FINAL REPORT—WISENGINEERING: Improving Math Performance through Engineering Design
1 July 2011—31 August 2012

Introduction

WISEngineering is a $249,453 collaborative proof of concept project by Hofstra University (lead), University of Virginia, and the Center for the Advanced Study of Education at CUNY. *WISEngineering* is a technology-based curriculum delivery, assessment, and feedback system that uses informed engineering pedagogy to introduce middle school math in innovative ways. It engaged learners and educators, promoted deeper conceptual understanding, and provided in-time assessment feedback to guide learning and instruction. Using CAD software such as ModelMaker™, students created solutions to virtual open-ended engineering challenges that required application of targeted Common Core concepts and then digitally fabricated their solutions using Silhouette™ printers. The learning activities underlying the design challenge, *Knowledge and Skill Builders (KSBs)*, were completed in a virtual, web-based, environment and with traditional paper and pencil learning activities. Students' designs required that they met specified math requirements and restrictions, promoting deeper understanding of the concepts. Students captured and recorded their designs in personal virtual journals and in hardcopy journals. The project site is located at www.hofstra.edu/wisengineering; the curriculum site is www.wisengineering.org.

Meeting Outcomes and Milestone

Appendix A includes the chart submitted with the proposal for Outcomes and Milestones. WISEngineering has met and in several instances exceeded the outcomes.

OUTCOME 1—Short term, end of unit student math performance and attitude improvement, knowledge of engineering gain.	**Discussion of Quarter 5 Progress and Completion**	**Above and Beyond**
Milestone 1-a—WISEngineering website and curriculum module development	*Finalize site and modules. Development of lessons learned from technology development.* Wisengineering.org is fully functional and available to teachers and students as an open-source site. There were modifications to the site as units were developed and refined, with teacher input assisting in refining functionalities. The units used different software and degrees of simulation, so the site redesign reflects this additional complexity.	In June 2012, Dr. Burghardt worked with computer science students and Dr. Xiang Fu (computer science faculty member) to further refine the functionality of the site. In addition, the team developed a standalone version for teachers to use in their classrooms, eliminating firewall issues and low speed connectivity issues. The work was done in consultation with Dr. Chiu at UVA.
Milestone 1-b—Curriculum	*Finalization of units. Development of lessons learned from curriculum*	In June 2012, Dr. Burghardt in collaboration with Dr. Fu and his

development of modules	*development*. Units 1 and 2 were developed using digital fabrication, ModelMaker and Silhouette Studio, for the Community Center and Community Garden design activities. The activities linked to Common Core Math Standards. The units had micro-testing and field testing with one of the development teachers and review by teachers affiliated with the evaluation team. Unit 3 is a virtual design activity that uses an open source PhET simulation that was modified to operate in the Wisengineering environment.	computer science graduate students started the development of a fourth unit dealing with plant development, linking common core math and common core science standards. Discussions are underway about additional topics that could be included, including units that focus on other content areas such as social studies or art. At UVa, four additional units are under development to pilot in science classes in the 2012-2013 school year. The four topics cover Core Concepts outlined In the new National Science Framework.
Milestone 1-c—Teacher professional development (includes using and refining curriculum, website, installation of equipment and software)	*Refinement of teacher tools/documentation based on implementation of units. Development of lessons learned from PD.* Two formal professional development meetings were held with the Paterson teachers, the first in November 2011 prior to unit 1 and the second in February 2012 prior to unit 2. In addition, project staff (Drs. Chiu and Hecht) were in contact with teachers via phone and email during implementation. Equipment was personally brought to the schools for installation. Dr. Chiu spent one week in January with the teachers as they began the implementation of the first unit. The Wisengineering website includes teacher support materials for the unit.	Dr. Burghardt introduced WISEngineering, units 1 and 2, to eight math teachers as part of a summer NSF experience in late June 2012. Over half of the teachers indicated an interest in implementing the curriculum in their classes. Chiu and her graduate student presented WISEngineering at the National Science Teacher Association (NSTA) annual meeting. Presentations have been submitted to AERA that will share the website. Informally the Paterson teachers and project team members have shared information about the website with others. Dr. Burghardt provided a teacher PD session (virtually) to teachers in Hawaii.
Milestone 1-d—Student Implementation of units	*Website available for students to use beyond the classroom. Development of lessons learned from implementation*. Students (102) implemented all three units in their classrooms. The website is available for them to continue work from outside their classroom. The website was continually modified in response to issues students found during implementation of the units.	Dr. Chiu and a graduate student worked with 60 additional students in June/July 2012, implementing WISEngineering unit 1 in an engineering summer camp context. Units were piloted with a small group of students in Hoboken NJ.

