

## **Exploring New Models for Authentic Undergraduate Research with Two-Year College Students:** An Undergraduate Research Collaborative Linking Ten Chicago-Area Two-Year Colleges with Local and Regional BS/MS/PhD Institutions

### **I. OVERVIEW**

This project aims to establish an Undergraduate Research Collaborative (URC) led by two-year college (2YC) students and faculty, working as equal partners with local and regional institutions of higher learning. The project has the considerable advantage of being built on a foundation of successful undergraduate research (UGR) programs already in existence at the participating 2YCs. This URC will:

- 1) Create, assess, and disseminate at least three complementary models that engage 2YC undergraduates in student-centered, faculty-mentored, authentic UGR;
- 2) Empower 2YC faculty to create sustainable on-campus UGR programs; and
- 3) Build equal collaborations among partnering institutions.

The partners in this Collaborative are united in their desire to:

- 1) Identify and recruit promising young scientists from 2YCs into the STEM disciplines, especially from traditionally under-represented groups;
- 2) Train 2YC students to become effective practitioners of science;
- 3) Instill in 2YC students the confidence to pursue science as a profession;
- 4) Encourage 2YC students to complete their undergraduate and graduate STEM education; and
- 5) Transform the cultures of participating 2YCs by embedding intensive research experiences during the academic year and summer into their curricula and their courses.

The 2YCs participating in this project are: The seven campuses of the City Colleges of Chicago (Harold Washington College is the lead institution); William Rainey Harper College; Oakton Community College; and College of DuPage. These institutions are located in the Chicago-metro area and collectively serve approximately 106,000 undergraduates annually, 42% of whom come from underrepresented groups. In City Colleges of Chicago, 70% of the 50,000 undergraduates are either Black or Hispanic.

Other partners are: Illinois State University, Youngstown State University, Chicago State University, and Hope College. Informal agreements to host summer students and/or build faculty collaborations have been made with DePaul University, Loyola University of Chicago, Northern Illinois University, the University of Illinois at Chicago, and Case Western Reserve University. The DuPont-Northwestern-Dow Collaborative Access Team at the Advance Photon Source and the Chemical Engineering Division, both located at Argonne National Laboratory, are also working with the Collaborative. Joliet Junior College has also expressed interest in the professional development opportunities of this URC.

Approximately 6.6 million students take undergraduate courses at 2YCs annually, and a substantial number of under-represented students start their postsecondary educations there. However, only a fraction of 2YC students are currently engaged in UGR, which presents a significant problem when they transition to senior institutions. As part of our effort in this area, this URC will make a substantial contribution to the scholarship of teaching and learning through its assessment and evaluation activities, which are centered on the following questions:

1. How do 2YC students who engage in UGR benefit and/or how are they adversely impacted?
2. How do the benefits of UGR differ for 2YC students versus students at 4Y institutions?
3. What activities motivate 2YC students to pursue science as a career?
4. What activities empower 2YC faculty to build UGR programs?
5. What activities sustain UGR on 2YC campuses?

### **II. INTRODUCTION**

The question of “What Works?” with respect to UGR in chemistry at 2YCs is of vital importance to its successful implementation on a broad and sustained basis. This question has only recently been asked and is, as yet, unanswered. Although 2YCs are considered “Bastions of Chemical Education”,<sup>1</sup> and their prowess as teaching institutions is well established, research activities at these institutions are not widely documented.<sup>2-3</sup> Given the strong link between the benefits of UGR and several aspects of the 2YC core mission<sup>4</sup> such as providing a quality learning environment,<sup>5-7</sup> strengthening the local community,<sup>8</sup> and developing a scientifically literate workforce,<sup>9</sup> it is perhaps surprising UGR has not been more widely embraced by 2YCs as part of their chemistry curricula.<sup>2-3</sup>

If one believes that “Increasing participation of underrepresented minorities is critical to ensuring a high quality supply of scientists and engineers in the United States over the long-term,”<sup>10</sup> then answering the question of “What Works?” in 2YC UGR is essential. By virtue of the size and diversity of their student bodies, this country’s 1,157 2YCs are a rich source of untapped academic talent. Nationwide, 2YCs educate 46% of all undergraduates, and this group is the most diverse student body with respect to age, financial status, and ethnicity. The average 2YC student is 29 years old. Thirty three percent (33%) of 2YC students receive financial aid. With respect to ethnicity, 47% of our nation’s Black students, 56% of our Latino students, 48% of our Asian/Pacific Islander students, and 57% of our Native American students attend 2YCs. Among first time college students, 45% attend 2YCs.<sup>11</sup> In addition, the number of students attending 2YCs has increased by 14% between 1990 and 2000, with enrollment of underrepresented students increasing by 65% during the same time period.<sup>12</sup> This trend shows no signs of slowing as the costs of attending a 4Y institution increase. Most importantly, more than 40% of recent graduates in science and engineering attended a 2YC at some point along their educational path.<sup>12</sup>

To truly increase the diversity and magnitude of the nation’s research capacity, and ensure a high quality supply of scientists and engineers over the long-term, it is imperative to tap into the 2YC talent pool and engage more 2YC students in authentic UGR. To sustain this effort, 2YC faculty must be empowered to mentor student-centered UGR as part of their regular academic duties, and to develop research projects that tap into their intrinsic interests and expertise. Building mutually beneficial long-term relationships among 2YCs and senior 4Y institutions is a key to sustainability. Therefore, a URC led by 2YCs partnered with 4Y institutions is both relevant and necessary.

This URC project is centered on providing a robust academic year UGR experience for 2YC students scaffolded by confidence building and professional development activities. This will be followed by a rigorous, summer UGR experience either with a 4Y partner or at a student’s home campus. The academic year experience will begin in the fall semester and will focus on training 2YC undergraduates to become effective practitioners of science. To this end, students will be enrolled in a formal research training course based on the *Fundamentals of Modern Scientific Research* model described below. At the same time, professional development events like *Meet a Scientist Seminars*, *Student Development Workshops*, and *Working Weekends* will round out students’ technical and soft skills, which have become essential components of the modern marketable scientist.

During the fall semester, students will concurrently undertake an authentic UGR project, either individually or as part of a team. They will work closely with 2YC faculty mentors to advance their project during the spring, and simultaneously develop a collegial relationship with prospective summer mentors from partnering institutions. Travel to prospective summer host campuses will build students’ comfort level about transferring to an unfamiliar environment. The spring semester will culminate in an UGR symposium during which all students will make poster presentations and celebrate their accomplishments prior to leaving for their summer research experience. The summer UGR experience will immerse 2YC students in an exciting and intense environment, where they will meet and interact with peers who value science as much as they do. They will also interact with faculty researchers committed to student-centered UGR.

