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BLENDED INSTRUCTION

Measuring the impact of technology-enhanced, student-centered learning on the academic engagement, skills acquisition, and achievement of underserved students

Frank LaBanca, Youn Joo Oh, Mhora Lorentson, Yueming Jia, Bernadette Sibuma, Margot Snellback
EDUCATION CONNECTION and Education Development Center, Inc.

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Introduction

There can be no doubt that digital technology has found its way into the mainstream of the education field. However, educators today still struggle with how to best incorporate technology into their instruction to promote student learning. One promising approach, blended instruction, combines online instruction with in-person learning activities. Such blended strategies have become increasingly popular, partly due to their success in combatting student disengagement in many school settings. We can expect continued growth in the adoption of blended and other technology-enhanced instructional approaches in the years ahead.

Research suggests that blended instructional formats are generally as effective, or more effective, than traditional instructional formats at improving student achievement (Shen, Wang, & Pan, 2008; Kliger & Pfeiffer, 2011; Moore & Gilmartin, 2010; Means, Toyama, Murphy, Bakia, & Jones, 2009; Heterick & Twigg, 2003). However, much of this literature focuses on higher education; there is limited research on blended instruction's impact on achievement in K-12 contexts (Means, et al., 2009). While one study explores how the integration of technology in secondary classrooms positively affects student engagement (Pierce, Stacey, & Barkatsas, 2007), research on blended learning's effect on student motivation has also been largely limited to undergraduate and adult populations.

To address this gap in research, we conducted a mixed method, quasi-experimental study with a diverse set of high school students that examines the impact of a specific model of blended instruction on student engagement, skills acquisition, and achievement in science.

Scope

Our study was completed within the context of a larger, longitudinal research study in 12 urban high schools in Connecticut and Massachusetts. As such, our examination is multifaceted and sits within a larger body of research that examines the affective and cognitive impact of blended instruction on students in grades 9-12.

We use a mixed methods approach to examine the impact of the STEM21 Academy's blended instructional approach on 9th-grade students' 1) engagement in science and mathematics learning, 2) acquisition of 21st century and inquiry skills, and 3) academic achievement in science. Additionally, the study examines the impact that blended instruction practices had on underserved students in particular.

We began with three quantitative questions, comparing 9th-grade students who had participated in the STEM21 Academy for one year with a control group that had not participated in the program. We asked:

- At the end of 9th-grade, do STEM21 students demonstrate higher levels of engagement in science and mathematics than their peers?
- Do they demonstrate higher levels of 21st century and inquiry skills acquisition?
- Do they demonstrate greater achievement in science on the TerraNova science assessment?

The qualitative portion of the study further elucidates these quantitative findings and consists of two components. In the first, we look at impact, asking:

- What specific components of this blended instructional approach resulted in increased student engagement, 21st century skills acquisition, and science achievement?
- What other contextual factors influenced the degree of impact of student learning?
- Was this blended instruction model more successful for some students than others? What was its impact on underserved students in particular?

The second portion of our qualitative study examines fidelity of implementation, asking:

- To what extent did the teachers and schools implement the program as originally intended by the developers?
- How much variation in implementation fidelity was there across schools and classrooms?

Background

THE IMPORTANCE OF PEDAGOGY

Advances in technology in the past several decades have created many new opportunities to integrate technology into classroom instruction (NCREL, 2005), but simply installing computers in schools does little to improve learning outcomes (Dror, 2008). The manner in which a teacher incorporates technology into instruction often reflects his or her pedagogical perspective (Henessy, Deaney, Ruthven, & Winterbottom, 2007; Niederhauser & Stoddart, 2001; Reeves, 1997), and that perspective greatly influences how successful students will be in technology-enhanced learning environments (Hartley & Collins-Brown, 1999; Purvis, et al., 2011; Williams, 2002).

National research consistently demonstrates that student-centered (or constructivist) instructional approaches more effectively develop both traditional and higher-order thinking skills than more didactic (or transmissive) forms of instruction (Resnick & Zurawsky, 2007; Pink, 2009; Darling-Hammond, 2010). Student-centered approaches have been associated with enhanced student motivation and engagement and with more effective decision-making by teachers as they select appropriate technologies to enhance learning (Krueger, Boboc, Smaldino, Cornish, & Callahan, 2004; Venezky, 2004).

