高等师范院校

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化学教育教学前沿研究

HUAXUE JIAOYU JIAOXUE QIANYAN YANJIU

（2012版）

范楼珍　刘正平　张　媛◎主　编

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BEIJING NORMAL UNIVERSITY PUBLISHING GROUP
北京师范大学出版社

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图书在版编目（CIP）数据

高等师范院校化学教育教学前沿研究：2012版／范楼珍，刘正平，张媛主编. —北京：北京师范大学出版社，2012.11
ISBN 978-7-303-15548-4

Ⅰ. ①高… Ⅱ.①范…②刘…③张… Ⅲ. ①化学教学－教学研究－高等师范院校－文集 Ⅳ. ①O6-42

中国版本图书馆 CIP 数据核字（2012）第 245343 号

营销中心电话　010-58802181　58805532
北师大出版社高等教育分社网　http://gaojiao.bnup.com.cn
电子信箱　beishida168@126.com

出版发行：北京师范大学出版社 www.bnup.com.cn
北京新街口外大街 19 号
邮政编码：100875
印　　刷：北京京师印务有限公司
经　　销：全国新华书店
开　　本：184 mm × 260 mm
印　　张：16
字　　数：379 千字
版　　次：2012 年 11 月第 1 版
印　　次：2012 年 11 月第 1 次印刷
定　　价：55.00 元

策划编辑：范　林　　责任编辑：范　林
美术编辑：毛　佳　　装帧设计：天泽润
责任校对：李　菡　　责任印制：孙文凯

内容提要

《高等师范院校化学教育教学前沿研究(2012 版)》一书收录了第十四届全国高等师范院校化学课程结构与教学改革研讨会和第二届全国高等师范院校大学生化学实验邀请赛暨高等师范院校化学实验教学与实验室建设研讨会提供的部分教育教学研究论文，共 67 篇。论文涉及我国高等师范院校化学教育和教学改革与创新方面的内容以及海外部分高等教育教学的经验总结，归纳为如下 5 个专题：专题一，高等师范院校大学化学创新教育理念与人才培养模式研究与实践；专题二，化学教师教育改革与创新(人才培养方案与课程体系改革)；专题三，化学实践教学体系构建与大学生创新能力培养研究；专题四，免费师范生化学创新教育研究与实践；专题五，现代教育技术在化学教学中的应用。这些论文的发表对提高我国高等师范院校化学教育教学质量和培养高素质人才具有指导和参考作用。

前　言

为了加强我国高等师范院校化学课程结构与教学改革，提高教育教学质量，促进同行相互联系与交流，受教育部化学教学指导委员会师范协作组委托，第十四届全国高等师范院校化学课程结构与教学改革研讨会于2012年11月23～26日在北京师范大学珠海分校(广东省珠海市)召开。会议主题是：深化化学教学研究，提高高师教育质量。会议期间代表将交流近年来我国高等师范院校化学课程结构与教学改革所取得的成果，探讨新时期高等化学教育所面临的机遇与挑战。

会议征文得到海内外从事高等教育教学工作教师的踊跃响应，收到的论文经审阅、遴选，结集出版了《高等师范院校化学教育教学前沿研究(2012版)》一书。本书编辑收录的67篇论文凝聚了高等院校各化学学院(系)中潜心于教育教学工作的教师和教学管理人员的心血，既反映了高师教育改革与创新的前沿研究成果，又汇集了作者对未来教师教育发展的真知灼见。根据所收录论文的内容和研讨会主题，我们将论文按5个专题归纳整理：高等师范院校大学化学创新教育理念与人才培养模式研究与实践、化学教师教育改革与创新(人才培养方案与课程体系改革)、化学实践教学体系构建与大学生创新能力培养研究、免费师范生化学创新教育研究与实践、现代教育技术在化学教学中的应用。

由于论文提交时间的跨度大，不同作者所提供的论文格式不尽相同，而编辑时间和编者的水平有限，论文的审理、编辑等工作难尽如人意，错误和不妥之处在所难免，恳请作者和广大读者批评指正。

本书的编辑出版得到了教育部化学教学指导委员会师范协作组的悉心指导，得到了北京师范大学教务处、华尔达集团、北京师范大学出版社以及北京师范大学化学学院的大力支持，同时得到了北京师范大学陈光巨教授和华中师范大学万坚教授的大力帮助。在此，对所有为本书出版给予关心和支持的单位和个人一并致以衷心的感谢!