The answer to “What Works?” in UGR is unique to every institution,<sup>18</sup> and perhaps even more so for 2YCs, where UGR is currently neither a common part of the institutional culture nor a formal part of the promotion and tenure reward system. Indeed, at many 2YCs it is formally or informally inhibited by a range of structural and attitudinal barriers. This Collaborative intends to change this paradigm by bringing together a group of individually distinct but geographically proximate 2YCs in the Chicago metro area who are current leaders in 2YC UGR, along with 4Y institutions who are seeking equal partnerships with 2YCs. Each 2YC will be a metaphorical test tube that adopts, adapts, and develops a model of UGR that works for them, with input, support, and mentorship from other members of the Collaborative. In addition, this URC will create robust models for “What Works?” with respect to building equal partnerships among institutions who share the common aim of training promising young scholars to become effective practitioners of science. Overall, this URC will make an unprecedented contribution to the scholarship of teaching and learning, and lay the foundation for future studies of the benefit of UGR experiences on 2YC students, faculty, administrators, and institutions. It will significantly increase the number of U.S. citizens who participate in the chemical enterprise, and strengthen the chemical enterprise itself. To paraphrase Lee Shulman, President of the Carnegie Foundation for the Advancement of Teaching, this URC will

provide 'visions of the possible', by shattering conventional notions of what 2YC students and faculty are capable of when they take a leading role in tackling daunting issues of national significance.

### **III. PROJECT DESCRIPTION AND RESEARCH**

This UCR will provide significant advantages to both students and faculty compared with the current environment, where 2YCs are working essentially independently and with limited resources because:

1. The collaborative atmosphere will promote efficient and vigorous exchange of ideas between faculty working with different UGR models;
2. A more connected network between 2YCs and 4Y institutions will provide students with more opportunities and greater diversity in research opportunities;
3. Scale-up of the UGR experience will have a greater impact both locally and nationally; and
4. Resources provided by this UCR project will enable 2YC students to have greater commitment to developing intellectual skills.

The economy of scale offered by this Collaborative will allow current activities to be expanded to include more traditionally underrepresented students; more thoroughly investigated and evaluated; and more widely disseminated and replicated. Most importantly, this project will hasten into the mainstream the important contributions that these innovative 2YCs are making to the quality of the first two years of undergraduate science education and of the scientific enterprise overall.

#### **Student Issues**

Several issues related to 2YC students' needs must be considered when designing an UGR program that works.<sup>1-3,19</sup> First, most 2YC students are first- and second-year scientists, and lack confidence and experience compared with their junior and senior counterparts. These factors deter many 2YC students from enrolling in summer UGR programs far from home. This project will provide that critical first UGR experience on students' home campuses, where they feel secure and with faculty they know and trust. As students' confidence and abilities grow, they will be encouraged to pursue off campus UGR in a more intense environment, with a URC partner with whom they have also developed knowledge and trust. This approach will also stimulate students to matriculate to 4Y institutions to complete their STEM degrees.

To compound the challenges presented by the issues of confidence and ability mentioned above, many 2YC students face familial and financial constraints that make traveling far from home difficult. A local, home-college UGR experience eliminates the need for students to leave their family for an extended period of time. Student stipends reduce dependence on outside income, providing students with more time to immerse themselves in a research project that adds value to their intellectual capacity and prepares them for future intellectual challenges.

Finally, many 2YC students are first generation college students, who lack strong role models for becoming professional scientists. They have never considered science as a career, and do not know about the opportunities, challenges, and rewards of practicing science. This project will provide students an opportunity to meet and work with established research scientists, and will provide first-hand experience of the thrills of working in a top-class research laboratory. Attention to these needs is critical to achieving success in the recruitment and retention of 2YC undergraduates into the sciences.

To address these issues, the URC will annually provide direct support for 32 2YC undergraduates to engage in academic year research training and UGR via the models described below. These students will be paid a stipend of \$900 per semester. During the summer, the URC will annually provide direct support for at least 30 2YC undergraduates to pursue UGR research with 4Y URC partners or on their home campus. These students will be paid a stipend of \$400 per week. Paying stipends is necessary to relieve the burden of working outside jobs, thereby permitting students the precious time required to immerse themselves in their research and the URC activities. In addition, student tuition for the research courses will also be paid by the project.

#### **Models of Authentic 2YC UGR**

The Chicago metro area is fortunate to have three 2YCs that have developed models for authentic student-centered UGR programs. Harold Washington College (HWC) and Harper College (HC) have cooperatively developed a Scaffolded Training (ST) program through the NSF Small Grant for Exploratory Research (SGER) program. The third institution, Oakton Community College (OCC), has developed an Interdisciplinary Team Research (ITR) model that involves up to eight students interacting with up to five

faculty members in a classroom-like setting. These core models will be adapted and adopted by the other 2YCs in the URC. In addition, a hybrid of the ST and ITR models, Distributed Team Research (DTR), will also be piloted and assessed among the seven campuses of the City Colleges of Chicago. We intend to examine the unique benefits and limitations of each in supporting 2YC student involvement and motivation in UGR. Finally, components of other models being developed nationwide, including the embedded research model being developed by the Ohio-REEL Undergraduate Research Center (with whom we have an established formal relationship, *vide infra*) will be implemented as appropriate.

***Model #1 – Scaffolded Training:*** This model adapts the traditional student-faculty mentor relationship to the needs of 2YC students, and builds their confidence and abilities through a scaffolded UGR experience on their home campus during the academic year. 2YC students and faculty mentors develop a research question that is mutually interesting and appropriate for the student's abilities. The ST experience is supported by formal coursework that illustrates the techniques of modern and ethical chemical research, seminars that allow students to present their work and meet with 4YC faculty, and *Working Weekends* during which 2YC students and faculty travel to the campus of a 4YC partner for a facilities tour and a short course in modern research instrumentation. These activities contribute not only to students' intellectual and professional growth, but also build their confidence and ability to carry out authentic, independent research.

In addition to building a student pipeline, this model contributes to the professional development of the 2YC faculty and sustainability of the 2YC research effort. As a result of HWC's SGER, PI Higgins and Professors Graham Peaslee and Kenneth Brown of Hope College have developed a research partnership to assess the toxicity of noble metal nanoparticles on aquatic ecosystems. During academic year 2005-2006, Higgins's students learned nanoparticle synthesis and characterization, and will spend summer 2006 at Hope College measuring nanoparticle toxicity on fathead minnows. Higgins also plans to spend June 2006 at Hope, working in the research lab with his students, Michele McMillan and Robert Johnson. Not only does this keep Higgins engaged in his discipline, it also eases McMillan and Johnson's transition to a new and unfamiliar environment with new and unfamiliar faces.<sup>1,13-14</sup> When McMillan and Johnson return to HWC in Fall 2006, they will be in a position to help Higgins mentor other HWC undergraduates.

This is just one example of how the ST model creates meaningful experiences for 2YC undergraduates. It benefits students by providing an intellectually safe and stimulating academic experience. It benefits faculty by promoting scholarly partnerships. And it benefits institutions by promoting a sustainable 2YC UGR program. This is the experience the proposed project seeks foster among the other partners.

The ST model is currently in place at HWC and HC, where it has been successfully implemented by PI Higgins, and co-PI Dowd. PI Higgins will work with other HWC faculty to engage two students in supramolecular chemistry projects, a project around which he has built a collaboration with faculty from Chicago State University. At HC, Dowd will work with other faculty to engage two students in studies of novel carboxypeptidase B inhibitors. College of DuPage (COD) Professors Jarman and Shih will also implement this model with at least three students beginning in Fall 2006. The COD team will expand an existing partnership with Argonne National Labs (ANL) and study novel materials for fuel cell electrodes.

***Model #2 - Interdisciplinary Team Research:*** For five years, OCC's ITR model has provided students with academic year, on-campus UGR working side-by-side with an interdisciplinary team of 2YC faculty from three different departments. Remarkably, OCC has developed this without any outside funding, which has limited its dissemination and formal study by the wider academic community.