Student-centered pedagogy emphasizes active learning through discovery and collaboration. In student-centered classrooms, students solve real-life problems, participate in group projects, investigate solutions to research questions, and reflect on their thoughts and actions (Jonassen & Land, 2012). Student-centered, or constructivist, strategies support the transfer and retention of knowledge by offering students opportunities to study examples in context, explore underlying principles, make choices about their learning, receive timely feedback, and reflect in writing. Educational technology that is influenced by constructivist theories often emphasizes the discovery of connections between concepts, with open-ended applications that help students develop a deeper understanding of content (Niederhauser & Stoddart, 2001).

In contrast, didactic learning models treat the teacher as the source of knowledge and students as passive receptacles (Jonassen & Land, 2012). In a typical example, the teacher might lecture at the front of the classroom, while students receive information espoused by the expert. There is minimal interaction between the teacher and students or among students themselves. Transmissive educational

Digitally supported, student-centered pedagogy can make abstract concepts more tangible and help students appreciate practical future uses for those concepts in their lives.

technologies are similarly didactic, emphasizing factual memorization and the practice of lower-order thinking skills (Niederhauser & Stoddart, 2001). Although such transmissive techniques may support foundational learning, they are generally not associated with the development of independent, self-directed learners.

Student-centered learning approaches have psychological advantages, too; they have been shown to effectively combat student disengagement, a factor that contributes to the nation's dropout problem. Student-centered environments aim to meet each student at his or her current level of interest and ability. Generally speaking, classrooms that attend to each student's engagement with learning seem to be effective at keeping students enrolled in school and increasing their academic achievement (Fredricks, Blumenfeld, Friedel & Paris, 2004; Azzam, 2007). Further, the type of deeper learning, critical thinking, and problem-solving skills developed through student-centered approaches may motivate students to take more ownership of their educational pathways over the long term.

BLENDED INSTRUCTION AS A STUDENT-CENTERED APPROACH

Blended instructional models can support a paradigm shift from teacher-directed to student-centered instruction by offering an online environment in which students can work through content at their own pace. Definitions of and approaches to blended instruction vary widely, however. Singh (2003) describes blended instruction as a mix of various event-based activities, including face-to-face classrooms, live e-learning, and self-paced learning, while Zenger (2001) describes blended instruction as a completely integrated instructional design, where the instructor-led and technology-based techniques fit logically together.

For the purposes of this study, we will focus on blended instructional approaches that are also student-centered. In a student-centered, blended classroom, students use online technology to interact and collaborate with others, gather information, develop new knowledge, solve problems, and communicate ideas. Meanwhile, the teacher adopts the role of a knowledgeable "guide on the side," supporting each student's independent learning trajectory. Ideally, such blended learning environments encourage problem solving, reflection, collaboration, and co-construction of new knowledge.

Digitally supported, student-centered pedagogy can make abstract concepts more tangible and help students appreciate practical future uses for those concepts in their lives (Lee, 2010). Evidence suggests that the integration of proficiency-based projects in a blended environment increases student engagement and achievement (DeGeorge-Walker, et al., 2010; Graham, 2006; Lou, et al., 2011; Wheeler, et al., 2010), as well as their ability to direct their own learning (Donnelly, 2010; Jeffries & Hyde, 2010).

Stem21 Academy:

PROGRAM OVERVIEW

Science, Technology, Engineering and Mathematics 21 (STEM21) Academy is a grades 9-12 program that uses a blended instructional approach to increase student engagement and achievement. The program's primary mission is to integrate digital media skills into the context of a high-quality science and technology curriculum. STEM21's school-within-a-school model creates cohorts of students within a larger school who participate in a core set of courses together (Table 1). EDUCATION CONNECTION began implementing the STEM21 Academy model in Connecticut schools in 2000.

In STEM21 courses, students solve real-world problems through self-directed and authentic learning tasks.

Technology-mediated activities help students develop content knowledge and the 21st century creative-productive skills that support success in school, higher education, and work beyond school (see Figure 1). Technology is also leveraged to maximize student interactions and decrease feelings of isolation. STEM21 faculty have opportunities to develop their capacity using blended instructional strategies through intensive summer learning conferences, ongoing in-class support and coaching, and face-to-face and virtual professional learning communities.