第十四届全国高等师范院校
化学课程结构与教学改革研讨会组织委员会
2012年9月23日

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1. The Impact of Undergraduate Research in STEM in the US and at a Hispanic Serving Institution

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Abstract: Undergraduate education in the areas of Science, Technology, Engineering and Mathematics (STEM) in the United States is undergoing a systematic transformation as new studies report on the practices that have the highest impact on student learning. Undergraduate Research (UR) is one of those prominent practices. This article makes a case for the connectivity of UR to several of the other educational practices, and describes the essential features of UR and the benefits of a good UR experience in STEM to students. Current and projected changes in US demographics are described in relation to specific approaches in STEM education in the US in order to frame results of a preliminary study on the impact of UR at the University of Texas at El Paso. This article is also intended to provide those who are not familiar with US demographics and the issues of underrepresented minorities in the US with a clear view of why it is such an imperative to increase the representation of certain groups in STEM careers.

Keywords: Undergraduate research; STEM; Underrepresented minority; Hispanics; High-impact learning

Introduction

STEM undergraduate research in context: high impact practices

In 2008, the American Association of Colleges and Universities (AAC&U) published the report "High Impact Educational Practices", in which George Kuh, Director of Indiana University's Center for Post-Secondary Research, describes the 10 educational practices that will enable contemporary students to prepare better for 21st century professional challenges. Kuh describes how traditional markers of success, such as grade point ave- rage, retention in the major and graduation rates are only partial indicators of student success. He emphasizes that the value of a college degree lies in the knowledge, capabilities and personal qualities that will allow the individual to thrive and contribute to society and the changing economy in these demanding times of globalization. Kuh's report points to markers of student success in terms of developing the kinds of learning needed and the kinds of curricular, co-curricular and pedagogical educational practices that foster intended learning outcomes. The study that culminated in the above report demonstrates that the following educational practices contribute to student cumulative learning through engagement:

- First year seminars and experiences
- Common intellectual experiences
- Learning communities
- Writing intensive courses
- Collaborative assignments and projects
- Service learning/community-based learning
- Undergraduate research
- Diversity/global learning
- Internships
- Capstone courses and projects

The US Council on Undergraduate Research (CUR), defines UR as "An inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline". UR engages students in the use of cutting-edge technologies, places them in a mentored relationship (master-apprentice) with the research advisor, actively involves them in empirical observation, and elicits in them the excitement of working on important questions and the creation of new knowledge. The most exciting feature of UR is that of the ten practices listed above, it is considered the most comprehensive because it offers a combination of experiences that involve several of the above educational practices.