As part of the ITR, students enroll in a formal research course and receive academic credit. Students formulate their own research questions, conduct their own literature reviews, and work in teams to design, implement, and evaluate their own experiments from an interdisciplinary perspective. All of the faculty mentors are present during the course to co-direct the research and co-mentor the students, which provides a meaningful interdisciplinary experience for everyone. As part of the experience, each student selects an article from the primary literature and presents the paper to the class, in the fashion of a graduate student journal club. At the conclusion of the semester, students present a poster of their work. Presently, however, no formal pipeline exists to allow OCC students to continue their UGR experience once their course has ended.

The OCC group will continue their work involving isolation and characterization of bird and reptile lysozymes, and will engage eight students per semester. The OCC team has built collaborative partnerships with faculty from Northwestern University, University of Illinois at Chicago, Northern Illinois University, and the DuPont-Northwestern-Dow Collaborative Access Team (DND-CAT) at Argonne National Labs. Up to three HC faculty intend to adopt this model, and engage six students in environmental testing and monitoring projects.

***Model #3 - Distributed Team Research:*** The DTR model is a hybrid of the ST and ITR models. The vision of DTR is to have small teams of students at separate campuses working in parallel on a mutually interesting research question. Each student team will be mentored by a team of faculty on their home campus. At regular intervals during the semester, all of the student teams will come together at a common location and share results, much like a research group meeting. Students will also be encouraged to communicate with each other between meetings to foster collaboration and analysis skills.

This model will be piloted by City Colleges of Chicago (CCC), which consists of seven distinct campuses distributed throughout the city. Teams are currently in place at three campuses in the District: HWC, Truman College, and Olive Harvey College. Each of these campuses will contribute faculty and students to the nanoparticle toxicity project, which involves a partnership with Hope College. This research project is ideal for this environment, because it allows the strong chemistry departments at HWC and Olive-Harvey to work with the strong biology and biochemistry department of Truman College, using the District's resources synergistically.

PI Higgins and co-PI Harris will recruit CCC students from all seven District campuses during Summer 2006. They are currently working with the District Grant Coordinating Council to identify twelve interested and able students.

#### **Nature of 2YC Research Activities**

As mentioned above, several 2YC faculty in this URC have active, student-centered UGR programs. Six projects are described below. These faculty will share their expertise developing a sound research program with other 2YC faculty, which is expected to lead to new research collaborations within the URC. A natural strength of the 2YC working environment is its interdisciplinarity, due to the proximity in which scientists from different departments interact and share resources. Therefore, although the research activities will be led by chemistry faculty, faculty from other departments, such as biology, physics, and allied health, have been recruited. This is a true representation of the chemical enterprise, which is inherently interdisciplinary and becoming more so.

***Project #1 - Flexible Macrocycles:*** Supramolecular chemistry is one approach to designing shape selective catalysts and chemical sensors.<sup>15</sup> One strategy involves the "weak-link" approach, which utilizes flexible, hemi-labile ligands<sup>16</sup> to form bi-metallic macrocycles in near quantitative yields.<sup>17</sup> These macrocycles are building blocks for assembling more complex structures by the addition of linking molecules that rupture the weak-link and bring together two or more macrocycles to form cage-type structures. By the judicious choice of macrocycle and linking molecule, cages of specific shape, sizes and hydrophobicity can be rationally designed. To date, a majority of the published weak-link macrocyclic structures utilize air-sensitive phosphine-based ligands<sup>18</sup> and air-sensitive transition metals.<sup>19</sup> Our work concentrates on synthesizing air-stable ligands and expands this chemistry to explore less expensive and more air-stable transition metals. We are also interested in developing microwave synthetic routes, a technique gaining favor in the pharmaceutical industry.<sup>20-21</sup> Students involved in this project learn how to design and carry out both organic and inorganic syntheses using both thermal and microwave techniques, principles of retrosynthetic analysis, NMR, IR, UV-Vis, GC-MS, HPLC, and electrochemistry.

***Project #2 - Nanoparticle Toxicity:*** This work aims to understand and quantify the environmental effects of nanomaterials on aquatic ecosystems. As nanomaterials proliferate, treatment and disposal of this waste will become an increasingly important issue. Since the physical and chemical properties of nanomaterials are distinct from their bulk cousins, one must also assume that their toxicological properties differ as well.<sup>22-23</sup> We are interested in measuring the toxicity of gold and silver nanoparticles as a function of nanoparticle chemical identity, size, shape, and surfactant using water fleas (*Daphnia magna*) and fathead minnows (*Pimephales promelas*). There are an abundance of noble metal nanoparticle synthetic pathways in the literature, and high quality gold and silver nanospheres and nanotriangles can also be synthesized in a straightforward manner from published methods.<sup>24-25</sup> All noble metal nanoparticles

require a surfactant to prevent aggregation, and the surfactants of interest are monodentate alkane thiols that form strong covalent bonds to noble metals via the sulfur atom. Since the surfactant may be toxic even if the nanoparticle is not, control studies will be done to separate these effects. Acute and chronic toxicity studies of water fleas<sup>26-27</sup> and fathead minnows<sup>28-30</sup> will follow established protocols.

*Project #3 - Protein Isolation and Characterization:* The goal of this project is to isolate and structurally characterize bird and reptile lysozymes. These proteins are isolated and concentrated from their sources and purified using chromatography. Protein electrophoresis is used to partially characterize the proteins and vapor diffusion is used to crystallize the proteins. Once crystals have been obtained, the structures are elucidated with the aid of the DND-CAT at Argonne National Laboratory, who assists in the analysis of the x-ray crystallography data. Students who work on this project learn protein extraction, purification, and isolation techniques, as well as protein and peptide characterization by spectroscopic means. They also learn how to grow crystals and solve crystal structures.

*Project #4 - Environmental Testing and Monitoring:* In the twenty-first century, we are faced with the daunting task of purifying the world's water supply. Many common pollutants have long half-lives in water. It is currently estimated that 10,000 - 100,000 new organic compounds are being discovered every year. Many of these compounds find their way into the fresh water supply and, unlike most naturally occurring organic compounds, biodegrade slowly and remain in the water supply. One approach to this problem utilizes photodegradation to break down organic pollutants that decompose slowly. Simple photolysis,<sup>31-32</sup> photolysis in the presence of ozone or hydrogen peroxide,<sup>33</sup> and photolysis in the presence of heterogeneous photocatalysts<sup>34</sup> are some of the methods used to eliminate organic pollutants in our fresh water supply. The efficiency of these methods can be measured and compared on several classes of pollutants. Reaction conditions will be varied to mimic conditions found in nature (e.g. temperature, pH, pollutant concentration and mixtures, and presence of humic substances). These procedures will determine the feasibility of using each technique to reduce pollutants in water, and identify the by-products of decomposition. Students involved in this project will learn some common analytical techniques and will become familiar with ion chromatography, HPLC, GC/MS, UV/VIS, and NMR.