Milestone 1-e—Assessment materials developed, implemented and refined.	*Analysis of assessments and refinements to units and professional development based on student outcomes*. The evaluation team developed pre/post assessment for the units related to the common core mathematics associated with unit, as well as questions related to student affective change pre/post the WISEngineering experience. The team also was able to include comparison students. Additionally, the district, in conjunction with NGLC, used the STAR data to assess student performance in mathematics. The WISEngineering software recorded student activity, which is also used in assessing various aspects of student engagement.	The research team has developed additional constructs and measures to assess how students integrate engineering and mathematical ideas, with the eventual goal to also capture how students connect science and mathematics concepts within engineering projects.

OUTCOME 2—Medium Term: student improvement on standardized exams, reduction in 8th grade remediation, interest in STEM careers. (Requires milestones for Outcome 1, plus additional milestones below).		
Milestone 2-a— Student improvement on standardized math exams.	*Collect end-of-the year state math exam data. Analysis of exam data.* The research and evaluation team collected baseline data for students using the project-developed instruments and using STAR data, which is also used by SRI in assessing project effectiveness. The end of year data is not available until the fall. The district indicated a willingness to share the data even though the project will be completed.	The STARZ data was not part of the original plan, but was made available to us.
Milestone 2-b— Reduction of students in 8th grade remediation.	Analysis of performance re remediation. The project collected class grades, teacher reports and year-end status for student participants. The complete analysis is contained in the evaluation	Although "average" classes were requested, several classes had high numbers of students with special needs (upwards to 50%.) The social worker who worked with these students reported

	report. The WISEngineering students did significantly better than comparison students on the STAR test. There were significant gains in math understanding, and in understanding engineering design. The affective change assessments indicate significant improvement in student interest in STEM careers. District personnel indicated in interviews that students were more engaged in school, and attendance improved.	significant social gains for them, to the point where she noted they were "indistinguishable from students who were not receiving special services."
Milestone 2-c— Increased interest in STEM courses and awareness of STEM careers.	*Collect post survey on interests and attitudes and teacher interviews and feedback about class interest and perform analysis of survey data.* The complete analysis is available in the evaluation report. On post assessment surveys students indicated increased awareness and interest in STEM careers. Interest was expressed in engineering and architecture. Performance in the math course, as confirmed by STAR data, improved, a pre-condition for continued interest in STEM courses.	According to the social worker student attendance improved on days of WISEngineering, suggesting an increased interest in STEM courses (at least on WISEngineering days.

OUTCOME 3— Long term, increase of students at grade level math performance, increase in STEM electives selected. WISEngineering freely available to students and teachers nationwide.		
Milestone 3-a— Increase of students at 8th grade level math performance.	*Commitment by project staff to analyze math performance in 8th grade*. The evaluation and research team continues to interact with the Paterson district and will be receiving the 7th grade standardized test performance. The team will also be receiving 8th grade placement for WISEngineering students. We met with Paterson administrative personnel in late July to ensure ongoing collaboration.	

Milestone 3-b— Increase in STEM electives selected.	*Commitment by project staff to analyze elective selection in 8th grade.* The research and evaluation team will be receiving from the Paterson district the elective selection by the WISEngineering students. We met with Paterson administrative personnel in late July to confirm access to data.	
Milestone 3-c— WISEngineering freely available to students and teachers nationwide.	*WISEngineering site fully functional with 3 tested and refined units.* Three units (Community Center Design, Community Garden Design, and Balancing Act) have been developed, tested, refined, implemented with teachers, refined again. There have been two presentations regarding WISEngineering made at the 2012 ASEE Conference. The WISEngineering site is open and freely available to students and teachers nationally and internationally. All three units are currently in the public "library" of WISEngineering projects.	A fourth unit dealing with plant development, linking common core math and common core science standards, is under development. Additional units developed for science classes will also be publicly available after pilot testing. Additional papers are being written for journal and conference presentations in 2012/13 AY.