STEM21 Academy's blended instructional model includes four major components: technology-enhanced learning, experiential learning, digital portfolios, and proficiency assessments (see Figure 2). The following section describes each of four major components in detail.

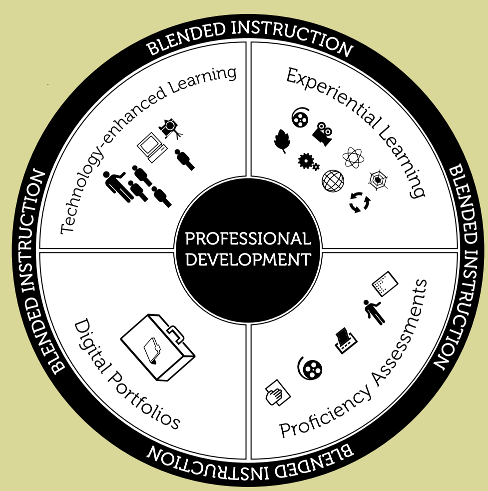
Table 1: STEM21 Academy Scope and Sequence

DOMAIN	9TH-GRADE	10TH-GRADE	11TH GRADE	12TH GRADE
Science	Earth and Energy Essentials (E3)	Biology21	Chemistry21	Physics21
Technology	Skills21	Digital Media & Movie Making or Research, Design, & Development	Game Design & Development or E-commerce Entrepreneurship	Capstone Experience
Mathematics	Algebra21	Geometry21		

Note: The numeral "21" indicates courses taught in a 21st century context (e.g., biology in the context of biotechnology, or chemistry in the context of material science). In addition to their STEM21 coursework, students take classes in other subject areas (e.g., English, social studies) as dictated by individual school's course of study and graduation requirements.

Figure 1: STEM21's Priority Skills for 21st Century Success

Figure 2: Components of STEM21's Blended Instruction Model



PROGRAM COMPONENT 1: TECHNOLOGY-ENHANCED LEARNING

STEM21's curriculum combines face-to-face and computer-mediated activities with technology, providing options for customized learning and enhanced interpersonal interactions. A learning management system (or LMS) houses the online components of STEM21 courses; through this online platform, students access standards-aligned, scaffolded learning activities. Students use the LMS to post assignments, communicate with the teacher, participate in tutorials and discussion forums, and complete assessments.

The LMS supports differentiation by offering flexible, developmentally appropriate tasks. Students who move at a faster pace can access extension activities to expand and deepen their understanding of new content. The teacher serves primarily as a facilitator of student learning, supporting students through messaging, online posts, and discussion forums, as well as one-on-one time in the classroom. Technology-integrated assessments allow teachers to monitor student progress and provide instant feedback and targeted support. Students can access resources at any time and tap into a support network as needed.

The LMS provides several options for online student interaction, including asynchronous forums, blogs, and wikis, as well as synchronous chats, video conferencing, and virtual worlds. Each tool has unique benefits, and all are designed to promote deeper, more meaningful interactions among students in and out of the classroom. Within the virtual world, participants develop a customized, three-dimensional, self-concept (or avatar) that represents a multidimensional "malleable self" (Jin, 2010). Avatars provide opportunities for real-time virtual collaboration. Such virtual experiences have been found to foster the types of social relationships that are critical to successful collaboration and learning (Ducheneaut & Moore, 2004; Seay, Jerome, Lee, & Kraut, 2004; LaBanca & Lorentson, 2013; Yee, 2006).

PROGRAM COMPONENT 2: EXPERIENTIAL LEARNING

Experiential learning activities engage students meaningfully with the curriculum, often in settings beyond the classroom walls. In the experiential component of the STEM21 curriculum, students visit authentic learning environments, including businesses and college campuses, where they have opportunities to interact with knowledgeable adult mentors. Through structured experiential meetings and an end-of-year Innovation Expo, students collaborate with professionals, present their work, and receive valuable feedback from mentors. Company tours provide opportunities to observe how technology and 21st century skills are used in practice. Because this project spanned multiple schools, experiential meetings had a value-add of being interdistrict whereby students collaborated, not only with industry professionals, but each other, creating interactions with considerable student diversity.