*Project #5 - Synthesis and Kinetic Study of Novel Carboxypeptidase B Inhibitors:* Metallo-carboxypeptidases are involved in many processes within animal cells and tissues. In addition to the breakdown and digestion of proteinaceous food molecules, these enzymes play a regulatory role within animal cells and plasma, and have been identified in bacterial cells.<sup>35-36</sup> This research project focuses on inhibition studies of carboxypeptidase B (CpB), a digestive exoprotease isolated from porcine pancreas and which is structurally similar to metallo-carboxypeptidases found in human cells and plasma. Although primary sequence homology between the pancreatic and the regulatory carboxypeptidases is low (15–20%), all of the amino acid residues that have been identified as catalytically important are conserved amongst CpB-type enzymes.<sup>37</sup> This fact makes pancreatic CpB a convenient and readily available model for kinetic study of the regulatory carboxypeptidases. It also indicates a broad potential for pharmaceutical application of novel inhibitors. The goal of this research project is to synthesize various inhibitors for kinetic study and pH profiling. This project is ideal for undergraduates because the synthesis and enzyme assay techniques don't require exotic equipment, the CpB enzyme is easily acquired, and its solutions are reasonably stable. Students will learn synthetic organic and characterization techniques using NMR, FT-IR, UV-Vis, and HPLC. The kinetic assays can be done on a UV-Vis spectrophotometer using a chromophoric substrate.<sup>38</sup>

*Project #6 - Novel Materials for Fuel Cell Electrodes:* This project is an expansion of Professor Jarman's work with his Honors chemistry class at the College of DuPage (COD) and involves a partnership with ANL Division of Education Programs. This partnership has given students the opportunity to use experimental techniques such as X-ray fluorescence, X-ray diffraction, flame atomic absorption, and polarized light microscopy. Building on this, three COD students intend to work with the Hydrogen and Fuel Cell Materials Group of the Chemical Engineering Division, investigating improved electrode materials for hydrogen fuel cells. The goal of the project is to establish structure – function relationships in the fuel cell electrodes. The tasks involved include synthesis of materials using ceramic tape-casting techniques, preparation of electrodes from these ceramics, evaluation of electrode performance in test cells, microscopic evaluation of electrode microstructure, and phase analysis with X-ray diffraction. Given the proximity of COD with ANL, it is a natural fit. Students can perform some experiments at COD using

X-ray equipment from the Physics department, access remote instrumentation via CyberInfrastructure provided by the YSU/STaRBURSTT partnership (*vide infra*), and also work at ANL.

### **Professional Development for Students**

To complement academic year UGR activities, several professional growth opportunities for students will be developed. These include: 1) New courses, to rapidly train students to undertake UGR; 2) *Meet a Scientist Seminars*, during which students meet prominent members of the scientific community, role models, and potential mentors; 3) *Student Workshops*, to develop essential “soft skills” such as oral communication and technical writing, and to discuss questions of ethics; and 4) *Working Weekends*, during which students visit other campuses to meet future mentors, take facility tours, and have some “hands on” time with new instruments. These activities will also offer URC students and faculty an opportunity to come together, building an *esprit de corps* that promotes the scholarly nature of collaborative learning. Students will meet and interact with faculty from collaborating institutions and learn about summer research opportunities. Faculty will come together and discuss future collaborations. This will be an important step in building the 2YC students’ confidence in their ability to do science.

*New Courses*: HWC, HC, and OCC have already developed formal courses that give students academic credit for lab work related to UGR. These courses will be models for COD as well as future partners and institutions contacted during dissemination. These courses are Chem 295 at HWC and HC, and CHEM/BIO 290 at OCC. All are 2-3 credit hour lab-based research courses.

*Fundamentals of Modern Scientific Research (FMSR)*: This new course is envisioned to be 3-4 credit hours in length and will be piloted at HWC and HC during the first project year. The goals are to: 1) Address the technical and ethical nature of high-quality scientific research; 2) give students quality hands on time with modern scientific instrumentation; 3) showcase best practices in the laboratory with respect to promoting a safe working environment and keeping a laboratory notebook; 4) promote the soft skills necessary for success in the 21<sup>st</sup> century workplace; and 5) build self-confidence in students’ ability to do science. Upon conclusion of FMSR, students will have: 1) Identified a topic of interest for their own research efforts; 2) begun a literature review of their topic, which they will have presented to their 2YC student and faculty peers; 3) gained significant proficiency in asking and answering scientific questions; and 4) built a collegial relationship with their faculty mentor.

*Meet a Scientist Seminar (MSS)*: This activity will be modeled after a graduate school seminar. Its goal is to allow students to meet and interact with prominent members of the chemistry community and learn about professional experiences in the chemical sciences. Speakers will be selected to emphasize gender and ethnic diversity, and to showcase scientists who match the backgrounds of our students. Examples of individuals who can be profiled at these events are Jim Shoffner and R. Bruce Merrifield. Shoffner is an African-American chemist with a distinguished career in industry and service to the community. He is currently retired, lives in Chicago, and serves the American Chemical Society at both the local level (Committee on Public Affairs) and national level (Committee on Minority Affairs). In his spare time, he is an Adjunct Professor of Chemistry at Columbia College. Merrifield is Professor Emeritus at Rockefeller University and winner of the 1984 Nobel Prize. He began his scientific career at Pasadena City College, a 2YC in California. These individuals are powerful examples who can convince 2YC students that they, too, can become scientists.

We intend to provide at least one URC-wide MSS seminar during both fall and spring semesters, with the location alternating between the City of Chicago (hosted by CCC) and the suburbs (hosted by either HC or OCC). Both PI Higgins and Susan Shih (COD) are Board members of the Chicago Section of the ACS, with significant professional connections in local academe and industry.

*Student Workshops (SW)*: Beyond formal qualifications such as content knowledge, data analysis, and critical thinking; personal skills, such as effective communication and leadership, are also necessary to ease the transition from 2Y to 4YC. To enhance the transferability and promote the success of our students, we will offer URC-wide half-day workshops that help students grow in essential areas such as oral and written communication, appropriate risk taking, working under pressure, time management, and leadership. We intend to provide at least one URC-wide student workshop during both fall and spring semesters, with the location alternating between CCC, and either HC or OCC.

SWs will be led by faculty members of the collaborative and experts from the private sector. For example, PI Higgins is a graduate of Project Kaleidoscope's Leadership Institute, and is well-qualified to lead a seminar on either time management or leadership. Faculty from other departments can also be tapped. For example, Philosophy faculty could lead a discussion about ethics, or English faculty could lead a technical writing seminar. Several HWC non-science faculty have voiced their enthusiasm to develop these activities for the Collaborative. From outside the URC, Ms. Gia Interlandi is well-known in the Chicago area for her half-day, interactive public speaking seminar. Ms. Interlandi has tailored this seminar to undergraduates, and is local resource the URC could employ to help our students grow.

Working Weekends (WW): WWs are an opportunity for students to visit a potential summer research site, and learn some new chemistry at the same time. A WW is a full day, hands-on workshop during which students learn about modern techniques and instrumentation essential to doing high-quality chemistry. It is also a wonderful example of the gestalt nature of this URC, which allows many institutions to share expertise and resources that advance the collective research enterprise.

Potential topics for working weekends include:

- Micro and Nanofabrication at the Nanotechnology Core Facility at University of Illinois at Chicago
- Nuclear Chemistry at Hope College
- Crystal Growth and X-Ray Crystallography at ISU
- Single and Multidimensional NMR Spectroscopy at CSU
- Remote Instrumentation (via CyberTechnology) at YSU

We intend to provide at least one URC-wide WW during both fall and spring semesters, with the location rotating among the 4Y partners of the collaborative.