The Collaborative Journey

When we learned that WISEngineering would be funded, we contacted the Paterson school district and made plans to visit them in July. We visited the principals of both schools, as well as a senior administrator from the Superintendent's office who arranged the meetings and agreed to facilitate any organizational issues that might arise. Two community organizations that support the Paterson school districts were also involved and met with us. The Boys and Girls Club of Paterson provides community service connections and resources in the schools, and were an important part of our WISEngineering collaboration from the beginning. In addition the New Jersey Community Development Corporation, a nonprofit with a mission to support educational innovations in Paterson, identified a liaison to work with us throughout the implementation. The principals were involved in the selection of the seventh grade math teachers, one in each building, who would be asked to participate during the school year.

We developed a management structure that was highly collaborative. We have essentially met virtually almost every Wednesday of the year, supplemented by face-to-face meetings. In the summer, the Hofstra team worked on refining the Community Center design in paper and pencil form. The team also explored a variety of virtual learning environments, such as Google Sketch-Up, but eventually found that the software did not allow student manipulation for the mathematics understandings we were seeking. The UVA team focused on refining the WISE4 open source program into WISEngineering, which required reprogramming parts of the code and developing additional functionality, such as the design portfolio, the wall for sharing ideas, the design journal, as well as a structure for changing the program flow from science inquiry to engineering design. The CUNY team focused on developing assessments, piloting the curriculum, working with both Hofstra and UVA teams, and assuring alignment of all activities. In terms of collaboration, at each step one team would assume primary responsibility while the other two teams served as resources and critical friends to help refine and enhance the work. The UVA team was passed the initial Community Center design challenge, which they refined and started creating a virtual learning environment in WISEngineering. This resulted in more programming and further refinement of the unit. The CUNY team examined Community Center from an evaluation and research perspective and sent the materials out for expert review. The UVA team worked with CUNY on refining and operationalizing the research design. The Hofstra team collaborated with UVA regarding how informed engineering design pedagogy could be included in the virtual design, and with the CUNY team regarding the evaluation effort. Ideas were shared and the result was a richer product. This level of collaboration continued throughout the project, so essentially every action involved collaboration from all three teams. When the school year started, the collaboration expanded and included the Paterson teachers and district administration Boys and Girls Club and NJCDC.

Despite careful planning, there was a turbulent beginning to the academic year. The city of Paterson experienced unprecedented flooding after a hurricane in early September. School was canceled for over a week, thousands of people were living in shelters, and one of the schools we were working with was closed for the rest of year. Students and teachers were moved to a temporary location. Once relocated, we reached out to the two teachers, met with them, and discussed the project, the requirements and benefits. In an action that demonstrated the commitment of Paterson School District to the project, the Superintendent's office (and the principals) allowed the teachers to teach the units and forego the traditional text material during the times the WISEngineering units were taught. They also agreed to allow the teachers to forgo the traditional test preparation and assured the teachers that they would not be penalized if test scores were low (which was not the case.)

It was important that the initial professional development of the teachers be very positive, engaging and while challenging, not intimidating. The teachers were provided with their own laptop with necessary software (ModelMaker) installed, digital fabricators and printers. We met on a Saturday in mid November in Paterson and introduced them to the Community Center design challenge, which they completed, engineering design pedagogy, the WISEngineering learning environment, and evaluation materials of student work they would be gathering, a lot. Our goal was for them to test out the materials at home, become comfortable with the software and the WISEngineering learning environment. The classroom use of materials did not really happen until January.

The Hofstra, UVA and CUNY teams continued with their primary and collaborative responsibilities as the second WISEngineering unit, Community Garden design was developed, reviewed and tested. A member of the Hofstra team had implemented Community Center design in her class, and in the fall introduced her students to Community Garden design. The UVA team worked at transforming the paper and pencil version to the WISEngineering virtual learning environment. Both units used digital fabrication with different software that the teachers and students needed to learn. We developed strategies so the software was very accessible to them and did not create impediments to learning, but facilitated learning. The CUNY team worked with the Paterson teachers and began development of assessments for Community Garden.

