



Gateway Sciences Initiative

Final Report
July 2016

Executive Summary

Teaching and preparing future scholars is essential to the mission of Johns Hopkins University. The foundational knowledge for these future scholars is typically taught in the “gateway” courses, those entry point courses that provide critical introductory material for undergraduate and graduate study in the natural, behavioral, medical, and engineering sciences.

This report summarizes the projects and findings from the Johns Hopkins University Gateway Sciences Initiative (GSI), a multi-dimensional program launched by the Provost in 2011. Through an internal grant program that funded 23 instructional enhancement and pedagogical innovation projects and a Symposium on Excellence in Teaching and Learning in the Sciences, Johns Hopkins generated and disseminated numerous strategies that serve as best practices for teaching gateway science courses. GSI projects inspired a pedagogical culture-shift toward active, collaborative learning that both energized faculty and improved student success in gateway classes. Further, the GSI challenged faculty and academic leaders to explore how its findings can be institutionalized across the university, beyond gateway courses and beyond the hard sciences. Collectively, the GSI projects and symposium exemplify Johns Hopkins’ continued commitment to teaching excellence, innovation, and discovery.

Creating a Culture of Active Learning in the Sciences

In 2011, the Provost's Office began the Gateway Sciences Initiative (GSI), with the goal of enhancing teaching and learning in courses that serve as entry points for study in the sciences. To that end, faculty were asked to help re-envision the classes that formed the backbone of early science instruction.

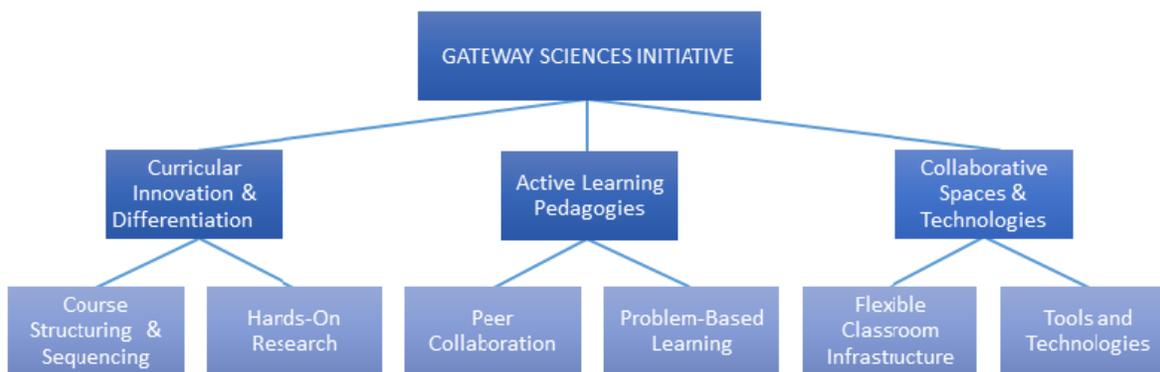
The scope of the initiative was ambitious, with 23 grants awarded in two phases between 2011 and 2013.¹ The impact has been far-reaching, with projects initiated across the Divisions in the Departments of Applied Mathematics and Statistics, Biochemistry and Molecular Biology, Biology, Biomedical Engineering, Biophysics, Chemistry, Economics, Epidemiology, Materials Science and Engineering, Mathematics, Molecular Microbiology and Immunology, and Physics and Astronomy; in the Krieger School of Arts and Sciences, Whiting School of Engineering, and the Schools of Advanced International Studies and Nursing; in Advanced Academic Programs; and in the Center for Educational Resources and the Center for Biotechnology Education. ***These initiatives have already served more than 6000 students.*** Many of the programs have, in a short amount of time, become ingrained in the Hopkins experience with a tremendous impact. For example, in the 2015-2016 academic year alone, the PILOT Learning program provided over 15,500 contact hours of academic support to the students served.

The results of the GSI are impressive, demonstrating educational gains and increased student and faculty engagement, satisfaction, and retention. ***Fourteen out of 22 GSI final reports showed concrete improvements in student learning outcomes.*** (Appendix 1) In addition, five final reports highlighted gains in student retention and persistence in the discipline. These outcomes are particularly notable given the fact that many of the programs were structured in ways that did not easily lend themselves to quantification: e.g., they recruited self-selected student groups, they were developed in a course or sequence that lacked a comparable control, or they were implemented in courses that were graded on a fixed curve that showed no year-to-year variability.

In addition, students and faculty were enthusiastic about the GSI's commitment to a pedagogical culture-shift toward active, collaborative learning. ***Nineteen out of 22 final reports noted improvements in student engagement and satisfaction.*** (Appendix 1) Critically, along with changing the pedagogical culture came higher grades for students, better retention, more thorough comprehension, and a more expert outlook on the sciences. Not surprisingly, faculty, too, showed considerable buy-in. Final reports describe how professors were energized by the changes and that departments as a whole were galvanized. ***Eleven final reports explicitly noted that faculty satisfaction and engagement improved under the GSI.***

¹ One grant was not completed due to the illness and retirement of the PI.

Collectively, the GSI projects exemplify Johns Hopkins' investment in teaching excellence, inspiring faculty to redesign courses and classrooms to the benefit of student satisfaction and achievement. The following sections of this report describe how the GSI projects implemented innovative instruction in the gateway sciences through three main strategies: (1) curricular innovation and differentiation, (2) implementing active learning pedagogies, and (3) leveraging spaces and technologies to promote collaboration.