### **Building Bridges: Summer Research Experiences for 2YC Undergraduates**

During the academic year, the focus will be on training students to become effective practitioners of science using a combination of laboratory-based training, coursework, and professional development activities. During the summer, students will be encouraged to engage in an off-campus UGR experience. This experience will be hosted by established, undergraduate-focused institutions that are committed to getting to know 2YC students prior to their arrival on campus. These institutions are a mix of liberal arts colleges, comprehensive universities, and research-intensive universities. They also represent a sample of schools to which 2YC students from the URC are likely to transfer.

Because of the summer research opportunity, this project is in a unique position to study the transfer of a 2YC research student to a 4YC. Since our intent is to open the pipeline to 4YC research by students from 2YCs, it is imperative that we study this transition, what successes and struggles are encountered by the students as they make the transition, and what supports need to be in place - both at the 2YC and the 4YC - to ensure that the students continue their work successfully.

ISU-2YC-REU: Under the direction of co-PI Ferrence, ISU will host eight 2YC undergraduates from the URC for a 10 week REU-like UGR experience. Ideally, this cohort will consist of 1-2 students from each 2YC in the URC, so students will know each other by their past participation in academic year professional development activities. They will also be familiar with a great deal of the research being carried out at ISU due to ISU Chemistry faculty visitations to the involved 2YCs. ISU is committed to providing these Fellows with a first rate undergraduate research experience and to making these new members of the ISU campus community comfortable during the Illinois State experience.

For the undergraduate research experience, 2YC Fellows will be matched with faculty mentors and will attend weekly round tables involving Fellows, ISU faculty mentors, and other ISU summer undergraduate researchers. Early round tables will focus on familiarization to ISU, safety with emphasis on the ISU Chemical Hygiene plan, and Responsible Conduct of Research (RCR). As round table participants gel into an ISU-URC team, discussions will shift to a focus on team research activities and outcomes. Various faculty mentors will lead the weekly discussions, yet the format will emphasize active student discussion of research as opposed to passive seminars. To complete the ISU-REU experience, 2YC Fellows will be invited to present the nature and results of their research at a capstone UGR Symposium.

The nine ISU faculty chosen to mentor the 2YC Fellows provide a blend of new, emerging, and highly established faculty from wide ranging areas of chemistry and overlapping research interests. They are:

David Cedeño (porphyrin photophysics; photodynamic therapy photosensitizers), Gregory Ferrence (organolanthanide-porphyrin complexes; X-ray crystallography), Jon Friesen (recombinant human coproporphyrinogen oxidase interactions; phosphatidylcholine biosynthesis), Christopher Hamaker (X-ray crystallography; transition-metal Schiff-base complex catalysis), William Hunter (Chemical Education; evaluation and assessment, including the proposed URC), Marjorie Jones (porphyrinogen substrate metabolism), Timothy Lash (porphyrin analog synthesis), Craig McLauchlan (X-ray crystallography; bio-mimetic insulin-enhancing coordination complex synthesis), Steven Peters (electron paramagnetic resonance (EPR) spectroscopy; macrocyclic radicals) and Lisa Szczepura (metalloporphyrin electrochemistry; supra-octahedral clusters; X-ray crystallography). Space constraints preclude a detailed description of each research activity; however, biographic sketches for ISU Senior Personnel cite recent publications mostly with undergraduate coauthors and related to the research activities in which 2YC Fellows will engage. Consultation of these citations will show a rich, productive undergraduate research tradition among Senior Personnel.

Regarding transition of 2YC Fellows to the ISU community, ISU has a long-standing commitment to the recruitment and retention of a diverse student body, aided in part by the Minority Student Academic Center, the Office of Minority Research Opportunity, and the Multicultural Center. The University is actively committed to redressing the current under-representation of women and minorities through the following three programs managed by the Center for Mathematics, Science, and Technology (CeMaST): Louis Stokes-Alliance for Minority Participation (LSAMP), a program in which proposed faculty mentors, such as Lisa Szczepura, are registered mentors. In addition, a number of NSF CSEMS (Computer Science, Engineering and Mathematics) scholarships target under-represented students and the Bridges to the Baccalaureate (NIH funded) program actively recruits minority students in the biomedical fields. Additionally, LSAMP students in Chemistry will be able to serve as mentors to the new students on campus to make them feel comfortable during the Illinois State Experience.

To facilitate a positive, comfortable transition to the ISU community, 2YC Fellows will be matched with undergraduate researcher hosts already matriculating at ISU. Organizers and mentors will work closely with 2YC Fellows and hosts to provide the necessary support to help Fellows feel as though ISU is their home away from home. Even though all the 2YC Fellows will hail from the Chicago-metro area, and may be a short drive from home, they will be encouraged to remain in residence at ISU most weekends. The success of this 2YC-REU site in part hinges upon participants forming strong bonds with each other and their ISU undergraduate hosts. This is most likely to occur if Fellows remain on campus throughout most of the program's ten weeks. To this end, we plan to involve 2YC Fellows in picnics, socials, and a group trip (such as a Six Flags, St. Louis outing). At least one group social activity will be planned each week. It is common for faculty and other members of the Chemistry Department community to host small group gatherings and activities. ISU is characteristically a social environment. Socials will involve activities such as invitations to a faculty member's home, movie nights, and bowling at the ISU Bowling and Billiards center. The community of Bloomington-Normal provides a wide range of recreational activity opportunities including the 25 mile multi-use Constitution trail, many parks, several with community pools, and a variety of events such as the Garden, Shakespeare, and Sugar Creek Arts Festivals. The last is held in downtown Normal, less than a block from the Science Laboratory Building.

*Summer Research Opportunities with Other 4Y Partners:* Not all of the 2YC students who participate in the URC will be both willing and able to go to ISU for the summer, so accommodations have been made to host students at other institutions: four will be integrated into existing REUs at Hope College, two will be hosted at Youngstown State University, and at least six others at partnering institutions in Chicago. These institutions were selected because they meet at least two of the following three criteria: 1) They have respected and student focused summer UGR programs, 2) their faculty have active and partnerships with 2YC faculty from the URC, and 3) they represent institutions to which 2YC students are likely to matriculate and complete their STEM degrees.

*2YC Summer Research Opportunities at Home:* For a variety of reasons, some 2YC students may wish to remain on their home campus during the summer. In this case, their home campus will support them as they either continue their work on their research project with their faculty mentor, or participate in the URC's high school outreach.

### **High School and Community Outreach**

Since 40% of the nation's K-12 teachers receive their science education at a 2YC, it is important to think of every 2YC student as a future K-12 teacher.<sup>39</sup> In addition, many current HS students are future 2YC students. Therefore, an important component of the URC is outreach to and recruiting from high schools that feed students into participating 2YCs.

Each summer, 12 high school students will spend two weeks designing a science fair project in collaboration with URC students and faculty. This activity will be modeled after the OCC ITR model, with three high school students working with at least one 2YC student mentor. The URC will provide support for 12 high school students, who will be paid a stipend of \$300. During the school year, URC sites will continue to share their resources, expertise, and time with these students. Half of these students will be recruited from Chicago Public Schools, and half will be recruited from suburban school districts. This outreach will expose participating students to the collaborative nature of scientific research, and encourage high school students to become involved in research early in their college careers. Mike Davis, the URC Outreach Coordinator, will be responsible for these activities.

