A Proposal for the

Johns Hopkins University Gateway Sciences Initiative

April, 2011

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Johns Hopkins University
Gateway Sciences Initiative Proposal

1. Introduction

In many undergraduate and graduate programs, entering students are required to master rudimentary concepts, methods, and facts in one or more sciences to pursue their academic goals. Examples abound. Premedical undergraduates typically study calculus and introductions to physics, chemistry and biology in their freshman year. Engineering undergraduates study introductory physics, chemistry, and calculus in their freshman year. Nearly all entering public health masters and doctoral students take introductory sequences in epidemiology and biostatistics in their first year. Entering public policy students must master introductory economics. PhD students in molecular biology require a survey of biology, chemistry, biophysics, and informatics.

We refer to these as “gateway science courses” (GSCs) because they are essential to open “gates” to study fields such as medicine, engineering, public health, public policy, or bioscience in the examples cited. Gateway science instruction as discussed in this report represents a range of courses. It can refer to large lecture foundation courses that provide knowledge and comprehension of content required to advance in the field, as well as smaller enrollment courses that expose students to higher level application and analysis of subject matter. (See *Appendix I, Bloom's Taxonomy of Learning* for a conceptual model that differentiates levels of learning apropos to gateway courses.)

At most universities, introductory gateway science courses are organized around large lectures, routine laboratory exercises, and high doses of scientific vocabulary. Although in some cases at JHU, gateway science classes have large enrollments, this is not a defining characteristic. (See *Appendix II, Table 1. Total Enrollments in 2010-11 for Up to the Five Largest GSCs in Each Johns Hopkins School*.)

Given the volume of students in gateway courses and the diversity of their backgrounds and learning styles, high quality courses must accommodate a range of experiences and strengths. Content can be provided in multiple formats, including live and online lectures, lecture notes, problem sets, lab problem-solving sessions, TA discussions, peer discussions, and/or one-on-one tutoring. Moreover, many corporate and government organizations (e.g., gaming, military, IT) have developed advanced communication technologies that engage viewers in active learning experiences. Some of these emerging technologies may have direct application to gateway courses in higher education.

2. Gateway Science Courses

Many faculty at Johns Hopkins and other universities teach highly successful GSCs. All share the following characteristics of effective teaching and learning. Students in successful GSCs:

- engage in active learning through problem sets, in-class quizzes/problem solving, and discussion groups with faculty, TAs or peer instructors;
- integrate ideas from lectures/readings with skills that put the ideas into practice and deepen understanding;
- enhance critical reasoning;
- exercise oral and written communication skills.

Tables 2 and 3 (*Appendix III*) contain summaries of some innovative courses and initiatives at Johns Hopkins. Table 4 (*Appendix IV*) summarizes GSC innovation at other R1 universities.

The Johns Hopkins schools are committed to providing the best possible learning environment for their students. Founded on the vision of Hopkins' first president, Daniel Coit Gilman, integration of learning with research and discovery enables students to fulfill their individual learning potential without regard to age or formal background.

While GSCs are not research courses, they must prepare students for research experiences in their undergraduate academic program and beyond. JHU GSCs must be consistent with the university's learning philosophy, which integrates discovery, research, and education. To be able to participate in faculty-led research, students must learn how to formulate relevant questions precisely, reason critically, generate and interpret evidence through experimentation and observation, and communicate accurately and clearly.

The three primary goals for students in gateway science courses are to master the course content essential to success in higher-level courses; enhance discovery skills, including self-learning, problem formulation, critical reasoning, and communication; and become excited about the discipline.

3. The Johns Hopkins Gateway Sciences Initiative

The Johns Hopkins schools are committed to providing the best possible learning environment for their students. As a research university, Johns Hopkins intends to experiment with gateway science courses to generate and disseminate evidence relevant to the deans, chairs, directors, and faculty who make many decisions each day about how best to enhance the JHU learning environment. Provost Lloyd Minor has established this Gateway Sciences Initiative to support their efforts.

The objectives of the *Johns Hopkins Gateway Science Initiative* are to advance our understanding of how students best learn gateway sciences, and promote pedagogical innovation that permits students to attain competency at the introductory level as rapidly as they are capable of doing.