Curricular Innovation and Differentiation

Course Structure and Sequencing

The primary focus of the GSI was to challenge the ways in which incoming students have been traditionally introduced to college science, via large, lecture-based overviews that can sometimes overemphasize passive learning and memorization. Among the limitations of the conventional gateway method was the one-size-fits-all approach to incoming freshmen. A major thrust of the GSI, therefore, was to encourage differentiation so that courses could more closely align with the varied experience and knowledge base of their students. This shift to “meet students where they are” derives from an evolved pedagogical mission – that the goal of a university is to ensure that all students learn and thrive to the best of their capacities, not just those with the biggest intellectual head start.

Several of the GSI grants focused on differentiating gateway curricula to meet the needs of incoming students, who enter college with diverse skills and capacities. Sometimes, that meant providing a landing spot for students who performed well enough on the AP exam to skip a traditional introductory course, but who were nevertheless unprepared to jump directly to the next level of classes. For instance, the Chemistry Department developed a bridge course, “Applied Chemical Equilibrium and Reactivity,” designed for students who place out of introductory chemistry courses but are not best served by moving directly into organic chemistry. Students with AP credit are usually some of the brightest students entering college, having demonstrated a firm mastery of high school chemistry. They also represent a sizable percentage of the incoming class at Hopkins: in 2013-2014, 624 students were granted credit for introductory chemistry based on AP scores. Yet these students frequently lacked the foundational understanding of chemical concepts as expected at Hopkins and often had limited laboratory proficiency. As a result, these otherwise gifted

students sometimes struggled in later classes. This new bridge course meets such students where they are, helping them develop crucial laboratory experience and setting them up for success in later courses. Aimed specifically at high achieving incoming students and incorporating active learning techniques, the course is built around nine inquiry-driven laboratory projects and focuses on those areas where faculty had previously seen deficiencies in incoming students' preparation.

The results have been very promising. Data from Fall 2013 revealed that students who took the bridge class had higher grades when they subsequently took Organic Chemistry, compared to those who skipped Introductory Chemistry by using AP credit and then took Organic Chemistry. Data from Fall 2014 further found that students who took a more challenging sequence during their freshman year—the bridge class followed by the course Chemical Structure and Bonding (103/204)—earned higher Organic Chemistry grades than students with AP scores of 4 or 5 who had elected to retake the less challenging introductory chemistry sequence (101/102). The performance of the bridge course students is all the more impressive, given that they were coming in with, on average, significantly lower Math SAT scores. Finally, students who took the bridge course were found to have more expert-like views on the atomic and molecular perspective of chemistry and on the connection between chemistry theory and the real world. Because of the success of the bridge course, the AP policy was changed to require students with AP scores of 4 to take more chemistry, and they are now almost exclusively taking the bridge course.

Through second round grants from GSI in 2013, Chemistry multiplied its first-year offerings, introducing four additional courses to ensure that incoming students are placed in courses that are appropriate for their level. The new courses have received enthusiastic reviews, with consistently high course evaluations across all the classes. Faculty also praised both the new courses and the students who have completed them, bringing more of these undergraduates into their research labs than ever before. Moreover, preliminary data indicate modest, but appreciable gains in final grades, especially for at-risk students.

Chemistry also began offering study modules that students could voluntarily use to shore up their knowledge of chemistry to meet course expectations. In all courses, students who completed the recommended modules had higher average course grades, sometimes as much as a full letter grade, than students who did not. ***Moreover, no student who completed the modules received a D or an F in any of these classes.*** The results were most stark with students who had the lowest entering SAT scores: within this group, the average GPA of students who completed all the modules was 3.8, compared to 1.3 for students who did not take the initial assessment or complete any of the modules. The modules have recently been expanded to include JUMP and Hop-In at-risk students as part of their transition to college – and in data collected from Fall 2015, the JUMP/Hop-In students using the modules performed better on average, and none were in the bottom 15% of their class.²

² Chemistry also offered a 0-credit class, Chemistry with Problem Solving, which was targeted to at-risk and underrepresented students. Student feedback for the course was overwhelmingly positive, and early data indicates that student grades in the related introductory course were higher for students who took this Problem Solving supplement.

Seeing a similar need to meet students where they are, intellectually and academically, the School of Engineering, in conjunction with the Center for Talented Youth and Cognitive Science, developed a spatial reasoning assessment and encouraged low-performing students to take a newly developed one-credit pass/fail course designed to strengthen spatial reasoning skills. Spatial reasoning is crucially important to success in many gateway science, engineering, and mathematics courses, yet it varies markedly between individuals (and routinely shows significant gender-based differences). Research demonstrates, however, that these skills can be taught. Seeking to help those students who demonstrated a need for greater assistance in this area, the team designed the one-credit course to help students develop two- and three-dimensional spatial reasoning abilities through model building, mental rotation, perspective taking, and paper folding. The results were encouraging, as *lower-assessment-score students who took the course significantly outperformed their peers who did not* on a post-course spatial reasoning battery. In addition, student perception of the course was largely positive. Long-term data are still being collected to determine the impact of the pass/fail course on subsequent-course GPA and student retention in Engineering.

