve chemistry-related problems, and the ability to interpret data in a meaningful way.

Part B. Outcomes by Level

Following are the individual outcomes that were determined by the committee to represent the knowledge and skills that a student graduating from the Purdue University undergraduate chemistry program should have. Within each level, these are organized into the subdivision categories. Within each category, no ranking of importance or priority is intended to be implied by the numbering.

Level 1 Outcomes

A: Technical Competency: Operational Skills

i. ability to write scientific reports, with graphical presentation of data (technical writing skills)
ii. ability to document scientific information and experimental data (keeping a lab notebook or other written record)
iii. ability to use theory to understand/predict experimental observations
iv. ability to make quantitative/structural measurements and interpret results (data collection and analysis)
v. ability to identify and handle hazardous materials (includes ability to access this information, and to apply reasonable cautionary measures)
vi. ability to design experiments that allow hypotheses to be critically evaluated
vii. ability to plan and execute chemical transformations (experimental skills)

B: Technical Competency: Knowledge Based

i. an understanding of the physical principles upon which chemical instrumentation is based (e.g., Beer's Law and analysis limits)
ii. an understanding of universal physical laws as they apply in chemistry (e.g., enthalpic and entropic factors applied to reactions and properties)
iii. an understanding of reaction chemistry
iv. an understanding of structure/activity and structure/property relationships (e.g., electronic effects in chemical reactivity)
v. an appreciation of the role and uses of theory

vi. a molecular understanding of chemical reactivity and materials

C: Critical/Analytical Thinking Skills

i. an understanding of the scientific process
ii. problem-solving skills: identifying the objective
iii. ability to evaluate data for quality and reliability
iv. ability to discern and practice good scientific ethics (e.g., avoiding plagiarism)
v. ability to organize data for meaningful interpretations

Level 2 Outcomes

A: Technical Competency: Operational Skills

i. ability to recognize and use chemical instrumentation and spectroscopy
ii. ability to use computational tools to organize/process data (e.g., spreadsheets)
iii. computer literacy: ability to use multiple programming, computational, online and database tools
iv. a demonstrated ability to comprehend scientific papers
v. ability to work in teams and develop collaborations
vi. ability to present a formal oral summary of a topic in chemistry
vii. ability to work with minimal supervision (specific to research experience)

B: Technical Competency: Knowledge Based

i. ability to carry out calculations related to specific chemistry topics (e.g., molarity)
ii. ability to find and evaluate the validity and usefulness of information (e.g., library or reputable online resources)
iii. an understanding of energetics and kinetics of chemical transformations
iv. ability to state the properties of the elements and many compounds
v. an understanding of the connections between different courses/ subdisciplines in chemistry

C: Critical/Analytical Thinking Skills

i. a demonstrated understanding of the connections between chemistry and current events, everyday occurrences and other scientific disciplines.
ii. an ability discern causes of experimental error
iii. an ability to use statistics to judge limitations of data; use math to understand data

Level 3 Outcomes

A: Technical Competency: Operational Skills

i. demonstrated initiative
ii. demonstrated leadership skills
iii. professional behavior: reliability, punctuality, efficiency

iv. ability to handle, store, and retrieve data (e.g., using computer programs such as LabView)

B: Technical Competency: Knowledge Based

No items in this category were rated as Level 3 outcomes.

C: Critical/Analytical Thinking Skills

i. ability to reduce complex problems into simpler components

II. Findings from Analysis of the Curriculum

Part A. Strengths

The current Chemistry curriculum offers an excellent quantitative and qualitative education in the major chemical disciplines – Analytical, Biochemistry, Inorganic, Organic and Physical Chemistry. Most of the essential Level 1 Outcomes are well covered throughout the four year curriculum (See Section III and Appendices C-E for details). Quantitative skills are a fundamental part of the introductory course sequences and they are then refined in the upper division Physical and Analytical Chemistry courses. Data generation, documentation and analysis are key components of all laboratory courses. Technical competence in the qualitative aspects of molecular properties and processes are introduced in the freshman courses and then comprehensively covered in the disciplinary Inorganic, Organic and Biochemistry courses. The development of critical and analytical thinking skills is fostered throughout the curriculum and finds particular emphasis in the higher level courses. The whole curriculum is permeated with educational opportunities for development of problem solving skills, for understanding scientific principles, and applying them to molecular level processes. The department provides a safe working environment for students with adequate training in the handling of hazardous materials when required for laboratory operations.