As part of preliminary data gathering, Vice Provost Scott Zeger met with many constituents of gateway science teaching and learning. (See *Appendix V*.) Each was asked how the provost's office might facilitate design of an institution-wide initiative to promote continuous enhancement of gateway science courses. More specifically, each was asked to make observations about three distinct categories of instructional excellence: instructional delivery, strategies for accommodating diverse learning styles, and curricular organization.

Instructional delivery. What are the most effective, efficient and enjoyable ways for students to master the content of gateway science courses? How can course design and organization improve learning? How can instructional technologies improve learning? What partnerships could advance the implementation of advanced technologies that would substantially improve learning gateway science material?

Diverse learning styles. How should gateway science courses be designed to accommodate the diversity of student learning styles? Is asynchronous, student-controlled access to learning materials preferred by a substantial number of students? What is the role for peer learning-teaching? How can faculty, staff, and teaching assistant time be used most effectively to improve gateway science learning?

Curricular organization. What are the advantages and disadvantages at JHU to organizing gateway science content by interdisciplinary themes rather than within departments? For example, it might be possible to organize gateway topics in biology, physics, chemistry, mathematics, and computer science into an integrated freshman curriculum, as has been done at Princeton. How would JHU develop such a concept; what would be its objectives; how would success be measured; and what would be the impact on more advanced department courses? (See *Appendix IV*, Table 4 for brief descriptions of other universities' initiatives.)

The following principles and recommendations emerged from these data gathering discussions:

- Begin a long-term process to change faculty and student cultures that encourages (a) faculty to value effective teaching on an equal plane with research and professional service and (b) students to contribute to the richness of their academic experience by collaborating with fellow students.
- Coordinate with the deans and chairs to assure the new initiatives enhance on-going curricular programs.
- Avoid exhorting faculty to do more with less.

- Set high intellectual standards and create an environment where students strive to achieve their full potential and enjoy their success.
- Promote active learning, collaboration, and student communication skills.
- Build on the Johns Hopkins tradition of learning through research and discovery with a strong emphasis on critical thinking.
- Bring faculty together across schools to address common needs.
- Include GSCs offered to PhD students**.**
- Act now. Major gains can be realized by widely implementing what is already known to work.

Also from the preliminary data gathering process, a number of concrete instructional ideas surfaced. (See *Appendix VI*.)

4. Proposed Strategy for Implementing The Johns Hopkins Learning Gateway Sciences Initiative

Faculty committee charge. Provost Lloyd Minor, President Ron Daniels and the Deans have requested that a faculty committee be identified and charged with addressing the questions above and others the committee deems pertinent. Among other actions, the committee will be expected to:

1. Identify the major gateway science courses at Johns Hopkins and describe the diversity of learning methods and technologies currently used.

2. Survey the quality of learning and student satisfaction for existing gateway courses across the schools.

3. Identify best practices at peer institutions.

4. Recommend the best ways for the university and schools to increase incentives to improve learning in gateway science courses.

5. Identify instructional technologies and/or partnerships with other universities or industries that JHU might pursue to improve learning in gateway science courses.

6. Evaluate and recommend to the provost strategic gateway science initiatives in which the provost's office should invest to promote continuous improvement in GSCs across the university.

7. Identify assessment and sustainability strategies for each funded initiative.

Potential GSI actions. In support of this initiative, the following actions might be useful as a starting point for discussions within the provost's office and among the GSI Faculty Steering Committee.

1. Establish a *Provost's forum* for a recurring series of conversations on teaching excellence that attracts JHU faculty, external educators, and corporate partners to participate in a continuing dialog of best practices.

2. Stage an *annual Symposium on Teaching Excellence* that highlights the achievements of a diverse group of JHU faculty, national experts, and students.

3. Sponsor a *faculty two-day workshop* to enable faculty to design concrete improvements to JHU GSCs with support from institutional teaching and learning staff.

4. Identify formal *strategies for measuring the quality* of gateway science learning across the university; reward deans and chairs for courses that reflect high GSI standards.

5. *Raise faculty and chair incentives* for on-going improvement of the quality of gateway science courses at JHU. For example, provide extra RA support to faculty who run high quality GSCs.

6. Institute on-line and/or in-person *educational technology showcases* to highlight successful examples of broadly defined technology-enhanced instruction.

7. Underwrite GSI *Implementation Initiatives* – in coordination with deans and chairs, provide funding to support implementation of strategic curricular redesign or instructional innovation in selected programs: 4 initiatives for $100,000 each; renew best among them (up to 2) for another $100,000.