In addition to the work of Chemistry and the School of Engineering, other groups have differentiated curricula and developed bridge courses under the GSI to meet the needs of academically diverse students. The Biology Department developed a laboratory course aimed at students who place out of General Biology due to AP credit, yet have no natural place to land when they arrive as freshmen. They also developed a new genetics course, Genetics, Genomics and Evolution, to provide additional options for the same population. Economics has addressed incoming students' wide range of knowledge by designing online problem sets under its GSI grant to target specific explanations of the material to those students who need it most. And Epidemiology broke up the single gateway model by developing a modular framework for three existing and three new courses, including a new introductory course and two follow-up courses.

Promoting Hands-On Research

While one means of diversifying the introductory science curricula is to provide a greater number of options for incoming students, another is to offer options that allow students to delve deeper into the science. To that end, some departments used GSI grants to develop new courses that allow students to begin doing substantive research from their first days on the Hopkins campus. The idea was to transform introductory pedagogy from a lecture-based model to an engaged, learning-by-doing, lab-based approach.

As an example, the Biology Department developed a new, freshmen-only laboratory course in which students isolate a novel bacteriophage virus collected from local soil, establish a pure population of the phage, name and characterize the phage, and annotate the phage's genome. Students begin the research on their first day of class and, after all the main tasks are complete, are permitted to propose and carry out their own experiments on the phage. Not surprisingly, *students who took the course report strong gains in "thinking like a scientist."* This "phage-hunting" course is exceptionally popular with students and earns

an “overall quality” score that is a full point above department average on student evaluations.

Similarly, Chemistry has begun to offer two new research-intensive lab courses for first-year students. The first, Chemical Structure and Bonding with Laboratory, is a flipped, problem-based research course. Students watch video lectures outside of class, while course time revolves around nine experiments developed to emphasize and extend what the students have absorbed in the lectures, followed by a tenth capstone project that the students design themselves. Both students and faculty have been positive about the course and, while longitudinal studies are ongoing, initial findings indicate significant gains in student performance. Indeed, *students who completed the Chemical Structure and Bonding with Laboratory course had higher grades in their subsequent Organic Chemistry class* when compared to both (1) students who took two semesters of introductory chemistry and (2) students who opted to skip introductory chemistry after scoring a 5 on the AP Chemistry exam.

The second lab-based course that Chemistry developed, Chemical Chirality, has also been popular with students and has received extremely high student evaluations. Faculty have been enthusiastic as well, and have been eager to take students from this course into their research labs for further work. *More than 40% of the students who took this course in its first three semesters are working or have worked in chemistry and science related laboratories at the University.* The Chemical Chirality course was not funded directly under the GSI, but a GSI funded post-doc was used to teach it.

The Biophysics Department also made a push toward hands-on pedagogy by developing a new course, Introduction to Scientific Computing. The goal was to sharpen undergraduates’ quantitative and data analysis skills by introducing them to UNIX, Python and Mathematica/Matlab programming environments. The course has proven so popular that new sections of the course have been added in four of the five semesters in which it has been offered, and almost all sections have been running at full capacity.

Finally, from a faculty perspective, these lab-based courses were exciting for their ability to transform the theoretical into the concrete, enabling the hands-on participation in actual science that gets to the crux of the GSI mission. As the Chemistry PIs wrote in their final grant report: “We would also suggest that the most important component of foundational courses is not the transfer of knowledge (although that certainly occurs) but rather the teaching of how to approach a problem or laboratory experiment.” The students certainly agreed, with one of them writing in an evaluation, “It was good that we had a real way of viewing what we were learning in class at all times. Nothing that we did seemed so abstract that it couldn’t be applied to anything...” This enthusiasm is being harnessed to implement these methods in other departmental courses.

Implementing Active Learning Pedagogies

Peer Collaboration

Direct research is not the only way to bring active learning to gateway courses. Perhaps the most straightforward means – and certainly the most popular means under the GSI – is through peer-based learning and team-based group work.

Prior to GSI, the Center for Educational Resources developed a team-based learning program named PILOT Learning to support Calculus II for Physical Science and Engineering, Calculus III, and General Physics for Physical Science Majors I & II. PILOT, a loose acronym for “peer-led team learning,” is built around supplementing large classes with small study groups of 8-10, led by peer leaders who have previously mastered the material. These groups meet for two hours a week, working together on a set of problems with the discussion moderated by the peer leader.

Through the GSI program, PILOT was expanded to Introductory Chemistry I & II, where it was met with overwhelming enthusiasm by both students and faculty. In light of this response, PILOT under the first round of GSI funding grew to include Calculus I & II for Biological and Social Sciences and, through funding secured in the second round of GSI, was further expanded to General Physics for Biological Sciences I & II and Linear Algebra. In fact, PILOT now supports every large-lecture freshman mathematics course in the Mathematics Department. ***The PILOT program now employs more than 100 peer leaders and supports approximately 950 students in each semester.*** PILOT has become such a popular and effective program that student demand routinely exceeds capacity. To address the strong demand for PILOT in upper-level and non-supported courses, students have spun off their own version of the program, called AutoPILOT, in which students meet in regular study groups without a group leader. The PILOT program mentors these AutoPILOT sessions through advice and resources for faculty and students.

The second-round PILOT grant also worked to institutionalize the program and make it self-sustaining. This round not only significantly increased the number of PILOT course offerings (bringing the total number of covered courses to 20), but also expanded plans to recruit and support at-risk students through numerous programs run through the Office of Multicultural Affairs, and developed a more structured leadership and training program for students who act as PILOT Leaders.