### **Empowering Faculty Through Professional Development**

The Project Kaleidoscope Faculty for the 21<sup>st</sup> Century program (PKAL F21) has conclusively shown the importance of not only investing in students, ideas, and institutions, but also individuals.<sup>40</sup> Faculty are the keys to institutional change and program sustainability in any endeavor, so a considerable amount of URC resources will be spent in the professional development of faculty. These activities will be aimed at: 1) providing faculty with the intellectual resources and information needed to successfully seek outside funding, and sustain their UGR programs; 2) bringing in programs and speakers from outside the URC to share ideas and programs that work with respect to UGR and STEM education; and 3) augmenting the travel and professional development funds available to faculty, so they can attend professional meetings and important networking events.

*Interactions and Stimulation:* Just as URC students are supported, URC faculty will be extensively supported by the project. We intend to provide 2YC faculty with the material and intellectual resources to set-up and sustain their own UGR programs. Professional growth activities related to this goal will include: 1) helping faculty reconnect with their disciplines through interactions with and stimulation by like-minded colleagues in geographic proximity, 2) fostering collaboration among 2YC faculty of the URC, 3) building collaborations between 2YC and 4YC faculty leaders, and 4) allowing newly hired faculty to retain their research expertise. These interactions will emerge naturally by virtue of faculty-faculty contact at student professional development activities.

*Outside Speakers:* With the critical mass and captive audience of 2YC faculty this project will bring together, we intend to solicit professional organizations and societies with the common interest in 2YC faculty professional development to come to Chicago. These organizations include the Council on Undergraduate Research, who offer workshops on proposal writing, beginning and sustaining UGR programs, and institutionalizing UGR; Chautauqua, who offer annual short courses for educators; and the Process Oriented Guided Inquiry Learning (POGIL) Project, which is promoting chemistry education reform materials and methods that parallel the benefits gained by authentic UGR.<sup>41-42</sup> Importantly, PI Higgins, has a pending NSF CCLI Phase 1 Grant to study the effects of POGIL on 2YC students, and is in contact with personnel from the POGIL Project who are eager to interact with 2YC faculty. In addition, considerable expertise in chemistry, research, and teaching exist among several members of the collaborative. This expertise will certainly be shared with fellow faculty both formally and informally.

*Augmented Travel:* Each 2YC member of the URC has been allocated travel funds to attend professional growth activities such as NSF Community College Day, which will allow the 2YC faculty to meet with program officers and learn first hand about funding opportunities; CUR workshops; and other germane professional development activities.

### **Intellectual Merit**

This work will provide an unprecedented opportunity to make a significant contribution to the scholarship of teaching and learning. It will lay the foundation for studying the benefits of UGR experiences on 2YC students, faculty, administrators, and research infrastructure, as well as the benefit to institutions who partner with 2YCs. A national model will be developed that increases the diversity and magnitude of the nation's research capacity and infrastructure. At least three research models and supporting courses will be evaluated.

Taking into account the as-yet-untapped talent of 2YC students, this project has great and immediate possibilities of changing practices in science education - practices that sorely need updating as our population of students continues to diversify. Our project directly addresses concerns Seymour and Hewitt offer to explain the exodus from science fields: lack of confidence, competitive atmosphere, dullness of subject matter, and scant availability of faculty.<sup>43</sup>

### **Broader Impacts**

2YCs enroll 6.6 million undergraduates annually, representing 46% of the undergraduate population, and a substantial portion of the underrepresented undergraduate population.<sup>12</sup> 2YCs hold the keys to expanding the number of first- and second-year college students engaged in authentic UGR and increasing the diversity of the STEM talent pool from which the nation's future scientific talent and technical workforce will be drawn. To do this sustainably, 2YCs must be empowered to offer UGR experiences to their students in a manner that is driven by 2YC faculty and fits the capacity, infrastructure, and culture of this diverse set of institutions.

The previously funded URCs – CASPiE at Purdue University, The Northern Plains URC at the University of South Dakota, and the Ohio REEL Initiative at Ohio State University – are all based at research intensive universities and take a top-down approach with respect to their engagement of 2YC students and faculty. This project, in contrast, takes a different and complementary approach – bottom-up engagement of 2YC students, with the project driven by 2YC faculty. We believe this approach is the key to sustaining true cultural change at the nation's 1,157 2YCs.

The education and research activities proposed will serve as a national model to empower other 2YCs to develop their own UGR programs. By developing and evaluating three different on-campus research models and developing related research-oriented courses, we are poised and qualified to assist with any and all of these activities during the dissemination aspect of this project. Because the Scaffolded Training, Interdisciplinary Team Research, and Distributed Team Research models will be implemented and evaluated among the participating 2YCs, attendees at dissemination workshops will be able to choose the model which best fits their personal interests and their institutional environment. For example, a faculty member who can find several colleagues who are interested in creating an interdisciplinary research program can learn from the ITR model. Alternatively, a faculty member who wishes to work alone with only one or two students can learn from the ST model. Importantly, faculty at other 2YCs will have a support network of peers willing and able to provide productive and constructive advice to circumvent the inevitable hurdles and trumpet the anticipated successes.

### **IV. PARTERSHIPS AND MANAGEMENT**

Many of the partnerships proposed in this project are already in place, and will be strengthened and expanded by this URC. All of the 2YC faculty in this URC have worked together in the past, and most of the participants know each other personally as well. There is an established record of working together productively. For example, Higgins and Shih (COD) collaborated as part of the CCLI DUE grant "Consortium to Improve Chemistry: Linking Nine Community Colleges with the National Science Foundation's Undergraduate Chemistry Systemic Reform Initiative" (Award# 9752885). Higgins, Dowd, and House are all collaborators on an NSF SGER grant titled "2YC-REU: A Two-Year College Research Experiences for Undergraduates Site" (Award # 0539214).

Higgins has active research collaborations with faculty from Hope College (Graham Peaslee and Kenneth Brown) and Chicago State University (David Kanis). He has also collaborated with co-PI Ferrence (Illinois State University) and Allen Hunter (Youngstown State University, YSU) on several proposals through the STaRBURSTT Consortium. Faculty from Harper College, Oakton Community College, and College of DuPage all have worked with personnel located at Argonne National Labs.

Higgins, Ferrence, and A. Hunter (YSU) are all founding members of the STaRBURSTT Consortia, who will work with all the 2YCs involved to provide remote access to state of the art research instrumentation. Although most of the 2YCs involved in the project have access to high quality instructional instruments, maintaining research-grade facilities is not within the realistic budget of most 2YCs. Partnerships such as this one are essential if 2YC faculty are going to engage their students in authentic research. A core role for YSU in this project is to implement remotely accessible instrumentation as a routine part of the 2YC toolkit. Through YSU, we are in contact with the leaders of the Ohio-REEL URC (for which A. Hunter is a co-PI). They have recognized the complementary nature of this URC effort to their own, and are eager to

work with us to bridge our projects, to leverage our different approaches, and to ensure UGR becomes a part of the first and second year undergraduate science experience at all institutions.