Connectivity between undergraduate research and other high impact practices

UR allows students to interact with other students like them, with more advanced researchers and with their mentor. They form a learning community which leads to a common intellectual experience. The latter, in turn results in a collaborative relationship between faculty and students. Intensive writing is necessary as students are required to write reports and make informal and formal presentations about their work. Often, the contribution of undergraduate researchers to discovery is significant enough to warrant their co-authorship in scholarly publications. This in fact is what Boyer describes as the most familiar forms of research, the scholarship of discovery, which "comes closest to what is meant when academics speak of research". Boyer argues that the scholarship of discovery, at its best, contributes not only to the stock of human knowledge but also to the intellectual climate of a college or university. Depending on the project, students may get involved in service to the community and learn in depth about a specific topic in the context of its impact to that community. UR related to service to the community is more common in the social, health and behavioral sciences. Essentially all research projects involve getting background literature information and learning about what others around the world are doing in the same field, leading students to attend large conferences, establish connections, and network with others outside their home institution. The latter provides excellent opportunities for students to learn about a subject in a culturally diverse global context. Furthermore, many programs nowadays send students abroad to conduct research, which also leads to global learning. Some students are able to start their research experience during their first year in college, and they attend relevant seminars and workshops on introduction to research. Students can conduct research voluntarily or for course credit, including capstone courses. Finally, a myriad of internships provided by potential employers involve research. Of the ten high impact practices described by Kuh in his report, it is easy to see why UR can be described as the one with the highest potential impact on student learning.

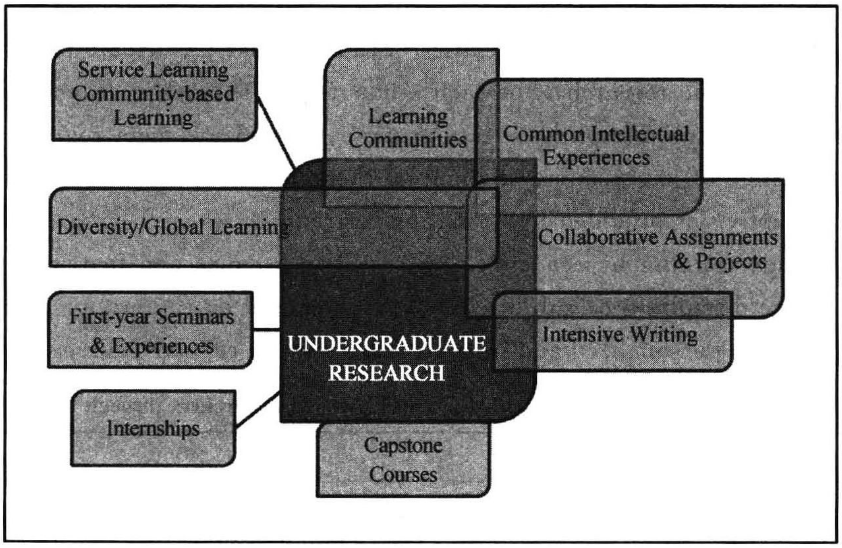

Figure 1　Overlap between undergraduate research and other high impact learning practices

Sheila Tobias of the University of Arizona states that "the undergraduate research experience in science has been acknowledged as the royal road to a career in science". The relationship of undergraduate research to the other high impact practices is illustrated in Figure 1. Note that some of the blocks overlap, which indicates that those experiences are part of every research experience. Other connections depend on the nature of the project and hence their blocks are represented as either touching the central UR block or simply connected by a line.

Undergraduate research programs in the US: basic types, essential features and benefits

For several decades, universities across the US have embraced the practice of involving students in undergraduate STEM research. It is a widespread practice, but for two important reasons, it is not exactly known how widespread it is. First, the number of undergraduate students that participate in research varies by institution and field. Second, the existence of one-on-one arrangements and formal multi-faculty/multi-student programs makes it difficult to get an exact count. One-on-one UR participation refers to those student-professor arrangements where the student agrees to conduct research under the professor's direction for a certain number of hours per week. It can be done voluntarily, for credit or for stipend/wages. In these one-on-one arrangements, training in specific techniques or the use of advanced instrumentation is done when the opportunity or need arises. Formal programs, on the other hand, are typically externally funded and go a few steps beyond the student-apprentice model. They may focus, for example, on a single major discipline like chemistry or cross disciplinary boundaries, like a neuroscience of drug-abuse program, which combines cohorts of students and faculty with interests in biology, psychology, biochemistry and bioinformatics. Students that participate in such programs still conduct one-on-one research, but each student does so with a different professor in various disciplines or sub-disciplines. As a group, the students meet regularly to participate in a wide-range of professional training workshops. Table 1 lists the most common workshops and activities provided by formal undergraduate research programs. Some programs also include training by academic experts in techniques and instrumentation commonly used in the disciplines or sub disciplines represented by the group. This training is intended to be more personalized and in depth than what a regular course would provide.