In addition to being popular, PILOT demonstrated quantifiable gains in student performance – PILOT students got higher grades on average than their non-PILOT peers. The results of students’ self-assessment are even more dramatic. 92% of students said that, through PILOT, they had a better understanding of the concepts from lectures, 80% said they believe PILOT helped them have a better understanding of how to do the homework, 70% said it increased their satisfaction with the course, and 75% believed that it had increased their own grade in the class. Moreover, a remarkable ***98% of the students said they would recommend the PILOT program to other students.*** Finally, perhaps the most

important result from the perspective of GSI, ***27% of students indicated that PILOT helped them stay in a course that they otherwise may have dropped.***³

Perhaps the greatest indication of PILOT's success remains the overwhelming demand of both students to enter the program and faculty seeking PILOT support for additional courses. In addition to the 20 supported courses, numerous others have also requested support, including Differential Equations, Discrete Math, Macroeconomics, Microeconomics, all sections of Organic Chemistry, and courses within the departments of Biological Science, Computer Science, Neuroscience, and Psychology. At present, resources are not available for this expansion, but with continued administrative backing, PILOT has the potential to transform gateway courses throughout the University.

Physics is also promoting peer instruction strategies in all of its General Physics classes, which enroll approximately 700 students every semester.⁴ As a supplement to its General Physics sequence, the department replaced its traditional TA-led discussion sections with cooperative group problem solving, supervised by newly trained TAs. To facilitate the group work, the department also added undergraduate learning assistants who serve as near-peer mentors and help supervise problem-solving exercises. Furthermore, the introductory Physics sequence catering to engineering students has been reorganized to reduce formal lectures, using class time instead for conceptual problem solving exercises.

In addition to these supplements to its traditional lecture course, Physics has also introduced a wholly new introductory course based on the SCALE-UP instruction model from North Carolina State University, where students work through activities in small groups of around three students. Compared to students in the traditional, lecture-style course who took the same exams, ***students in the SCALE-UP course did better on all three midterms and the final.*** Moreover, according to student evaluations, 84% of students found the use of class time to be helpful or very helpful in learning the material. SCALE-UP instruction was expanded through the second round of GSI funding, which allowed Physics to develop small, hands-on experiments known as “tangibles” which make the abstract lessons of the course material more concrete – an addition that 85% of the students rated as helpful or very helpful. Since its implementation, demand for the SCALE-UP course has surged, so that the class now is at full capacity with a sizeable waiting list.

Problem-Based Learning

While peer-lead learning has shown great promise under the GSI, it requires a substantial investment in the organizational support needed for student leaders, meeting space, and oversight. A leaner approach to active learning is for faculty to augment courses with case studies and in-class problem solving tasks that allow students to confront course material through applied examples.

Through the GSI, the Applied Mathematics & Statistics Department restructured its introductory statistics class, using case studies to teach material normally covered through

³ These data are from the Spring 2015 evaluations, but the percentages are comparable to other semesters.

⁴ Nearly 60% of all JHU undergrads take General Physics.

lectures. By design, the case studies cover multidisciplinary material, appealing to the wide variety of majors who take introductory statistics. In addition, several of these case studies are based on actual research conducted by faculty in other departments at Johns Hopkins, making the material particularly relevant to the students by demonstrating what real research looks like at their own university, across the disciplines. While it took some time on the front end to create the case studies, they are intentionally modular and can now easily be used both in introductory and upper level courses.

The statistics case studies were well received by both students and professors. Faculty perceived an “improved conceptual grasp” when compared to students in the traditional, lecture-style class. Students, meanwhile, rated the overall quality of the class highly (4 out of 5), which is relatively unusual in introductory statistics classes. One student wrote, “The best part about this course was that it was designed to give some context to the abstract mathematical concepts that we were learning.” This case-study based approach has now been implemented by multiple instructors across multiple statistics courses, with seven different courses now using this model. According to the PIs, the approach “is thriving, and has resulted in a shift of our approach to the teaching of applied mathematics and statistics in general.” Moreover, the shift to active learning has energized the faculty. As the PIs write, *“The GSI project was a tremendous galvanizing force within the department.”*

Other departments have similarly implemented problem-based learning under the GSI. The Energy, Resources and Environment Graduate Program in SAIS implemented a flipped model for its gateway course, which allowed students to use class time for group-based problem solving. The initial student response was so positive that three other courses have since been flipped, and three additional faculty members have inquired about flipping their own courses.

Nursing was able to use a flipped format for an introductory nurse practitioner course, Diagnosis, Symptom and Illness Management I-Pediatrics. Prior to class, students reviewed readings and watched video material, while class time was used for small-group, student-centered learning using structured activities that were aimed at promoting clinical reasoning. Faculty reported that students in the flipped course format were more consistently engaged than students in the traditional class setting; students, on their part, also provided positive feedback of the new teaching methods via course evaluations. In addition, students showed greater retention of knowledge in the subsequent semester. Similarly, the School of Public Health experimented with online and blended case study formats for its Introduction to Biomedical Sciences course, finding large gains in student satisfaction for a new web-enhanced on-campus version of the class.