In the meantime, we worked with the Paterson IT department re the installation of WISEngineering, trying to resolve any firewall issues, and delivered the printers and fabricators and software in early January. Dr. Chiu spent a week in January with teachers during the first week of Community Center Design, and in hindsight, it was essential that she was there. There were a variety of unanticipated IT connectivity problems that she helped resolve, within the district and with the WISEngineering server. She also provided a knowledgeable extra hand when digital fabrication was implemented in the classrooms. Although we hoped to have a computer for every student, the reality in Paterson was much different and instead many days we were limited to 3-4 work stations. Our experience indicates that having 3-4 stations in a classroom worked well. Students used a computer lab for some of their work, had paper and pencil activities, such as sketching and doing some problem sets, and saved their virtual work on flash drives (provided by WISEngineering), which they brought to their classroom for fabrication of their designs. The unit took longer than anticipated, four weeks instead of three, but there were several interruptions and lack of time in the computer lab, despite the teachers best attempts to schedule time in advance (standardized testing overrides other schedules). The teachers reported students were very engaged in the process and very much liked using engineering design in mathematics. One of the teachers, Nat Gerson, is a videographer and produced a video of his students at the conclusion of the unit, available at http://www.hofstra.edu/Academics/Colleges/SOEAHS/CTL/wisengineering/wisengineering_resources.html.

The second professional development day was held in late February and Community Garden Design was introduced to the teachers. Scheduling required the agreement of the building principals and the Superintendent, as the teachers were supposed to be part of a district professional development day. The PD was housed in the BGCP, again reflecting the collaborative nature of the WISEngineering endeavor. The teachers were introduced to new software, Silhouette Studio and the unit. We worked throughout the day minimizing technological issues with using the software, the WISEngineering site, and understanding the curriculum and pedagogical strategies to use with students. The teachers implemented the Community Garden Design challenge in mid-March, and again, it took at least a week longer than anticipated. There were several scheduling challenges that were overcome by creative instruction. The teachers expressed an interest that the third unit be shorter and totally virtual, something that we were interested in as well.