8. Underwrite *RFPs for* GSI *Seed Initiatives* – start-up awards for groups of faculty to improve existing gateway science programs and courses. RFPs would provide $75,000 each, to be matched by $25,000 from each school; 2 in year one; 4 in year two.

Appendix VI highlights concepts that emerged from the data gathering discussions.

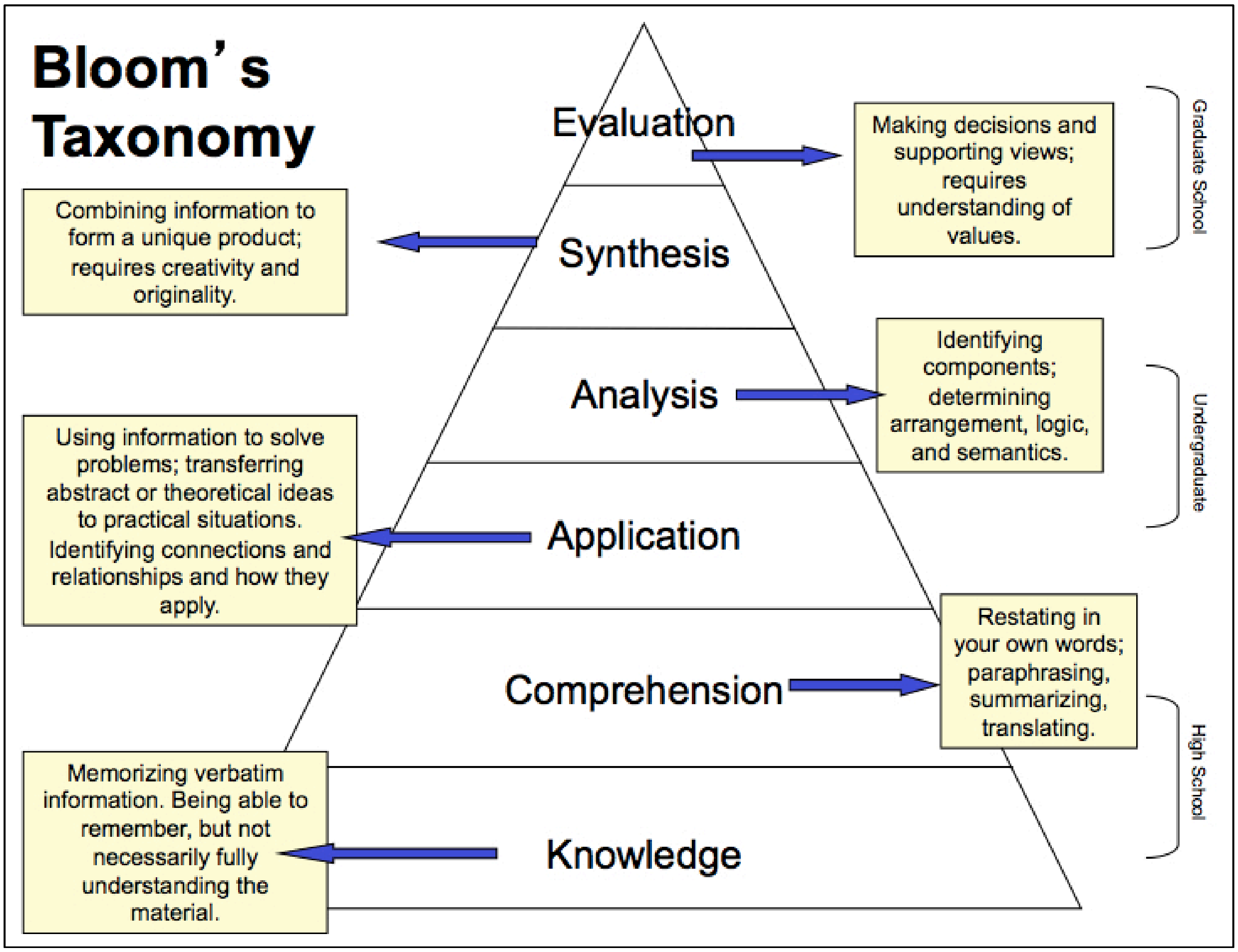
If these concepts were embraced by the faculty committee, a partial list of tasks and a time line might be as follows. Note, this timetable is likely to change when the GSI Faculty Steering Committee begins its work.