The Level 2 Outcomes are also generally well covered in the curriculum although some exceptions exist (see following sections). Undergraduate research and seminar courses provide students with the opportunity to develop their independent creative skills, put their book knowledge into practice, review the literature, design meaningful experiments, critically evaluate data, produce oral and written reports, and begin to appreciate the scientific enterprise. Undergraduate research is the capstone of the curriculum and is one of the few places where chemistry is encountered as an integrated subject. Computers are used throughout the curriculum to record and analyze data, and to search databases and the literature.

A practical indicator of the strength of the current curriculum is the placement of our graduates. Approximately 40% are admitted to leading chemistry graduate programs, 40% are hired by industry and the remaining 20% are admitted to medical and professional schools, teaching and government.

Part B. Areas to be Strengthened

The outcomes listed below have been identified as areas that are currently covered in classes although to a lesser extent than those detailed in the previous section. Therefore the integration of these outcomes into additional courses is encouraged. These particular areas were determined to be addressed in 35% or less of the courses evaluated. The specific courses in which these outcomes are met at present can be found in Appendices C-E .

<u>Level 1</u>

A. vi. Ability to design experiments that allow hypotheses to be critically evaluated.
A. vii. Ability to plan and perform chemical transformations.

<u>Level 2</u>

A. ii. Ability to use computational tools to organize/process data.

A. iv. Demonstrated ability to comprehend scientific papers.
A. v. Ability to work in teams and develop collaborations.
A. vi. Opportunities for students to present formal oral summaries of topics in chemistry.
A. vii. Ability to work with minimal supervision.
B. ii. Ability to find and then evaluate the validity and usefulness of information.
C. ii. Discern causes of experimental error.
C. iii. Use statistics to judge limitations of data; use math to understand data.

Level 3

A. i. Demonstrated initiative.
A. ii. Demonstrated leadership skills.

The committee believed that an additional area needing to be strengthened is retention of our majors. As detailed in section I of this report, losses in enrollment can be seen over the entire span of the undergraduate program. There are numerous issues that contribute to these numbers, some of which are beyond the control of the department. However, it is imperative that an examination of all possible causes of this retention issue be undertaken and various possible strategies to alleviate it be considered. Possible solutions include separate courses for chemistry majors starting in the first year.

Part C. Areas That Are Missing from the Undergraduate Curriculum

Throughout the review process there were certain content areas that the committee felt were severely underrepresented or completely missing.

Missing Outcomes

Both of the identified missing "outcomes" are from Level 1 (as defined in Part III.b of this report.)

- Sublevel A, number v:
  "ability to identify and handle hazardous materials"
  this area is only covered to the extent that students are provided with information as they need it (e.g., lab experiments) to carry out their work safely; formal training that would allow students to identify and handle *any* potentially hazardous materials that they might encounter is missing.
- Sublevel C, number iv:
  "ability to discern and practice the ethics of science"
  this area is covered only in a very limited way (e.g., course policies on cheating, plagiarizing, etc.); formal training is completely missing (see below)

Missing Topics

These topics were raised as important ones that are not currently represented in our curriculum. They came either from the discussions with the divisions, the committee retreat, or committee discussions during regular meetings. This list is unordered; no ranking of importance is implied.