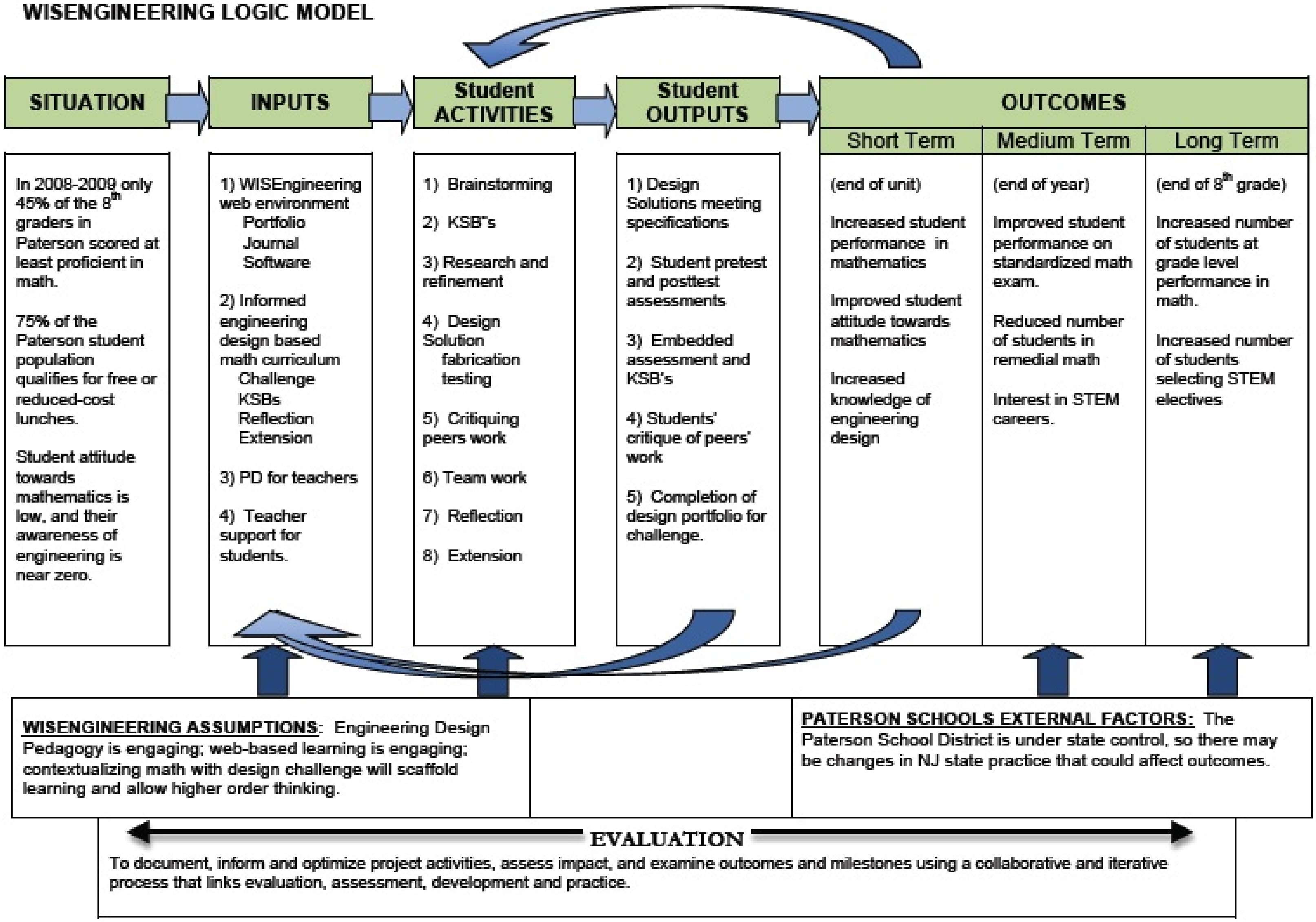
Balancing Act, the third unit, uses the open source resources of PhET at the University of Colorado, Boulder. In this case, the Hofstra team modified the simulations, requiring changing source code, so they would function in the WISEngineering environmental as Knowledge and Skill Builders. The development of Balancing Act continued through the spring and was handed off to the UVA team for refinement. Simultaneously, the CUNY team developed assessments and had the unit reviewed by experts and tested by students. Feedback was incorporated in the final design.

The UVA team took the lead in developing two peer-reviewed conference proceeding articles for WISEngineering that were presented at the 2012 Annual American Society for Engineering Education conference. One paper examined student performance gains using WISEngineering and the second paper discussed the WISEngineering learning environment from a technological perspective. The papers were well received and are being developed as refereed journal articles. The UVA team also presented introductions to WISEngineering at the 2011 annual meeting of the Association for Educational Communications & Technology in Jacksonville, FL, and the 2012 annual meeting of the National Science Teachers Association in Indianapolis, IN.

The WISEngineering platform was upgraded over the year by the UVA team. In late spring 2012, the U.C. Berkeley team announced that they were making a significant change to the coding, resolving some of the clunky issues they and we had been facing. The UVA team worked in conjunction with Berkeley team on these activities. By late spring the WISEngineering team realized that it needed to evolve the WISEngineering platform independent of Berkeley once the revised version was installed and that there were additional changes that we wanted to make. For instance, we needed to create a standalone platform for WISEngineering that could operate on a teacher's computer in a computer lab, so there would be no need to go through school firewalls or contend with slow connect speeds. In addition, there was the desire to build more intelligence into the WISEngineering platform in terms of student responses, so students would get feedback on their responses, correct or incorrect, and there would be more flexibility in accepting student input responses. The initial version used character recognition, so even if the answer is correct, say 8, if the student puts a space before the 8, the character the computer sees is not correct.

Dr. Burghardt contacted with a colleague, Dr. Xiang Fu, in the Computer Science department at Hofstra who had several graduate students who were interested in working on a challenging project. Over the course of six weeks they worked on building greater intelligence into the platform, making it more interactive, and developing a standalone version of WISEngineering. In addition, Dr. Burghardt led a curriculum development project, in conjunction with the UVA and CUNY teams, to create a STEM unit dealing with plant growth, linking common core math and common core science standards.