Tentative Time Line	
Date	**Task**
May	Appoint a GSI Faculty Steering Committee (FSC).
June	Hold first two meetings of GSI FSC to shape ideas and plan initiative.
July-August	GSI FSC symposium sub-committee to plan a one day meeting

	to be held on January 20, 2011
September	Host the first Conversations on Teaching Excellence for faculty, students, staff and external "experts" to share their ideas about the GSI. Two-slide maximum to all presenters, submitted in advance. Invitations to current GSC, student leaders, deans and chairs and local industry who might partner with us.
September-December September-October 2011-12 2012-13	Plan and launch GSI Implementation RFP process • Identify other initiatives and prioritize them through conversations with deans and chairs. • Identify successful PIs for prospective two-phase initiatives. • Design and test programs • Implement and evaluate new programs
September-December September 2011 January 2012 2011-12 2012-13	Plan and launch GSI Seed RFP process • Issue call for proposals • Announce selected programs • Design and test programs • Implement and evaluate programs
January 2012	Plan two-day workshop of funded GSIS programs to plan dissemination of lessons learned.
2011-12	Design Provost-led UA decanal process to continuously improve gateway science courses; consider with deans creation of a university-wide Center for Educational Resources (CER) by pooling parts of current investments and increasing efficiency.
2012	Stage education technology showcase to highlight leading cases of technology use in education, broadly defined (e.g., including gaming, movies).

Appendices

Appendix I. Bloom's Taxonomy of Learning



Appendix II. Enrollments for JHU Gateway Science Courses

Gateway science courses (GSCs) exist in every school at Johns Hopkins. The largest ones for each school are summarized in Table 1. The courses with the largest enrollments are in KSAS, BSPH and SoM.

Table 1. Total Enrollments in 2010-11 for Up to the Five Largest GSCs in Each Johns Hopkins School For year-long sequences: first semester (second semester)

KSAS	Organic Chemistry 602	General Physics Lab 528 (515)	Intro Chemistry 512	Intro Chem Lab 492	Intro Social Psychology 434
WSE	Prob and Stat 146	JAVA Programming 141	BME in the Real World 126		
SoM	Human Anatomy 134	Cellular and Molecular Medicine 130	Macromols, Cell Phys, Metabolism 127	Infectious diseases 123	
BSPH	Stat Methods in PH 521 (476)	Principles of Epi 279	Epi Methods 229 (185)	Intro to Internat Health 172	Fund of Budget + Fin Management 170
SoE	Psychopharm 33	Human Development 30	Program Eval 27	Org and Admin 25	
SAIS	Corporate Finance 69	Renewable Energy 59	Macroecon 48	Public Sector Econ 44	
Carey	Info Systems 50	Economics for Decisions 48	Marketing 47		
SoN	Princ of Pharm 83	Princ of Pathophys 79	Research Process 77	Stat Literacy 50	Info Tech 30

Appendix III. Summaries of Innovative Courses and Initiatives at Johns Hopkins

Table 2. Description of Two Johns Hopkins Innovative Graduate Level Gateway Science Courses
Bloomberg School Statistical Methods in Public Health Marie Diener-West, Director, Master of Public Health Program, Bloomberg School of Public Health; Professor of Biostatistics Karen Bandeen-Roche Hurley, Dorrier Chair of Biostatistics James Tonascia, Professor of Biostatistics
This one year, four-term sequence is the middle in technical level of three introductory sequences taken by nearly every entering MPH, MHS or PhD student, more than 400 in 2010. The first three terms are split into two lecture sections of roughly 200 and 10 laboratory groups of 30-40. For first 24 weeks (3 terms) are organized into 10-day modules built around a data analysis problem set and ending with an in-class evaluation (quiz or exam). During the module, the students are presented 4 lectures (90 minutes each) and 2 problem-solving labs (120 minutes each) taught by the 2 professor and 2 "lead TAs" who rotate around the 10 groups. The problem sets take students through the analysis of 4 major public health data sets. One TA discussion group for statistics and another for statistical computing are held every day. In addition, students make appointments with TAs or faculty for personal discussions. In the final term, there is a review and extension of the methods from the first three terms. Here, students use their own data set to implement what they have learned and write a final data analysis project on their dataset. The course content is discussed each year with an advisory board of faculty from the programs in which the students seek their degrees.
School of Medicine Genes to Society First Year Charles Wiener, Professor of Medicine Pat Thomas, Associate professor of Medicine, Associate Dean of Curriculum David Valle, Professor of Pediatrics and Director of McKusick-Nathans Institute of Genetics David Nichols, Professor of Anesthesiology and Vice Dean for Education