### Management

The URC will be managed by a five-member Board of Directors: PI Higgins (CCC, Harold Washington College), co-PI Harris (CCC, Truman College); co-PI Dowd (Harper College); co-PI House (Harper College); and co-PI Ferrence (Illinois State University). This Board will meet three times a year: In the Fall at HWC, in the Spring at ISU; and in the Summer at HC. This last meeting will be in conjunction with the Advisory Committee (*vide infra*). PI Higgins will be responsible for the overall management of the URC, and coordinating among all of the partners. Co-PI Harris will supervise all activities within the seven colleges of CCC, including recruiting and mentoring of CCC faculty. Co-PI Dowd will supervise all activities in the suburban campuses of Harper College, Oakton Community College, and College of DuPage. In addition, he will plan all Advisory Committee Meetings and events hosted by Harper College. Co-PI House will direct the assessment and evaluation effort, and assist the URC faculty in translating the lessons learned into actions. Co-PI Ferrence will supervise the 2YC-REU and match 2YC students with their mentors. The work at Oakton Community College will be under the direction of Melodie Graber. The work at College of DuPage will be under the direction of Richard Jarman. The work at Hope College will be under the direction of Kenneth Brown. CCC will hire a full-time Project Manager to assist the Board with managing the URC with project funds.

### Advisory Committee

The vision and activities of the URC will be supported by a seven member Advisory Committee, whose members come from diverse backgrounds. The one common characteristic of each is a passionate commitment to educational innovation and to undergraduate research experiences for 2YC students. The following individuals have agreed to serve as advisors: Melvin George (President Emeritus of Saint Olaf College and the University of Missouri, and the author of the NSF ten-year review "Shaping the Future"), Nancy Hensel (Council of Undergraduate Research), Moses Lee (Dean of Sciences at Hope College and co-author of "Exploring the Concept of Undergraduate Research Centers"), Iraj Neptad (Mount San Antonio College and former NSF Program Officer), Jeanne Pemberton (University of Arizona and co-author of "Exploring the Concept of Undergraduate Research Centers"), Mark Ratner (Morrison Professor of Chemistry at Northwestern University and Member of the National Academy), and Linette Watkins (Texas State University, San Marcos and current chair of the American Chemical Society's Committee on Minority Affairs).

## **V. STUDENT ASSESSMENT AND PROJECT EVALUATION**

The project evaluation will make an important contribution to the sparse research documenting the impact of UGR on students' learning gains and attitudes about science.<sup>42,44-51</sup> Given the importance of 2YCs in higher education, and the call for more authentic learning experiences earlier in the curriculum, this project lies at the intersection of two important themes in science education: 1) It will inform teaching and learning at all levels, and 2) it holds promise for reaching a population of students traditionally under-represented in STEM professions. We intend to study the following:

- The impact on attitudes toward and conceptions of science and research held by 2YC students.
- Benefits, limitations, and evolution of the UGR models and faculty mentor roles in the research.
- The successes, struggles, and strategies that characterize 2YC UGR experiences.

Preliminary results from our SGER project (NSF Award #0539214) highlight the potential impact of this URC and the rich evaluation that is possible. Based on interviews conducted so far, 2YC students measure their success in research based more on personal growth rather than on laboratory results. With respect to success in science, our students report learning gains similar to those reported by Elaine Seymour and colleagues.<sup>42</sup> But our students also report significant personal gains with respect to their life outside the lab and the classroom. For example, one student (and aspiring artist) reported how her research has inspired her to create an exhibit on the artistic beauty of chemical reactions. She reported her excitement has prompted her to talk about her scientific research with her family and friends, something she would have never done before. Another group of students has created an on-line chat group for discussing the project when away from the lab. And, importantly, our fear that research would take focus away from other obligations was unfounded. Every student involved in the project claims that time spent on research would otherwise be spent on frivolous pursuits (watching television, walking the mall, or napping, in their own words). Clearly, the impact of UGR on 2YC students who are in proximity to

the lab, who would work in a collaborative, familiar environment, and who have time to devote, is potentially enormous.

We also have data showing how research changes students' attitudes about science. One student, a future science teacher, initially became involved in the project mainly to improve her resume. In the beginning, she believed independent research was challenging, unmotivating, monotonous and of little practical use to her career. Currently, however, her attitude has changed to the point where she now intends to continue summer research at a 4YC so that she can perfect her research skills and pass them on to her future students. Another student, professing a deep fascination for but limited success in previous chemistry classes, left science as a major at a large university, citing "...you kind of get lost in math and science over there." This student is now back at a 2YC, enrolled in the science classes, "I told myself I would never, ever take," and because of the UGR, is "...much more interested in pursuing a degree in chemistry." A project such as this could very well be the gateway for students to recognize their potential for success in the field.

Finally, we have noticed that students do make sense of the habits and practices of science, and students do develop skills in data analysis, but only to the extent to which they have ownership of their project. Students who are relegated to positions of mere data-taking do not develop the deep, analytical skills that are prized by science, and they are unable to place the objectives of their research within the larger framework of research in science. They know, narrowly, what they are doing, but they cannot intelligently elaborate on the meaning of the project, either on a microscale (such as why a particular piece of data might need to be taken) or on a macroscale (such as why the overall project is worth doing). One participant, who has a deep immersion in her project, stated that when she was asked about her project by friends, it was "...cool to be able to answer their questions rather than say 'we don't know that much about it'." Our UGR model, in which 2YC students and faculty take complete ownership and execution of the project, is poised to be the successful model of authentic research at 2YCs.

This evaluation plan will parallel and expand that already in place for the previous project. We believe that a qualitative evaluation plan supplemented by quantitative data is best suited to evaluating the success of our project objectives. During the project evaluation, we anticipate three main data sources will contribute: 1) interviews, 2) written survey responses, and 3) journals. Each of these data sources is described below. Data will be analyzed each semester, with these triennial reports used to guide and shape project goals and subsequent data collection and analysis.

Interviews with consenting students and research mentors will form the bulk of the data for the project. Interviews will be conducted in person when possible (especially initially) but might be conducted over the phone as the project progresses. Our plan is to talk with students twice during each semester of their research (4 times total per academic year). Later interviews may be better handled in a focus-group format, depending on the depth and results of previous interviews and number of students involved at each campus. Projecting a cohort of 32 undergraduates pursuing research each semester, this amounts to 128 student interviews total. Due to the large number, these interviews must be focused and semi-structured, with some allowances made for follow-up questions unique to the student. A script will be developed to guide the data collection. Students continuing in the project for multiple years may be interviewed less, perhaps once a semester. As new students are rotated into the research, either in-between semesters or in mid-semester, every attempt will be made to keep them on the defined interview schedule. Interviews will also be conducted with the research mentors, once per semester or as needed, for a total of 15-20 interviews each year. Finally, students who participate in summer research projects will also be interviewed once or twice in order to assess the transition from research at a 2YC to a 4YC, as easing this transition is a prominent objective of the project. All interviews will be transcribed and iteratively coded and analyzed to assess the larger experience of all the students and mentors involved.

Two secondary sources of data will be used to corroborate and further refine conclusions about the experiences of those involved. First, surveys and questionnaires will be administered to students and mentors before the start of the project and periodically throughout. The first will attempt to get students to describe their motivation for involvement, their self-reported mastery of various skills, their initial conceptions of what the project will be like, prior coursework and preparation, interest, and career choice. Other surveys, such as attitudinal surveys, will be administered later in the project. For mentors, we will discuss with them initially the nature and scope of the project, their experience working with students, and

their vision of their role and duties in working with the students. The second source of data will consist of student artifacts such as lab notebooks and journaling. Journaling (written and electronic) will serve as a means to follow up with students when interviews raise provoking or interesting issues that invite further discussion. This communication will allow for formative, ongoing probing into the student experience. Every couple weeks students will also submit a time sheet of activities accomplished and a journal that reflects on what they have done. Journals will be short (one page or less) but over the duration of the project, this will amount to 8-10 pages of personal, honest thought about their experience obtained in a regular, periodic pattern in the project. This writing would be directed by prompts by the evaluators to write about specific topics/concerns, and evaluators would provide ongoing contact and follow-up as needed to elicit more direct and robust feedback. This continuing "dialogue" with the students is well-suited to tracking students' changing habits, attitudes, and rewards over time. This method would be a great venue for the mentors to describe their experiences and thoughts as well.