The Biology Department also introduced group-based, in-class problem solving into its gateway Biochemistry course under the GSI. When problem sets were solved in class, rather than as homework, students performed better not only on those specific questions but also on later exams. Both students and faculty had positive opinions about the in-class problem sets, with the majority of students stating that more problem sessions should be

included in future classes. Problem sets are now being extended to other course offerings within the department.

Epidemiology extensively redesigned both of its gateway courses to incorporate alternative instructional strategies. Each course was offered in a blended/flipped format beginning in Fall 2014, which entailed providing students with video lectures (recorded in 2013 with GSI support) and developing practical applications and other activities to use in class. A variety of active learning strategies (including PollEverywhere as well as “think-pair-share” and “muddiest point,” two widely used classroom assessment techniques) were also coupled with in-class activities to further promote active learning.

Leveraging Spaces and Technologies to Promote Collaboration

Flexible Classroom Infrastructure

One element that directly impacts the implementation of active learning techniques is physical space – learning occurs in specific classrooms, with specific seating arrangements, and specific technologies at its disposal. Some re-envisioned courses through the GSI were able to utilize renovated active learning classrooms and workshops and, when that occurred, faculty and students were unanimous in their praise for the collaborative space. Two GSI projects were directly focused on creating new spaces for student learning, and both were so successful that they are nearly constantly at capacity.

The first fully redesigned space under the GSI was the active learning eStudio, planned and implemented through the Center for Educational Resources. Envisioned as a multipurpose collaborative space, the eStudio maximizes flexibility and provides numerous configurations for group-work, with five round tables that can each seat seven, local projection to multiple locations, full wall-covering whiteboards, and space for faculty to observe the whole room and move between projects.

Both students and faculty raved about the space. As one professor said, ***“I love the classroom and will teach here every chance I get. I also recommend it to other faculty to facilitate group activities.”*** With student groups working simultaneously on the whiteboards, a professor is able to, as one of them put it, “monitor the whole class working this way and move around the room providing feedback.” Another faculty member noted that, when students enter the collaborative space, they “expect something different. They come in, get settled, and are ready to get to work.” Faculty have further remarked on the way that the group-work bonding created a tighter and more supportive cohort that would help as those students moved through the rest of the curriculum. Students also found that the space enabled them to create learning communities with their peers and work more effectively. One student summarized the experience of using the classroom: “The smaller and more intimate learning environment was more conducive to collaborative learning, and helped me pay attention better.”

The benefits of the classroom extend beyond just happier students and faculty. Tangible

gains in student performance were found for classes housed in the eStudio. ***In one case, measures of student learning more than doubled in the eStudio with active learning techniques, compared to the same course taught in a traditional lecture hall.***

The success of the eStudio has prompted other departments to create a dedicated collaborative, active learning space. Through the second round of GSI funding, the Department of Biomedical Engineering built the BME Design Studio. The new, state-of-the-art active learning workspace enabled the department to completely re-envision their gateway design course to allow students to operate as engineers from their first day at Hopkins. The space was immediately successful, not only for the freshman gateway BME course, but also for several other hands-on courses in the BME curriculum, and it was highly sought-after as a design space for students from other departments. The BME Design Studio also supported the interdisciplinary Qualcomm Tricorder XPrize team – an undergraduate group that is a top 10 finalist (and the only academic team remaining) in a global competition to create a portable, wireless device to monitor and diagnose medical ailments. In addition, in October 2014 the BME Design Studio hosted the Emergency Ebola Design Challenge, and teams from the event were awarded State of Maryland and USAID grants to continue working on a redesign for personal protective gear used in emergency medical situations. Student reviews of the studio have been extraordinarily positive, and ***upper class mentors for the freshman gateway course were nearly unanimous in their praise for the new space compared to previous options.***

As a corollary to its GSI project creating the SCALE-UP course (though using other funds), Physics also created an active learning space capable of accommodating up to 84 students. The layout of that classroom is very similar to the eStudio and is being used by both Physics and Chemistry for multiple classes and discussion sections, including the GSI-funded “Chemical Structure and Bonding.”

Johns Hopkins is fortunate to have highly productive campuses, but unfortunately space is always at a premium. We will need to identify old classrooms that have potential for renovation and repurposing, particularly as renovations often result in slightly lower student capacity. Nonetheless, the remarkable improvements in student outcomes, student satisfaction, and faculty engagement that redesigned gateway courses can provide depend upon suitable spaces for collaborative and active learning. The eStudio, the BME Design Studio, and the Physics active learning space stand as exemplars and templates as JHU continues to be an innovator in active learning education.

Tools and Technologies

In addition to having classrooms suited to active learning, spaces must be equipped with the most effective tools and technology to fully develop students’ understanding and skills. Some of that technology is a simple extension of what already exists at a first-rate university such as Hopkins. Other tools, however, require a significant investment of up-front time and resources in order to pay dividends down the road.

In a simple solution to support active learning, the Energy, Resources and Environment Program began using a modified PowerPoint presentation, supplemented by student clickers, to ensure that students fully understood material in advance of in-class problem solving exercises. The clickers were used in a flipped format course, in which students reviewed voiced-over PowerPoint lectures outside of class, and class time was devoted to group projects and problem solving. There remained a need, however, to determine that the materials from the out-of-class lectures had been absorbed and properly understood. To address this question, students were given short, in-class PowerPoint-based quizzes that they answered with clickers –the professor could then use this real-time data to assess whether the students grasped the material and, if not, give a short, targeted lesson on topics that students were struggling with.⁵ The students appreciated the targeted reinforcement that these in-class quizzes provided. As one student said: “In-class quizzes... really help solidify the key concepts and provide direction for material that needs further review.”