In 2009, the SoM implemented "Genes to Society" (GTS), "aimed at reframing the context of health and illness more broadly, to encourage students to explore the biologic properties of a patient's health within a larger, integrated system including social, environmental variables. This approach presents the patient's phenotype as the sum of internal (genes, molecules, cells, and organs) and external (environment, family, and society) factors within a defined system. Unique genotypic and societal factors bring individuality and variability to the student's attention. GTS rejects the phenotypic dichotomy of health and illness, preferring to view patients along a phenotypic continuum from *asymptomatic and latent* to *critically ill*." (Weiner, et al, 2010, *Academic Medicine*)

The course integrates clinical practice, clinical science and basic science throughout year one. It uses team learning and teaching. For examples, students work in groups of two to regularly present lectures to their classmates starting in year one. They work in teams of 6-8 in problem solving projects.

Table 3. Description of JHU Innovative Approaches to Undergraduate STEM Curriculum Opportunities
Krieger School Interdepartmental Major in Global Environmental Change and Sustainability
The curriculum is constructed from a broad array of existing courses from complementary departments. GECS majors take a common core of courses, including a common gateway foundation course, to obtain a solid background in the study of both environmental science and social science. Students participate in robust advising activities to select advanced courses for more in-depth study in their areas of interest. Students are exposed to theory, research methodology, and the practical applications of the major discipline. In GECS, a key component is the senior capstone experience, which consists of projects, research, internships, and field trips that provide "hands on" experiences. These projects are coordinated with other activities at JHU, including those of the Hopkins Sustainability Committee and also lead to greater outreach activities. (http://eps.jhu.edu/gecs/)
Krieger and Whiting Schools' PILOT program in Calculus II, III, Physics I and II Ed Scheinerman, Professor of Applied Math and Statistics, Vice Dean for Undergraduate Education, WSE Richard Brown, Professor of Mathematics, and Director of Undergraduate Studies, Department of Mathematics, KSAS Dan Reich, Professor of Physics and Astronomy and Chair, Department of Physics and Astronomy KSAS (*text from ES)
*PILOT is a loose acronym for Peer Led Team Learning. It is a highly organized, voluntary

program for students in problem-solving oriented courses. Each week, roughly 8 students meet with a specially-trained, paid peer leader to work on a set of problems similar to, but disjoint from, their weekly homework. The students solve the problems under the gentle guidance of the peer leader who directs the students to work in a highly scripted fashion. For example, the leader may specify that a problem is to be solved using the "scribe method" in which one student stands at the board and writes what the group specifies. Using this and other methods, students are made to interact with each other and articulate their ideas, strategies, and insights. The leader's role is to keep students focused and to ensure that all students actively engage the material. The leader is not to give students hints or answer, and is not to tell the students if they arrived at the correct solution. PILOT is not remedial; it is meant to be an organized study session in which students learn how to learn, and develop camaraderie. Because the method depends highly on students working together, we require students who (voluntarily) elect to participate, do so for the entire semester. They are not to come just when they feel they are having difficulty. The philosophy is that they are responsible to the group as well as to themselves. The experience has been that students generally enjoy the sessions and find them helpful. The Center for Education Resources has been tracking student attitudes about PILOT and they have been strongly positive.
Krieger School Freshman Biology Lab Course and Bio-organic Chemistry Greg Ball, Professor, Psychological and Brain Sciences, and Vice Dean for Science and Research Infrastructure
To introduce freshmen to lab research and to build a sense of community, establishing project lab courses patterned after the Howard Hughes Medical Institute's National Genomics Research Initiative is proposed. *These labs will focus on biological projects, will have no prerequisites, and will be open to all regardless of intended major.* Once the project labs are started, courses will be implemented that are designed to introduce students (primarily freshmen) to the possibilities of the post-genomic world, as well to as reinforce biological principles. In the second phase, development of a year-long bioorganic chemistry lecture course, with accompanying lab, for sophomores is proposed. The course will introduce principles of organic chemistry, and use them to provide students a comprehensive, mechanism-based description of biochemistry. The new lab building will have the facilities required for the lab portion of this bioorganic chemistry. Ideally this course will be ready for implementation at or shortly after the opening of the building, and would this curricular enhancement will be linked with the institutional investment in the lab building.
Freshman Experiences in Mechanical Engineering I and II; Mechanical Engineering Freshman Laboratory I and II