- Group theory
- Photochemistry
- Biochemistry lab (and instrumentation)

- Mass spectrometry experiment
- Ethics
- Polymer chemistry
- Colloid & surface chemistry
- Computational chemistry
- Comprehensive treatment of kinetics
- Comprehensive treatment of statistical mechanics

Part D. Area of Opportunity: CHM 499

Various aspects of the scientific process are represented in the list of outcomes. Among these are the level 1 outcomes for designing experiments, technical writing, documenting scientific information, understanding experimental observations, understanding the scientific process, and the practice of scientific ethics. Several of these have been identified as areas that need to be strengthened or which are missing. Our CHM 499 independent studies experience provides an opportunity to address some of these. However, it is possible to involve students in a CHM 499 that does not take full advantage of the experience from the perspective of learning and developing scientific skills and approaches. An ideal CHM 499 experience includes but is not limited to the following: opportunities to be involved in experimental design, data collection and analysis, opportunities to speak and present at group meetings, opportunities to present posters, generation of a final written technical report and receiving feedback on these activities. Students should be involved in CHM 499 experiences as soon as possible after starting at Purdue and remain in a laboratory as long as possible. For reference, the numbers of students enrolled in CHM 499, by class, are shown in Table 3.

Table 3. Student Enrollment in CHM 499 and SCI 290H by Class per Semester

	2001-02	**2001-02**	**2002-03**	**2002-03**	**2003-04**	**2003-04**	**2004-05**	**2004-05**	**2005-06**	**2005-06**
	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
	Count	Count	Count	Count	Count	Count	Count	Count	Count	Count
FRSH 290H	6		9		14		14		12	
FRSH 499		2	1	5	11	6	6	14		6
SOPH 499	15	13	5	15	13	13	12	9	15	17
JR 499	18	17	19	20	23	25	17	25	10	8
SR 499	28	30	29	19	30	36	29	27	18	15
Count	67	62	63	59	91	80	78	75	55	46

On average, 9.7% of freshman, 13% of sophomore, 18% of junior and 26% of senior chemistry majors are in CHM 499. Overall, this is amounts to an average of 28% of the chemistry majors in any given semester nor does it include the freshman involved in the SCI 490H honors course during their first semester. These data, however, do not include the students who carry out research during the summer semesters, or through internships and coops. We recommend that the department strive to significantly increase these numbers in general.

III. Recommendations

Part A. Course Content Recommendations

The content recommendations can be separated into two categories: specific topics and more general skills.

Specific topics. There are several topics where the coverage is either lacking or not present at all. There are two different priority levels for including these topics into the curriculum.

The high priority topics are:

- group theory
- biochemistry laboratory
- mass spectrometry experiments
- comprehensive treatment of kinetics
- ethics

The medium priority topics are:

- photochemistry
- polymer chemistry
- colloid & surface chemistry
- computational chemistry
- comprehensive treatment of statistical mechanics

More specifically, it is recommended that the high priority topics be covered in the following courses:

- Biochemistry Laboratory – create new class
- Ethics – CHM 294 (emphasis on research ethics) and CHM 513 (emphasis on plagiarism)
- Group theory – CHM 342 and 374
- Comprehensive treatment of Kinetics – CHM 373
- Mass Spectrometry experiment – CHM 126, Organic Labs, CHM 424

It is recommended that the medium priority topics be covered in the following courses:

- *Colloid & Surface Chemistry – Course offerings in other departments
- Computational Chemistry – Create new module
- Photochemistry – Organic Chemistry
- *Polymer Chemistry – Courses in other departments or new module
- Comprehensive treatment of Statistical Mechanics – CHM 373 and 374

*(Note: the committee has recognized that these topics are not present in the current curriculum for our majors, but feels that they should be. There are other courses on campus that offer an introduction to these topics. If it is not possible to include these topics in our own chemistry courses, then the committee recommends that students be explicitly encouraged to take these courses outside of the department.)

General Skills. In this case, again, the coverage is either lacking or not present at all. In either case it is recommended that faculty consider ways in which acquisition of these skills can be worked into the curriculum. In particular, the committee strongly recommends that the faculty work to include at least one of these skills into their classes. It would be ideal to have students gain exposure to these skills in multiple classes.

Here again the topics fall into different priority levels. The list is not meant to be all-inclusive.