WISENGINEERING LOGIC MODEL



Logic Model Analysis

The logic model developed as part of WISEngineering remains valid.   The situation in Paterson is still dire, made more so by the flooding of the city in early September that several schools, including the Frank Napier Academy, a WISEngineering school, which was temporarily housed in another location. The **Situation** remains the same. We have refined the **Inputs**, the four categories of inputs remain the same, the WISEngineering learning environment is substantially improved, the informed engineering design math curriculum has been developed and refined with input from teachers and students; we have refined the PD and enabled the two teachers in Paterson to be able to support colleagues should they wish to implement the WISEngineering curriculum; and the teachers understand the WISEngineering curriculum and have supported their students during unit implementations. The **Student Activities** remain consistent with informed engineering design pedagogy, the critiquing of one another's work has evolved and the WISEngineering sharing wall facilitates student critique. The **Student Outputs** have been developed and refined for all units. The pre and posttest assessments have been vetted by experts and honed, mostly in terms of language clarity, on input from teachers.

The **Short and Medium Term Outputs** have been achieved. Students improved their math content understanding as demonstrated on pre/post assessments and the standardized STAR exams given by the Paterson School District. The WISEngineering affective assessments indicate improved student appreciation of math and understanding of engineering, particularly the design process. The end of year state examinations were given to students, but the data will not be available until September. Indications from the STAR assessments and the project assessments indicate the students should show significant growth. The assignments for 8th grade are being made and the need for remediation should decrease for the WISEngineering cohort when contrasted with comparison students. Students have expressed interest in and knowledge of engineering as possible career paths. This was discerned from project assessments and in debriefing discussions with teachers.

The **Long Term Outputs** cannot be determined until summer 2013. We hypothesize that if students perform well in mathematics, they should be performing at or above grade level when they complete 8th grade, and similarly, their interest in STEM as evidenced by affective change and improved content ability, will direct more to select STEM elective choices as their education advances.

NEXT STEPS

The next step for WISEngineering is to dramatically and ambitiously expand the its potential, through continued development of WISEngineering, building upon what was learned during the proof of concept work and by reaching out to and engaging key stakeholders from informal and formal STEM learning environments.   The goal is to create a product (WISEngineering) that will be open source although training and supplemental materials can be distributed on a fee for use basis.

Our development strategies include the following:

First, the user friendliness of the WISEngineering platform will be expanded and more fully tested. We have made great strides in continuing a re-design so it can be deployed locally using in-school, in-community center, or in-house networks. Enhancements to the graphical user interface will continue during along with improvements being made to the graphics within the program.

A second focus will be the development of additional curriculum materials for math and science as well as prototype development of curriculum materials for use in social studies and humanities. An iterative process of development, piloting, revision and testing will be used, modeling the informed design process.

A third area of development will be to create consistent yet differentiated professional development procedures and materials.

A fourth area of development will be to create consistent yet differentiated professional development procedures and materials.

The fifth area of development focuses on long term sustainability. To fully meet its potential, we believe WISEnginering needs to be supported though a business which has the resources to expand its usage nationally. To this end we envision partnering with an educational software company to move WISEngineering from a strong college-based project to a national market.

Budget Analysis

There were minor modifications to the Hofstra University budget. The funded budget follows with modifications and justifications highlighted.