Table 1 Most common workshops presented to undergraduate researchers through formal programs

Responsible Conduct of Research
Maintaining Laboratory Notebooks
Preparing Research Reports and Conference Abstracts
Preparing Resumes and Curriculum Vitaes
Writing Journal Articles
Preparing and Delivering Technical Presentations
Selecting and Applying for Graduate School
Writing Personal and Professional Statements

Most formal UR programs are supported by federal sources of funding such as the National Science Foundation, the National Institutes of Health, the Department of Energy, the Department of Defense and the Department of Education. These agencies strongly encourage the programs they fund to engage students who are underrepresented in STEM fields, a crucial factor in the US educational arena, which will be discussed later in this article.

Science in Solution—The Impact of Undergraduate Research on Student Learning by Lopatto and co-workers is a study that has become one of the best guides for anyone interested in starting, developing or improving undergraduate research programs. In the study, Lopatto describes the essential features of undergraduate research in the sciences and the benefits of participation. We summarize Lopatto's findings below.

Essential features of undergraduate research

There are many successful models of UR programs. They vary by

- the type of institution

—Doctorate Granting University

—Baccalaureate (4-year), or

—Associate (2-year) Colleges

—Industry

—National Laboratories

- the type of student that the program serves

—entering first year students versus more advanced students

—underrepresented minorities (see below) versus non-minority

—local versus from out of the city/region

- the location of the program-country or region

—The United States

—Abroad

—Remote field station

- the field(s) of study or theme of the program
- the timing of the program

—academic year

—summer

Not one model fits every situation, but it is easy to adapt and implement aspects of existing models that are suitable to a particular institution and its students. The Lopatto study reports results from interviews to faculty and surveys taken by a large sample of students participating in various programs. The interviews and surveys revealed that there are several features that are common to many of the successful models. Faculty responses to the question "what are the essential features of UR?" can be summarized from the report as follows:

- Faculty should provide some structure to the experience
- There should be a good (state-of-the-art) environment
- Students should

—read scientific literature

—design some aspect of the project; have an opportunity to design and conduct the research; opportunities should exist for exploration of the student's ingenuity and creativity

—establish a mentoring partnership with faculty

—feel ownership of the project; work independently of faculty and have an opportunity to work on a team of peers; there should be increased independence in the daily routine and problem solving

—use careful and reproducible lab techniques; there should be a mastery of the techniques necessary to the research

—have an opportunity for oral communication

—have an opportunity for written communication

—have a meaningful or focused research question

—strive to produce a significant finding

—have an opportunity for attendance at professional meetings

—earn pay or credit

Using a mixed-method analysis of interviews and surveys of both faculty and students participating in one-on-one as well as formal programs, Lopatto's results point to four categories of features which are essential for successful programs.

• Project features

—Good research projects have a balance between being structured and unstructured. Structured projects are designed and assigned by the mentor to get concrete results in a reasonable amount of time and hence reinforce student's positive attitude towards research. However, they do not necessarily provoke student development, since the student has little or no input in its design. Structured projects feature little or no risk, making them more suitable for initial experiences, particularly those of short duration, like the typical 10-week summer research programs. Unstructured projects on the other hand allow students to have major input into their design and direction, and thus require the student to take risks. They have no timeline for delivery of results, and require a higher level of creativity, critical thinking and self-reliance, which in turn enhance student development.