High:

- Ability to handle and identify hazardous materials;
- Ability to design experiments that allow hypothesis to be critically evaluated;
- Demonstrated ability to comprehend scientific papers;
- Ability to work in teams and develop collaborations;
- Opportunities for students to present formal oral summaries of topics in chemistry;
- Ability to work with minimal supervision;
- Ability to find and then evaluate the validity and usefulness of information;
- Demonstrated understanding of the connections between chemistry and current events, everyday occurrences and other specific scientific disciplines;
- Ability to discern and practice the ethics of science.

Medium:

- Demonstrated initiative;
- Demonstrated leadership skills;

Part B. Course and Sequence Recommendations

In evaluating the current curriculum for chemistry majors, several areas and topics were found either to be underrepresented or not represented at all.

We recommend the following changes:

1. A 500 level biochemistry laboratory course be implemented for chemistry majors. This laboratory course in biochemistry will provide hands-on instruction in basic modern biochemical and analytical instrumentation techniques. We will focus on the gene cloning and expression as well as the production, purification, and analysis of proteins and nucleic acids. The goals of the course are to learn laboratory methods, learn to use the methods to collect reproducible, interpretable data, to calculate useful results from the data, and to explain the meaning of the results, by describing molecular models and mechanisms.
2. CHM 241 be offered in the Spring semester to accommodate Freshmen who take Honors General Chemistry (CHM 136) or CHM 116 in the fall.
3. Develop a series of 5-week one-credit modular courses that could be taken concurrently or in series. These should be offered to fill in content gaps in our curriculum. The committee recommends the following as possible modules:

a. Group theory – To teach the fundamentals of group theory, including symmetry operations and elements, mathematical and point groups, matrix representations and character tables. Provide examples of how these concepts relate to spectroscopic selection rules and molecular orbital theory.

b. Photochemistry – To help the students develop an understanding of the interaction of light with matter at the molecular level and the chemical consequences of that interaction.

c. Computational chemistry – To introduce electronic structure calculations and illustrate strategies for using these methods to solve problems of chemical significance. Alternative to creating a new course, the current computational chemistry course would be offered both as a 3 credit course and a module, in which the first 5-weeks would constitute the 1 credit version.

d. Polymer chemistry – To introduce the synthetic and analytical techniques specific to polymeric materials.

4. Students with interests in polymer chemistry, colloid chemistry and surface chemistry should be encouraged to take these courses in other departments that have existing courses.
5. Mass spectrometry experiments should be incorporated into new and existing laboratory courses where appropriate.
6. Computational chemistry experiments should be incorporated into new and existing laboratory courses where appropriate.
7. Ethics training for undergraduates, a level one outcome, should be incorporated into the existing curriculum as follows:

    a. In the Fall semester, a discussion of professional ethics as it pertains to the research laboratory should be taught as part of CHM 294. Case studies should be used to discuss unethical practices such as selective treatment of data, selecting only data that support a hypothesis, adjusting data to better match theory, and outright fraud.

    b. In the Spring semester, writing and publishing ethics should be taught as a part of CHM 513 and include a discussion of the allocation of credit, citations to published and unpublished work, and plagiarism.

    c. Both CHM 294 and CHM 513 should be required of <u>all</u> chemistry majors.

8. Hazardous material training, a level one outcome, should be offered to teach students to identify and handle any potentially hazardous materials that they might encounter. The training we recommend goes beyond what is presently done in our efforts to make a safe working environment for our students. We recommend that this formal training be done in CHM 294 and also incorporated into laboratory courses.

Part C. Methodology Recommendations

Practice with scientific reasoning can be enhanced by using predictive pre-lab questions and homework problems that require more than the ability to plug numbers into equations. For each laboratory course, a multi-week capstone experience can be given that requires students to design an experiment to test a hypothesis that they have posed. Connections between areas of chemistry and/or science can be demonstrated by linked laboratory experiments extending across one or more course laboratories.

The curriculum should provide students with practice working with others to achieve common goals. This skill can be learned by what is generally called cooperative learning. For example, in the classroom a question can be posed, with neighboring students working together to arrive at an answer. These small groups can then compare their results with another set of neighbors. The person in charge can have the larger groups share their answers verbally with the class as a whole. In the laboratory, teams of students can be assembled to perform an experiment with each individual being given a specific task, e.g. project manager, data processor, instrumentation specialist, and report writer. These roles are rotated during the semester so that everyone obtains experience with each type of task.