Other tools similarly required little upfront investment of time and resources, but yielded positive results. The Center for Biotechnology Education and Advanced Academic Programs introduced a student-led wiki tool to encourage collaborative research in a gateway cell biology class. Students were responsible for creating a wiki page, producing substantive comments, and supplementing their classmates’ wiki pages throughout the semester. Students were overwhelmingly positive about this project. ***80% of the 115 students agreed that the wiki format provided a rich environment for learning and interacting with classmates, and 81% further agreed that participating in wikis increased their understanding of cell biology processes.***

Not all of the tools were as simple to generate, of course, and many of the tools and technologies developed through the GSI are still works in progress. Nonetheless, most show encouraging signs. In addition to the wikis, the Center for Biotechnology Education generated three professionally produced videos (with animations and voice actors), which the students were enthusiastic about.⁶ Even though watching the videos was not required, *all* of the students in the course that used the videos watched them at least once, found them helpful in performing experiments, and recommended that other courses use such videos. On the faculty side, the effort involved to generate the videos, by already busy professors, is not insignificant. And yet, they are an important investment, as ***the videos used for this course can be used in at least eight other courses.***

In a similar and prolific venture, the Mathematics Department created 250 ten-minute, single topic instructional videos for an introductory linear algebra course, which serves 300 to 500 students each semester. In addition, a YouTube channel now houses lecture-based video content to replace some of the classroom lectures, in order to facilitate a more active learning environment. Combined with mastery quizzes, other dynamic content, and project-oriented group work outside of the classroom, the faculty’s vision is that these tools would become a teaching resource and, eventually, allow for a flipped or blended course. At the time of the GSI final report, videos had not yet been made for all

⁵ Clickers were also tested by the Chemistry Department in 2014 and are being used as of 2015. Epidemiology used a similar smartphone-based system called PollEverywhere.

⁶ The Center also produced 15 shorter videos to be used in a later Bioinformatics course.

the course material, but the GSI project has jumpstarted a redesign of the linear algebra course into a much more student-centric collaborative learning environment.

Epidemiology took a different approach to technology. In their core sequence, GSI funding was used to redesign the course project by using Wikis and Voicethread technology. The redesign has successfully promoted interactive collaboration, even in large class settings of more than 100 students. The GSI also supported Epidemiology building its own interactive, self-guided electronic workbook, *e-Epi*, to supplement its introductory courses. Available as an app for smartphones and tablets, *e-Epi* includes text content, case studies, interactive graphics and demonstrations, and embedded video/audio, including lectures, embedded links, a detailed glossary, flashcards, and an extensive set of practice problems with annotated feedback.

These tools and technologies, while still being produced and experimented with, are an investment in a culture of engaged teaching and learning at Hopkins that can yield flexibility and pedagogic enrichment down the road.

Sharing the Investment in Teaching and Learning at Hopkins with Outside Academic Leaders

On January 12, 2016, more than 275 Johns Hopkins University faculty, staff, students and guests participated in the 2016 *Symposium on Excellence in Teaching and Learning in the Sciences: Learning through Science, Theory, and Practice*. The symposium featured seven keynote presentations by three GSI award recipients and four outside faculty experts. Dr. David Asai, Senior Director of Science Education at Howard Hughes Medical Institute, opened the symposium with an exploration of the topic of inclusive education in his session titled, “A non-linear approach to inclusion.” Dr. Sherri Sheppard, Professor of Mechanical Engineering at Stanford University, then addressed the topic of learning objectives and course design in her session, “Cooking up the modern undergraduate engineering education—learning objectives are a key ingredient.” In her session, “The biomedical engineering design studio: form and function,” Dr. Eileen Haase, Johns Hopkins University Senior Lecturer in Biomedical Engineering, delved into the topic of active learning classrooms and courses. The topic of curriculum reform and assessment was subsequently addressed by Dr. Melanie Cooper, Lappan-Phillips Chair of Science Education at Michigan State University, in her presentation, “Evidence-based approaches to curriculum reform and assessment.” Johns Hopkins University Associate Professor of Chemistry, Dr. Tyrel McQueen, discussed the concept of discovery-driven experiential learning in his session titled, “Chemical structure and bonding with laboratory.” Dr. Robert Leheney, Professor of Physics at Johns Hopkins University, explored the topic of active learning in Physics in his presentation, “The development of an active-learning based course in introductory physics at JHU.” Dr. Steven Luck, Professor of Psychology at the University of California Davis, closed the symposium by addressing the topic of flipped classrooms in his session, “An exploration of the methods, benefits, challenges and assessment recommendations for transforming a traditional large lecture course.” The participants actively engaged in the

talks as well as the extended question and answer periods, resulting in a stimulating exchange of ideas about methods to improve STEM education.