Allison Okamura, Professor of Mechanical Engineering
To address lack of intuitive connections between physics, math, and engineering, the JHU Department of Mechanical Engineering has developed a new integrated freshman sequence that integrates hands on lessons in physics and mechanical engineering. The goals of the new curriculum are to capture the imagination of students by engaging them in engineering experiences as quickly as possible; retain a diverse group of students (especially students who are traditionally underrepresented in engineering); and generate a love of engineering design. The one-year course sequence integrates applications of mechanics, elementary numerical analysis, programming in Matlab, use of computer in data acquisition, analysis, design, and visualization, technical drawing, the design process and creativity, report preparation, teamwork, and engineering ethics. In addition, the required lab courses' experiments are designed to give students background in experimental techniques and to reinforce physical principles. Mechanical dissections connect physical principles to practical engineering applications. Design projects allow students to synthesize working systems by combining mechanics knowledge, physics fundamentals, and practical engineering skills. Faculty have been retaining data since 2008 from student exit interviews to assess the impact of course content on student attitudes toward engineering.

Appendix IV. Innovative Learning Initiatives at Other Universities

Table 4. Descriptions of Innovative Learning Initiatives in Gateway Science Courses at Other Universities (descriptions from university documents)
Princeton University, Integrated Quantitative Introduction to the Natural Sciences David Botstein, Anthony B. Evnin Professor of Genomics and Director, Lewis-Stigler Institute
"Integrated Science is a revolutionary new introductory science curriculum developed at Princeton, intended for students considering a career in science. By breaking down traditional disciplinary barriers, a series of courses taken in the freshman and sophomore years provides students with first-rate preparation for a major in any of the core scientific disciplines, and in such a way that helps retain the connections to the other disciplines. The curriculum is founded on the expectation that much of the most important science of the future, though based on the classical disciplines, will lie in areas that span two or more of them." http://www.princeton.edu/integratedscience/
Yale University, Perspectives on Science Charles Schmuttenmaer, Professor of Chemistry William C. Summers, Professor of Professor of Therapeutic Radiology and History of Medicine
"Science 198 'Perspectives on Science 'is a special course designed to supplement the educational program of selected freshmen with outstanding preparation in the areas of science, mathematics, and engineering. The course extends over two semesters, with 1.5 hour meetings each Friday afternoon. It is built around a series of six lectures per semester, given every other week by some of Yale's most distinguished science faculty. Discussion sections are held in the alternate weeks. Each lecture is designed to introduce a key scientific problem and to illustrate it with a specific observation, theory, or experiment in a way that the students will be able to evaluate critically. Supplementary reading is provided for background and details. Each lecture is followed by a set of web-based lecture questions which each student must answer during the following week. Discussion sections provide an opportunity to evaluate questions, ideas, and problems related to the lectures and supplemental readings. Each section consists of fifteen students and two faculty discussants (see above). Discussions are organized and lead by 2 to 3 discussion leaders, with the responsibility rotated among the students in the section. The faculty discussants are involved, not as leaders, but as fellow participants. Their role is to add to the discussion and to draw on their expertise when appropriate.

The goal is a lively discussion of interesting scientific topics among students and faculty. Active participation, originality, and depth-of-thought are expected of all students and will be considered in the final grading process." http://info.med.yale.edu/therarad/summers/Sci198/PS198.htm
University of Minnesota, Foundations of Biology Robin Wright, Professor of Genetics, Cell Biology, and Development and Associate Dean for Faculty and Academic Affairs, College of Biological Sciences Susan Wisk, Professor of Plant Biology
Transforming the notion of how a large "lecture" course can be run, *Foundations of Biology* (Biology 2002-2003) is a lecture-free course in which students have no lectures *per se*; they must learn basic text material on their own. During class, faculty probe students' knowledge of basic concepts with questions from a variety of angles. Before answering, students consult with their tablemates and respond with a "table-wide vote." Faculty and students examine all table votes together. Students are encouraged to defend their responses, a process that promotes active discovery and critical thinking about the concepts under consideration. http://www.cbs.umn.edu/bioprog/courses/interactiveclass/

Appendix V. Faculty and Groups with which GSI planning meetings were held.