Student awareness of modern approaches to problem solving can be improved by the frequent use of computational problems or experiments. Possible programs might be: calculation-based such as Gaussian, Mathcad or a statistics package; graphics-based such as molecular structure programs; component simulation-based such as OSLO (optics simulation) or PC-Spice (electronics simulation); or instrument simulation-based such as ITSIM (ion trap simulator).

Improvement in student communication can be achieved by course work that emphasizes scientific reading, writing and speaking. Several courses have utilized poster sessions based on student-chosen topics. We encourage courses to involve students in technical, oral presentations when possible. We also encourage more courses to consider ways to involve students in writing assignments, particularly the writing of technical reports and journal-style articles.

Professionalism can be encouraged by integrating safety into each laboratory experiment (having students look up MSDS or create a hazard assessment), by using case studies in discussions of ethics and scientific misconduct, and by holding students accountable for late work, plagiarism, etc.

IV. Assessment

This report was researched and written as a response to a departmental mandate to review our curriculum and find ways to meet the departmental strategic plans for undergraduate education. The report aims to provide a snapshot of the current situation, and a potential roadmap in the form of recommendations. As in any goal-based scenario, the only way to determine if progress is being made will be to examine the evidence. The departmental strategic plan outlines metrics for every one of its goals. Likewise, the department will need to formulate which metrics to use with respect to the learning outcomes described in this report. The UGC committee feels that this is a separate phase of work, which must come only when the department chooses to adopt the listed outcomes overall and find ways to achieve them.

In order to ensure that the department is achieving its educational goals with respect to learning outcomes, it will be necessary to assess our efforts on a regular basis. The assessment measures that are collected would serve to assist in departmental decision making about our curriculum and approaches to teaching. It would be most useful to collect a variety of data to serve as indicators of our success at achieving our stated goals. In this report, we can only provide a general view of how such an approach could take shape. The details of implementation must be overseen by a person or group specifically assigned to that effort, working closely with all faculty. It is imperative that such an assessment effort does not become an *additional* work burden on the faculty or students of this department. Instead, it is imperative that assessing our progress toward these curricular goals take advantage of assessment work that already exists or that certain assessment tasks replace ones that are already in existence but are determined, in some manner, to be obsolete.

Many of the learning outcomes can be measured by direct, course-embedded assessments that are of a standardized "objective" nature [8]. However, several of the goals that have been described would be difficult to fully measure in these ways, and will require a combination of assessment approaches and triangulation among these. As Walvoord points out in her book on this subject [9]:

> *Assessment does not limit itself only to learning that can be objectively tested. It need not be a reductive exercise. Rather, a department can state its highest goals, including goals such as students' ethical development…then it can seek the best available indicators about whether these goals are being met. Faculty regularly assess complex work in their fields and make judgments about its quality; in assessment of learning, faculty make informed professional judgments about critical thinking, scientific reasoning, or other qualities in student work and then use those judgments to inform departmental and institutional decisions.*

Walvoord asserts that the informed judgment of our students' work must be based on criteria that are explicitly described and made available to students. This does not mean that the criteria need to be simplistic, just that they need to be clear to those assessing as well as those being assessed. For example, we must be able to define what constitutes achievement of each learning outcome that we have listed. In some cases, this can be measured directly, such as by evaluating student exams, papers, and projects. It is, in fact, possible to use direct classroom-based measures for learning outcomes that are integrative and complex, such as demonstrating an understanding of experimental design. While a written exam could be devised to measure such a thing, it is more practical to develop a scheme to assign point values based on explicitly described quality of performance. This is generally referred to as a "rubric".