Finally, in an effort to include some longitudinal perspectives on the program, we propose to interview alumni of the UGR one year and again two years after the conclusion of their participation (this time frame puts them at the end of their baccalaureate program). This follow up with the students will allow us to examine their experience at a 4YC, to see how their lives and careers were impacted by UGR, and to determine the longer impact on their thinking and habits.

A team of evaluators is in place to conduct the rigorous evaluation. Roger House (HC) will oversee the evaluation program and will work with colleagues in the Chicago area and at collaborating 4YCs. An external evaluator, Kathryn Race (Race & Associates) will work with House to manage the project evaluation and assist project staff in identifying core strategies and outcomes. Although all project personnel will share responsibility for data collection, Race and House will take responsibility for the collection, archiving, and inventorying of all project data and artifacts. House has experience with qualitative data collection (interviews and writing analysis), and Race brings to the project extensive experience with quantitative survey construction and analysis and focus group interviews. Both House and Race are geographically close to all of the Chicago-area 2YCs. Hunter (ISU) will help to oversee the study of the transfer to 4YCs and the summer research activities. A 2/3-time doctoral student will also be necessary to assist with interviewing, data collection, ongoing analysis, and general communication.

## **VI. DISSEMINATION**

Dissemination of the project results will begin in the first year and continue in each year of the project. The goals of dissemination are to: 1) inform other 2YCs about the value of engaging 2YC undergraduates in UGR; 2) provide robust models for engaging 2YC undergraduates in UGR; 3) empower more of the nation's 2YCs to build sustainable, UGR programs on their own campuses; and 4) provide examples of equal partnerships between 2Y and 4Y institutions.

Most of the faculty members at the nation's 2YCs do not believe it is possible to include authentic research in their curriculum. Therefore, the first dissemination activity will be to inform other 2YCs of the support from NSF for the creation of the URC and to show them the success of the URC. Representatives of the URC will make presentations at professional meetings that engage a large number of 2YC faculty like regional 2YC3 meetings and BCCE. We also intend to make contacts with other community college systems, such as Richland Community College (Dallas, Texas), Miami-Dade (Miami, Florida), and Mesa Community College (Arizona) and to present day-long dissemination workshops. Cecilia López, Vice President of Academic and Student Affairs at Harold Washington College, has agreed to use her extensive contacts within the 2YC and higher education communities to assist in this effort. In addition, PI Higgins has extensive contacts within Project Kaleidoscope (PKAL) and the Science Education for New Civic Engagement (SENCER), who have agreed to assist with dissemination. The 2YCs in Ohio will be one of the first dissemination sites targeted via our collaboration with Ohio-REEL URC team.

The Harper Department of Instructional Technology (Do-It) will collaborate with the URC to produce video and CD materials of the MSS and FMSR courses. These materials will be historical documentation of the URC and a valuable resource for the dissemination process. Do-It will provide guidance in other forms available to enhance the dissemination process and create a project website that will include schedules, curriculum development, poster presentations, topics of seminars, research topics, and the annual report.

## **VII. RESULTS OF PRIOR SUPPORT**

Thomas Higgins – Associate Professor, Harold Washington College (Project PI)

Higgins is currently a PI on the NSF SGER Project “2YC-REU: A Two-Year College Research Experiences for Undergraduates Site” (Award #0539214). This award led to the creation and implementation of the ST model described in the narrative. He is also PI on a pending CCLI Phase 1 Project titled “Adapting and Implementing Process Oriented Guided Inquiry Learning (POGIL) into the Harold Washington College Chemistry Curriculum”. This award seeks to implement POGIL materials and methods into a 2YC curriculum that serves a large number of underrepresented minorities, and assess the effects of the intervention. Higgins has been the PI on two Air Force Office of Scientific Research Grants, which have allowed him to remain active in UGR. As a result of these awards, he has mentored 13 2YC students in both academic year and off-campus summer research projects. Higgins has also been PI on the NASA/UNCF-SPC Curriculum Improvement Project Award. This award involved supervising a team of five HWC faculty across three different departments to write, implement, and evaluate three modules that infused NASA-related science and active learning pedagogies into HWC’s general chemistry curriculum.

Yvonne Harris – Associate Professor, Harry S. Truman College (Project co-PI)

Harris was funded through a NSF CCLI award “Integrated Science Courses for Elementary Education and Non-Science Majors” (Award #0311624). As part of this effort, she worked with a cross-institutional team of science faculty from University of Illinois at Chicago, Harper College, and City Colleges of Chicago to develop new undergraduate science courses focused on problem based learning and inquiry. The courses were designed to comply with the education standards of Illinois and have been offered at UIC, HC, and CCC since 2003. Harris also runs the Biotechnology program at Truman College, established by NSF Award #9054609.

Thomas Dowd – Associate Professor, William Rainey Harper College (Project co-PI)

Dowd is currently a co-PI on an NSF-SGER Project entitled “2YC-REU: A Two-Year College Research Experiences for Undergraduates Site” (Award #0539214). He is also a co-PI on an NSF-CCLI Phase 1 Project “Adapting and Implementing Process Oriented Guided Inquiry Learning (POGIL) into the Harold Washington College Chemistry Curriculum,” (award pending).

Roger House – Instructor, William Rainey Harper College (Project co-PI)

House is currently a co-PI and Evaluator on the NSF-SGER Project “2YC-REU: A Two-Year College Research Experiences for Undergraduates Site” (Award #0539214). He is also Evaluator on an NSF-CCLI Phase 1 Project “Adapting and Implementing Process Oriented Guided Inquiry Learning (POGIL) into the Harold Washington College Chemistry Curriculum.” In graduate school, House was a research assistant on an NSF-DUE (#9852167) award “The University of Illinois at Chicago-Community College Collaboration for Excellence in Teacher Preparation”, which led to the creation of a network of 2YC and 4YC faculty concerned with improving the science education given to future K-12 teachers.

Gregory Ferrence – Associate Professor, Illinois State University (Project co-PI)

Ferrence is currently the PI on an NSF-CAREER Project entitled “CAREER: Solid-State Structure and Solution Behavior of Lanthanide Scorpionates” (Award #0239462). One goal of this research is to modify the supporting ligand environments of Group 3 and lanthanide metals in order to gain insight into chemical structure and reactivity that is distinct to rare-earth compounds in their predominant trivalent oxidation state. Rare earth complexes with N-confused-porphyrin and carbaporphyrin ligands are being prepared. They are expected to display contrasting reactivity compared to their traditional porphyrin analogs. Divalent lanthanide complexes incorporating trispyrazolylborate ligands are also being examined in order to also provide a fundamental understanding of the chemistry of divalent lanthanides. The educational component of this grant focuses on teaching principles and practices in X-ray crystallography by using extensive computer based course materials that better enable students to determine aspects of molecules dependent on three dimensional visualizations. Faculty and students from regional liberal arts colleges and universities are to be involved so as to offer aspects of the X-ray course via distance education and to foster regional research collaborations