Appendix A: Original Outcomes and Milestones Charts

APPENDIX A: OUTCOMES AND MILESTONES CHART

	Anticipated Progress or Completion				
	Quarter 1	**Quarter 2**	**Quarter 3**	**Quarter 4**	**Quarter 5**
OUTCOME 1					
Short term, end of unit student math performance and attitude improvement, knowledge of engineering gain.					
Milestone 1-a					
WISEngineering website and curriculum module development.	Alpha version of website completed with unit 1 (Skyline) and refined in WISEngineering.	Refinement to design technologies and environment using 2 additional units created in website.	Refinement of environment based on teacher feedback and micro-testing.	Refinement of environment based on implementation of unit 1 and 2.	Finalize site and modules. Development of lessons learned from technology development.
Milestone 1-b					
Curriculum development of modules	Development of units 2 and 3. Refinement of unit 1 for WISEngineering.	Expert reviews and microtesting of units 1, 2 and 3 with additional feedback with participating teachers.	Refinement of units 1 and 2 based on implementaion, unit 3 refinement informed by unit 1 and 2 implementation.	Refinement of unit 3 based on implementation.	Finalization of units. Development of lessons learned from curriculum development.
Milestone 1-c					
Teacher professional development (includes using and refining curriculum, website, installation of equipment and software).	Review and development of professional development materials.	Micro-testing of unit 1 with teachers. Begin two sessions of teacher PD. Installation of equipment in classrooms.	Teacher technical support for implementation of units 1 and 2 in classrooms	Teacher technical support for implementation of units 3 in classrooms.	Refinement of teacher tools/documentation based on implementation of units. Development of lessons learned from PD.
Milestone 1-d					
Student implementation of units.	Collect baseline data from students.	Micro-testing of units 1, 2 and 3.	Student implement units 1 & 2.	Student implement units 3.	Website available for students to use beyond the classroom. Development of lessons learned from implementation.
Milestone 1-e					
Assessment materials developed, implemented and refined.	Development of embedded, pre/posttest measures of math performance, attitude, and knowledge of engineering	Pilot tests of assessment measures and tools	Implement embedded/pre/posttest assessment measures of math performance, attitudes, and knowledge of engineering	Implement embedded/pre/posttest assessment measures of math performance, attitudes, and knowledge of engineering	Analysis of assessments and refinements to units and professional development based on student outcomes.
(Anticipated) External Challenges or Factors					
Developing WISEngineering functionality from WISE4 may face urdebase and design. Teachers may have setbacks with using web-based instruction and fabrication. Project staff support should reduce these. Access to WISEngineering site through school network.					

	Current Status/Baseline	Anticipated Progress or Completion				
		Quarter 1	Quarter 2	Quarter 3	Quarter 4	Quarter 5
OUTCOME 2						
Medium Term: student improvement on standardized exams, reduction in 8th grade remediation, interest in STEM careers. (Requires milestones for Outcome 1, plus additional milestones below).	Results from 6th grade math assessments.					
Milestone 2-a						
Student improvement on standardized math exams.			Collect baseline information about student test scores from prior years.			Collect end-of-the year state math exam data. Analysis of exam data.
Milestone 2-b						
Reduction of students in 8th grade remediation.			Collect class grades, teacher reports about remediation status for students involved.		Collect class grades, teacher reports and year-end status for student participants.	Analysis of performance re remediation.
Milestone 2-c						
Increased interest in STEM courses and awareness of STEM careers.			Collect baseline interest and attitudes survey.		Collect post survey on interests and attitudes and teacher interviews and feedback about class interest.	Analysis of survey data.
Milestone 2-d						
(Anticipated) External Challenges or Factors						
Completing the analysis by the end of the 4th quarter, or 5th quarter.	Commitment by project personnel to do so regardless of time frame.					

	Current Status/Baseline	Anticipated Progress or Completion				
		Quarter 1	Quarter 2	Quarter 3	Quarter 4	Quarter 5
OUTCOME 3						
Long term, increase of students at grade level math performance, increase in STEM electives selected. WISEngineering freely available to students and teachers nationwide.						
Milestone 3-a						
Increase of students at 8th grade level math performance.	MOU with Paterson providing us with student data.					Commitment by project staff to analyze math performance in 8th grade.
Milestone 3-b						
Increase in STEM electives selected.	MOU with Paterson providing student elective selection.					Commitment by project staff to analyze elective selection in 8th grade.
Milestone 3-c						
WISEngineering freely available to students and teachers nationwide.					Presentations at conferences; linking of WISEngineering to SITE, ISTE, ITEEA, ASEE, and other organizations.	WISEngineering site fully functional with 3 tested and refined units.
Milestone 3-d						
(Anticipated) External Challenges or Factors						
Make sure students have continuing access to WISEngineering and their work, so they stay connected and interested, able to revise and continue with WISE community.						