An example of a rubric for a written journal-style report [10] would include a grading scale for each section, such as title, introduction, materials and methods, experimental design, data collection, interpretation of data, etc. Each section would be assigned a point value based on completeness and quality, such as:

Methods and Materials Section

5 points: Report contains effective, quantifiable, concisely organized information that allows the experiment to be replicated; is written so that all information inherent to the document can be related back to this section; identifies sources of all data to be collected; identifies sequential information in an appropriate chronology; does not contain unnecessary, wordy descriptions or procedures.

4 points: As 5 above, but report contains unnecessary information and/or wordy descriptions within the section.

3 points: Report presents an experiment that is definitely replicable; all information in document may be related to this section; however, fails to identify some sources of data and/or presents sequential information in a disorganized, difficult pattern.

2 points: Report presents an experiment that is marginally replicable; parts of the basic design must be inferred by the reader; procedures not quantitatively described; some information in Results of Conclusions cannot be anticipated by reading Methods and Materials section.

1 point: Report describes the experiment so poorly or in such a nonscientific way that it cannot be replicated.

Several of the learning outcomes proposed in this document are of an integrative, complex nature and can best be assessed (and demonstrated) in an *authentic* setting - one which actually involves the student in doing the task for which they are being assessed. An example of this is in giving oral scientific presentations; the best way to measure a student's ability to do this is to actually observe the student doing it. Another example is the outcome related to designing experiments. For these integrative tasks it may be useful for the department to consider a forum that would allow for such authentic assessment. One possibility is a capstone research experience that results in a poster session or oral presentations which are specifically intended to be assessed on objective, explicit criteria for performance. While our current approach to undergraduate research (via CHM 499) allows for some involvement in research design, writing and presentation, these are currently not uniformly employed or measured. Thus, perhaps the "capstone" experience can simply be a redefinition of one of the CHM 499 semesters which includes more explicit assessment.

Many of the assessments that we would need for measuring our progress with respect to outcome goals are already being administered and collected. Others could be collected by compiling departmental statistics which already exist. Types of assessment measures that could be used include:

- Formal Examination: written "hour" exams, quizzes, written comprehensive exams, oral exams
- Non-Exam Work Submitted for Evaluation: homework, laboratory reports, term papers
- Informal or Formal Evaluation of Laboratory Skills: experimental results, laboratory notebook, familiarity with procedures and instrumentation, ability to perform established laboratory operations
- Informal and Formal Evaluation of Oral Communication Skills: seminars on course-related material, seminars on undergraduate research, poster presentations
- Participation in Undergraduate Research: informal and formal evaluation of higher level skills and understanding of more advanced/abstract concepts
- Percentage of Students Engaged in Interdisciplinary Studies
- Percentage of Students Engaged in International Studies
- Percentage of Graduates Accepted into Graduate/Professional Programs
- Percentage of Graduates Finding Employment Requiring Scientific Knowledge/Skills
- Percentage of Current Students Obtaining National-Level Awards/Scholarships
- Percentage of Current Students having Leadership Positions in Campus/Off-Campus Organizations

As outlined in the Rationale and Background section of this report, there are many changes occurring that may soon require our department to demonstrate a curricular plan that is in line with College, University or Federal mandates. We hope that the findings and recommendations in this report can prepare our department for this and make it much easier and quicker for us to respond. A goal of continued departmental assessment of our learning outcomes should be to result in a report indicating which learning outcomes are being addressed and assessed in each course. Tables similar to those in Appendix C could be generated on a regular basis to continually monitor our progress._ It would be most meaningful if this were combined with data resulting from surveys of recent alumni, exit interviews or surveys, and selected focus group interviews on a recurring basis with current students and faculty. However, this must be approached and planned carefully so as not to result in a burdensome increase in workload for faculty or students. Surveys or interviews should be conducted to specifically reveal the achievement of the learning outcomes, and not for ill-defined attitudinal results.

V. Tables of Outcomes by Course

In the tables below, W = the outcome is well addressed in that course; S = the outcome is somewhat addressed in that course and could be addressed more; R = the outcome is not addressed in that course and we recommend that it be added.

*Note: CHM 499 is not included in any of the next 3 appendices (C-E) because of the varied nature of the experience.