Table 5. Persons or Groups Interviewed to Inform Gateway Sciences Initiative
Katherine Newman, Dean, Krieger School of Arts and Sciences
Nick Jones, Dean, Whiting School of Engineering
John Harrington, Associate Dean for Academic Affairs, School for Advanced International Studies
Pam Jeffries, Associate Dean of Academic Affairs, School of Nursing
Center for Educational Resources (CER) Candice Dalrymple, Associate Dean of University Libraries and Director, Center for Educational Resources Mike Reese, Assistant Director of the CER, Senior Instructional Designer Macie Hall, Senior Instructional Designer Richard Shingles, Science Curriculum Design Consultant
Marie Diener-West, Director, Master of Public Health Program, Bloomberg School of Public Health, Professor of Biostatistics. Sukon Kanchanaraksa, Director, Center for Teaching and Learning with Technology, Bloomberg School of Public Health.
School of Medicine, Leaders of Genes to Society MD Curriculum Jon Lorsch, Professor of Biophysics and Biophysical Chemistry Harry Fessler, Associate Professor of Pulmonary and Respiratory Medicine Patricia Thomas, Associate Professor of Medicine-General Internal Medicine Bob Siliciano, Professor of Medicine-Infectious Diseases David Nichols, Vice Dean for Education, Professor of Pediatric Anesthesiology
Ed Scheinerman, Vice Dean for Academic Affairs and Professor, Statistics and Applied Mathematics, Whiting School of Engineering
Sarah Steinberg, Interim Vice Provost for Undergraduate Education
Steven David, Vice Dean for Undergraduate Education and Professor of Political Science, Krieger School of Arts and Sciences Greg Ball, Academic Dean, Krieger School of Arts and Sciences Ed Scheinerman, Academic Dean, Whiting School of Engineering Nick Jones, Dean, Whiting School of Engineering Candice Dalrymple, Associate Dean of University Libraries and Director, Center for Educational Resources
Kevin Hemker, Chair, Mechanical Engineering, Whiting School of Engineering

David Andrews**,** Dean, School of Education
Ben Schafer, Chair, Civil Engineering, Whiting School of Engineering
Richard Brown, Director of Undergraduate Studies, Mathematics, Krieger School of Arts and Sciences
Provost's Office Members

Appendix VI. Instructional Concepts and Proposals from Faculty Interviewed by Vice Provost for Research

1. Establish a **reward system that underscores and rewards high quality teaching** and learning in gateway science courses. The president, provost, deans and chairs should establish a policy that rewards faculty (with more free time; high profile public recognition, additional TA assistance or other incentives) who contribute the most to gateway science courses. They should make it clear that GSC excellence is a priority and mediocrity is not acceptable; but they should NOT exhort faculty to do better with the same or less support.

2. **Free faculty to teach** - support GSC administration with non-tenure track faculty and additional TAs.

3. **Expand PILOT**, a peer instruction method developed at Case Western Reserve University and adapted for Hopkins by WSE Vice Dean for Undergraduate Education Ed Scheinerman, which supplements gateway science lecture courses with peer-led learning sessions in math and physics.

4. **Reverse the order of curriculum requirements**: introduce freshmen and sophomores to research-oriented, problem-based technical courses, followed by theoretically based survey courses. Civil Engineering is willing to test the impact of this approach.

5. **Create a JHU Gateway Learning "Platform"** – set of tools embedded in the learning management system to make it easier for faculty to organize and teach GSCs.

6. Introduce 10-15 minute **"TED-like" on-line videos to introduce basic content,** accompanied by in-class team problem sets and evaluations, effectively reversing the role of face-to-face and outside-the-classroom activity; BSPH and Materials Science are developing now.

7. Promote **active over passive classroom learning activities**: introduce team discussions, in-class problem solving.

8. **Endow a small number of Feynman-esque GSC lecturers** who are stars in their fields and stage artists whom students will long remember.

9. **Modularize GSCs** so students and faculty can enjoy small accomplishments, then move onto the next one.

10. **Revise the grading system** to promote student risk-taking in challenging courses.

11. Build **new collaborative learning space to support** discussion, team problem solving.

12. Support **GSC planning retreats** within programs to improve individual courses, coordinate across disciplines, and design cross-cutting themes