A half-day faculty retreat was subsequently held on January 13, 2016 with the aim of synthesizing what faculty had learned from outside experts, GSI experiments, and evidence-informed best teaching practices in order to address the question: how should Johns Hopkins advance and distinguish STEM education at the gateway science level? During the first session, GSI Symposium keynote speakers and nearly 45 STEM faculty participated in one of four small group discussions, facilitated by GSI committee members. Dr. Joel Schildbach, Professor of Biology and Vice Dean of KSAS Undergraduate Education, facilitated group discussion on the topic of discovery-based learning through research. A second group, facilitated by Dr. Tyrel McQueen, Associate Professor of Chemistry, discussed curriculum differentiation. Dr. Dan Reich, Professor of Physics and Astronomy, expedited discussion about engaging students in the lecture. Finally, Dr. Michael Falk, Professor of Materials Science and Engineering, led a discussion about teaching foundational skills in the disciplines. Following the small group discussion, all participants re-convened as a large group to further explore the themes, findings, and questions identified in small group discussions.

Moving Forward: Lessons on Investment in Teaching and Learning at Hopkins

GSI Recommendations

- Encourage Differentiation of Introductory Course Options
- Increase Options for First-Year Research
- Institutionalize the PILOT Learning Program
- Provide More Active Learning Spaces

The nature and content of faculty discussions at the retreat support that the Gateway Sciences Initiative has marked a shift in thinking about how best to introduce students to the sciences at JHU. By adding active, research-based, collaborative, differentiated models to their instructional repertoires, the GSI faculty have responded to the challenge of re-envisioning the traditional university science experience. As results from the GSI demonstrate, a switch to active learning can be modest in design or sweeping and ambitious, but no matter the mechanism or scope, the gains in student satisfaction, student learning, and faculty engagement are real. The successes of the GSI grants have yielded ideas and structures that are ripe for expansion along four main lines:

Encourage the differentiation of introductory course options to meet the varied nature of incoming students and ensure that every student can succeed. Biology, Chemistry, and Epidemiology have all had success multiplying course options for first-year students. Equally important is the development of assessment and placement tools to ensure that students end up in courses that are most appropriate for them. A pedagogical shift to “meet the students where they are” means that every student is given the best chance to succeed.

Increase options for first-year research experiences to promote learning through discovery and build expertise through scientific exploration. Biology’s “phage-hunting” course and the two first-year Chemistry laboratory classes demonstrate how first-year students can thrive by directly engaging in research from their first days on campus. Such students also become better scientific thinkers and more experienced hands-on scientists, allowing them to contribute sooner to the University’s numerous research labs. Adding more research opportunities to gateway science labs is a fruitful means of fostering active learning opportunities and strengthening student engagement.

Institutionalize the PILOT Learning program across the curriculum and support its continued expansion. PILOT has shown tremendous promise under the GSI and is extraordinarily popular with students and faculty. Even with PILOT supporting 20 courses and 950 students per semester, demand is still outstripping capacity. As the program grows, it requires additional, dedicated support to ensure that peer-instruction remains excellent and consistent, that students are placed appropriately, and that high quality problem sets are developed for the numerous covered disciplines. Consequently, in July 2016, the Provost’s Office approved \$13,000 in funding to support three PILOT fellows charged with creation of a problem bank that will serve as a permanent resource for the program.

Provide more active learning spaces by reconfiguring a portion of traditional classrooms to ensure that every active learning class has an available active learning classroom. The success or failure of a new pedagogical technique can be impacted as much by physical space as by course content. For instance, in the new Chemistry course designed for students who had performed well on the AP exam, students initially expressed negative opinions as to the value of working in groups. But when the class was partly moved the following semester to the Bloomberg active learning classroom, where students sit around circular tables, their responses changed to value working with other students to solve challenges. Inspired by the GSI, there are now five active learning spaces on campus with plans for a sixth. As the roster of active learning courses grows, so will the demand for spaces to house them. Every effort should be made to ensure sufficient availability of cutting-edge classrooms to maximize cutting-edge teaching and learning.

Broadening the Mission: Beyond Gateway, Beyond the Sciences

The Gateway Science Initiatives succeeded in thinking big and thinking diversely about how to maximize the gateway science experience for every student. Each project—differing by structure, course, discipline, student level, and pedagogical technique – approached the problem from its own angle and yielded its own insights. How can we best build upon that innovative spirit moving forward?

One step would be to apply the GSI insights to gateway courses beyond the hard sciences. The arts, humanities, pre-professional, and social science departments have their own gateway courses that could equally benefit from engaged and active pedagogy. Of course, strategies would have to be targeted to new audiences, and faculty would need to innovate

and customize solutions for their own departments. Nonetheless, many of the ideas developed through the GSI could have application beyond the STEM lecture hall.

Upper-level courses could also benefit from the innovations of GSI. While upper-level courses tend to steer away from large lectures, they are not immune to passive and one-size-fits-all pedagogy. Finding multiple paths to student success is essential to creating the maximum number of great minds. Similarly, active learning techniques and technologies can be implemented across the undergraduate and graduate schools.

Finally, the framework from the GSI seems directly applicable to the drive for interdisciplinarity at JHU. Just as first-year students sometimes need to leave their classroom to conduct research out in the world, so, too, do they need to leave their own departments to solve problems and learn lessons from related disciplines. Paired with the Provost's Signature Initiatives, active learning gateway courses could serve as a bridge between the classroom and the world. Just as the BME Design studio is already being used to tackle problems in global health, many of the GSI ideas can be used in the service of solving real world problems. First year business and economics students could work together on devising full-employment solutions in Baltimore and for 21st century cities worldwide. Engineering students could compete with chemistry students to see who can desalinate water using the least energy. Computer science and applied math students could work to reduce false positives in data-based self-diagnostic programs targeted at improving individual patient health. Moreover, active learning and service-learning are naturally complementary and provide a perfect opportunity for multiple departments to work together to engage students in ways that promote a deep understanding across disciplines and with the world around them.