Table C1: Level 1 Outcomes

A: Technical Competency: Operational Skills	125	126	136	261	265/7	262	266/8	241	342	342L	373	374	376	533	538	321	424	513	294	494
i.write scientific reports, with graphical prese	W	W	W		W		W	W		W		R	W			W	W			S
ii.document scientific information and experi	W	W	W		W		W	W		W			W			W	W			S
iii.use theory to understand/predict experimer	W	W	W	W		W		W		W	W	W	W	W		W	W			S
iv.make quantitative/structural measurement	W	W	W			W		W		W			W			W	W			
v.identify and handle hazardous materials	R	R	S		W		W									R		S		
vi.design experiments that allow hypotheses	S	S	R				W			W			S			R	R			
B: Technical Competency: Knowledge Based																				
i. physical principles upon which chemical in	W	W	S					W				W	S		S	W	W			
ii.universal physical laws as they apply in che	S	S	W					S	W	S	W	W	W	W			W			
iii.reaction chemistry			W	W		W		W	W	W	S	R		W	W	W				
iv.structure/activity and structure/property r	.		S	W		W		W	W	S	S	W		W						
v. uses of theory	W	W	W	W		W		W	W	W	W	S	W	W	W	W	W			
vi. chemical reactivity and materials	W	W	S	W		W		W	W	W	S	R		W		W				
C: critical/analytical thinking skills																				
i. scientific process			R	W		W		S		W	W		W		S		R	W	S	S
ii. problem-solving skills: identifying the obje	W	W	W			W		S	W	W	W	W	W		W	S	W			
iii. data for quality and reliability	S	S	W		W					W			W			W	W	W		
iv. ethics of science (eg. not plagiarizing)			R			S		S	S	S	S		W					S		S
v. organize data for meaningful interpretatio	W	W	W			W		W		W			W				R	W		W

Table C2: Level 2 Outcomes

A: Technical Competency: Operational Skills	125	126	136	261	265/	262	266/8	241	342	342L	373	374	376	533	538	321	424	513	294	494
i.chemical instrumentation and spectroscopy	W	W	S		W	W	W	S		W		W	W			W	W			
ii. computational tools to organize/process da	S	S	W									W	W		S	W	R	S		
iii. computer literacy: ability to use multiple p	.					S		S		S		W	W		W	W	W	W		
iv. comprehend scientific papers	.					W				W		R	W		W			W	S	S
v. work in teams and develop collaborations	R	R	S			W		R			S		W					W		
vi.present a formal oral summary of a topic i	.					W				W								W		W
vii. work with minimal supervision	.		S					S		W			W					W		W
	.																			
B: Technical Competency: Knowledge Based	.																			
i.calculations related to specific chemistry to	W	W	W			W		S	W	W	W	W	W	W		W	W			
ii.find and then evaluate the validity and usef	.					W			S	S			S			S	S	W		
iii.energetics and kinetics of chemical transfo	S	S	W	W		W			W	S	W	W	S	W		W				
iv. state the properties of the elements and n	.		S	W		W		W	W	W		W		W				S		
v.connections between different courses/su	.		S	S		S		S	W		S	S	S	W	W			W	W	W
	.																			
C: Critical/Analytical Thinking Skills	.																			
i.current events, everyday occurrences and	.			S		S			W		S	R	S	W	W			W	W	S
ii.discern causes of experimental error	.							S		W			W			R	S			S
iii.use statistics to judge limitations of data; u	.												W			W				

Table C3: Level 3 Outcomes

A: Technical Competency: Operational Skills	125	126	136	261	265/	262	266/8	241	342	342L	373	374	376	533	538	321	424	513	294	494
i.demonstrates initiative	.									S			S							W
ii.demonstrated leadership skills	.									W			S							
iii.professional behavior: rel., punct., efficien	.		W					W		W			W				W	W		W
iv. ability to handle, store, and retrieve data	.		W		S		S	W		W			W			W	W	W	S	
	.																			
C: Critical/Analytical Thinking Skills	.																			
i.ability to reduce complex prob. into simple	.		W	W		W		W		S	W	W	S		W		W			