—Good projects are more interesting if the student can make a connection with coursework, and future coursework becomes more attractive when students make a connection with prior research experiences

• Procedural features

—Sufficient contact hours with the mentor are provided

—The mentor is available for questions

—Social activities are organized for faculty and student researchers to interact beyond the research work

—Work is conducted within a group of other researchers—out of 5 200 responses to a survey, only 2.5% said that "working with peers was the worst part", whereas 37% said "working with peers was the best part"

• Students are able to provide input into the project development (see above)

—Structural features

—Individual and group tasks are assigned

—A schedule for research goals and meeting times is set

—Initial set of primary literature articles are provided

—Posters and reports are required

—Co-curricular activities are scheduled (see table 1 for an example of program activities)

• Communication features

—Effective presentation and reflective critique opportunities are provided

Benefits of UR

The Lopatto' study also points out that the benefits to students are rich and varied. Although one of the main goals of UR program directors is to recruit students, retain them, and entice them to pursue careers in STEM fields, it has become evident that UR is not necessary to achieve this goal. Lopatto argues that in the US, the majority of students of Science and Engineering have made up their mind about their interest in these fields before they enter college. The true benefits of an UR experience are primarily related to:

• Career differentiation

Students are able to narrow their interests. The experience allows students to determine whether for example they are more inclined to developmental biology than genomics, neuroscience than chemistry or biophysics than astronomy.

• Career clarification

—Students that initially thought of themselves as pre-medical migrate to science PhD programs. The study shows that 15% of students that self-identify as pre-medical change their plans in favor of PhDs, whereas fewer than 4% migrate in the other direction.

—A very small set of STEM students decide that a career in STEM is not for them after a research experience (exact numbers are not reported in the Lopatto' study, only anecdotal comments from surveys). This is interpreted as a positive outcome since the UR experience provides those students with "the insight about their incompatibility with a career in science and the courage to face the fact".

• Improvement of student attitudes

—The majority of students report that a research experience helps them become better students and connect classroom experiences with their research

—Most students report an increase in self-confidence

• Better prepared to work independently

• Thinking more like a scientist

—Students report acquiring patience and higher tolerance for obstacles

• Value of continued experience

—During a first experience, students' gain is associated with an increase in maturity as well as early training in techniques, instrumentation, safety, and ethics in research

—In a second or continued experience, students demonstrate that

• It is easier to find, read and understand primary literature

• They have more opportunities for publication

• They have more opportunities for giving presentations

• They acquire a greater sense of accomplishment

• They develop leadership skills as they are designated peer mentors

• They have greater learning gains as they learn more by teaching others

Despite Lopatto's evidence that participation in UR does not increase the number of students that end up pursuing careers in STEM, there is strong evidence indicating that participation in UR increase the interest of students in pursuing STEM careers and graduate studies. A study conducted by Russell, Hancock, and McCullough and published in the journal Science in 2007 surveyed 3 400 students between the ages of 22 and 34 who had obtained bachelor's degrees in STEM fields and had participated in UR. Of those surveyed, 24% indicated that participation in UR had not changed (increase or decrease) their desire to pursue a career in STEM, while 68% indicated that the UR experience had indeed increased it. Another striking result of that study is that although 37% of the respondents indicated that they had expectations to pursue a PhD before entering college, 63% did not have such expectations. Of the latter, 29% reported that they had developed "new" expectations of pursuing a PhD degree while in college. In a control sample of individuals who had also received bachelor's degrees in STEM but had not participated in research, only 5% reported developing "new" expectations of pursuing a PhD degree while in college. When comparing the last two numbers, one realizes that there may be a correlation between UR and increased expectations of obtaining a PhD after graduation. Another important result of the study is that 30% of undergraduate researchers with more than 12 months of research experience reported that they expected to obtain a PhD compared to only 13% of those with only 1～3 months of research experience.

US STEM workforce, demographics and approaches to STEM education of underrepresented minorities

The relatively short history of the US has been characterized by an influx of immigrants from various regions of the world. As a consequence, the present US population is composed of five races and two ethnic groups. Race and ethnicity are social categories;