The GSI has succeeded by utilizing 21st century pedagogical methods to further enhance Hopkins' track record of academic excellence. Through risk-taking and experimentation, faculty rose to the challenge, re-envisioning and improving the gateway experience across the sciences. But the legacy of the GSI extends beyond its component grants. The efforts and methods that were inspired and concretized through the GSI now establish frameworks and pathways whereby faculty can invest in enhanced teaching and learning across the disciplines, keeping the oldest research university in America at the forefront of innovation and discovery.

Title	Department	Div	PI(s)	Outcomes			
				Gains in Student Learning Outcomes	Gains in Student Satisfaction/Engagement	Gains in Faculty Satisfaction/Engagement	Gains in Student Persistence in Discipline
EPI: Epidemiology, Pedagogy & Innovation	Epidemiology	BSPH	Gange and Celentano	Yes	Yes	No	No
Active Learning eStudio	CER	CER	Dalrymple, Wagner, Cole, and Sczerba	Yes	Yes	Yes	No
Active Learning in General Physics	Physics & Astronomy	KSAS	Krolik and Leheny	Yes	Yes	No	No
Applied Chemical Equilibrium and Reactivity, a New Course for Students with AP Chemistry Credit	Chemistry	KSAS	Greco and Reese	Yes	No	No	Yes
Online Self-Paced Learning	Mathematics	KSAS	Wilson and Kong	No	No	No	No
Peer-Led Team Learning for Introductory Chemistry	Chemistry	KSAS	Dagdigian and Pasternack	Yes	Yes	Yes	Yes
Proposed Curricular Enhancements for Biology and Biological Sciences: Revamping the Freshman Experience	Biology	KSAS	Schildbach, Fisher, and Spencer	No	Yes	No	No
Using Technology to Enhance Understanding in Gateway Science Courses	AAP	KSAS	Koval, Lessick, Obom, and Ogg	No	Yes	Yes	No
Spatial Reasoning Assessment and Course	Engineering	WSE	Scheinerman	Yes	Yes	Yes	Yes
Statistics through Case Study	Applied Math & Statistics	WSE	Athreya, Fishkind, Jedynak, and Torcaso	Yes	Yes	Yes	No

Title	Department	Div	PI(s)	Outcomes			
				Gains in Student Learning Outcomes	Gains in Student Satisfaction/Engagement	Gains in Faculty Satisfaction/Engagement	Gains in Student Persistence in Discipline
"Tangible" Activities to Support SCALE-UP Instruction of General Physics	Physics & Astronomy	KSAS	Leheny, Maksimovic, and Krolik	Yes	Yes	No	No
Chemical Structure and Bonding with Laboratory: A New Course for Advanced Freshmen	Chemistry	KSAS	McQueen, Greco, and Reese	Yes	Yes	Yes	No
Harnessing the Undergraduate Teaching Laboratories to Enhance the Freshman/Sophomore Science Experience	Biophysics	KSAS	García-Moreno, Fitch, Damjanovic, Richman, and Caro	No	Yes	No	No
In-class Group Problem Sessions in Biochemistry	Biology	KSAS	Tift, Fisher, Hilser, and Lee	Yes	Yes	Yes	No
Institutionalizing Peer-Led Team (PILOT) Learning into the Culture of the Johns Hopkins University Undergraduate Experience	KSAS	KSAS	Kelly and Brown	Yes	Yes	Yes	Yes
Interactive Online Problem Sets for Elements of Macro-economics	Economics	KSAS	Moffitt, Hamilton, and Li	No	No	No	No
Interdisciplinary Space Science and Space Systems - Engineering CubeSat Laboratory	Physics & Astronomy	KSAS	Murray	N/A	N/A	N/A	N/A
Transformation of the Chemical Sciences to Enhance the Freshmen Experience	Chemistry	KSAS	Greco, Falzone, Hill, Reese, and Meyer	Yes	Yes	Yes	Yes

Title	Department	Div	PI(s)	Outcomes			
				Gains in Student Learning Outcomes	Gains in Student Satisfaction/Engagement	Gains in Faculty Satisfaction/Engagement	Gains in Student Persistence in Discipline
Global Energy Fundamentals – Blended Learning Format	SAIS	SAIS	Bleviss, Kreps, Rana, and Hurt	No	Yes	Yes	No
Introduction to the Biomedical Sciences: Collaborative Learning Onsite, Blended and Online Classroom	Microbiology and Immunology	SoM	Levitskaya, Bosch, and Rose	No	Yes	No	No
Improving Clinical Reasoning in Diagnosis for Pediatric and Family Nurse Practitioner Students	Acute and Chronic Care	SoN	Mudd and Flagg	Yes	Yes	No	No
BME Design Studio	Biomedical Engineering	WSE	Allen, Haase, Logsdon, Tung, and Yazdi	No	Yes	Yes	No
Introducing Online Learning Modules into Introduction to Materials Chemistry	Materials Science & Engineering	WSE	McGuiggan	Yes	Yes	No	No