Back in the classroom, students interact with mentors face-to-face and through online video chat services and forums. STEM21 also brings professionals into the classroom for interviews, guest lectures, and other interactive learning opportunities. All of these experiences provide students with knowledge and expertise beyond what a single teacher could provide.

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PROGRAM COMPONENT 3: DIGITAL PORTFOLIOS

STEM21 Academy utilizes an open-source content management system for students to showcase their work digitally. A tool for reflection and sharing, the digital portfolio allows students to document and present their work to others. Each student has a personal web address, where they display a portfolio of their own work. Portfolios enable students to demonstrate knowledge and skills, define their interests, focus on building particular expertise, communicate ideas and personal values, and celebrate growth. Students may share their site with peers, parents, prospective employers, and college admissions officers.

To guide students in selecting work for their portfolios, STEM21 Academy classes use a 21st century skills framework (see Figure 1 on page 5). For example, a Biology21 student might select a lab report that demonstrates their understanding of diffusion and osmosis, classifying this assessment under the 21st century skill of problem-solving. The student would then provide a reflection to demonstrate how his or her problem-solving skills improved through the assignment.

PROGRAM COMPONENT 4: PROFICIENCY ASSESSMENTS

STEM21 Academy courses are made up of standards-aligned learning units that each explore a set of essential questions. In each unit, students perform a variety of learning activities—e.g., face-to-face discussions and debates, readings, lab activities, and small projects—that build toward mastery of the course objectives and support them to become more independent, self-directed, and collaborative learners.

Each unit concludes with a capstone Unit Performance Assessment (UPA). These authentic, project-based assessments provide diverse opportunities for students to demonstrate mastery of course objectives according to a four-point rubric. UPAs are intentionally open ended and loosely defined (Jonassen, 1997), allowing for student choice and self-direction, while measuring essential learning outcomes. The products can easily be embedded into a digital portfolio.

Every course culminates in a Challenge Project, an extended project that derives from an essential question or challenge and serves as a final demonstration of proficiency. For each project, students engage in exploratory activities, gather resources, determine a solution, implement that solution, reflect, assess their success, and share the results. These extended, team-based projects require students to integrate course content with relevant skills through technical writing, research, computer-assisted design, team collaboration, field experiments, storytelling, and/or web-based presentation.

Figure 3: Sample Unit Performance Assessment

COURSE: EARTH AND ENERGY ESSENTIALS
Grade level: 9
Unit: Natural Resource Use and Environmental Impact

Assignment:

Your environmental consulting firm has been hired by the state's Department of Environmental Protection (DEP) and has been tasked with researching one of four important topics related to the environmental effects of natural resource use. Each team in the firm must conduct research and create an educational piece designed to inform the general public about:

- municipal solids waste (garbage) and its disposal (e.g., landfills, incineration)
- pollutants generated by industry and agriculture (e.g., mercury, phosphates, nitrates.)
- pollutants generated by energy production in power plants and automobiles (e.g., SO_2, CO_2, NO_x)
- land use (e.g., housing development, transportation, mining)

Research:

Research and identify a list of natural resources and effects that are connected to the topic.

Research and identify a variety of options for minimizing the environmental effects of a natural resource of your selection. Include some practical suggestions for how we can balance our need for natural resources and problems caused by their use.

Product:

Choose how you would like to present your findings to the public. You may:

- create an educational pamphlet that could be distributed in the local community.
- create an informational video, podcast, or public service announcement that could be placed on the DEP website or aired on local TV stations.
- develop presentation materials (i.e., PowerPoint, Prezi) that can be used by the DEP at community meetings.
- design another method of presentation.

Whichever format you choose, your group should include specific statistics, facts and figures whenever possible (include citations). Your project will be evaluated using a rubric to indicate the quality of (a) research, (b) information, (c) presentation, and (d) teamwork.

A model depiction of an instructional year is provided in Figure 4 on next page.

Figure 4: Stem21 Academy Model Program Implementation

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
	Fall Semester: Individual				**Spring Semester: Team**					
Computer-mediated / online learning	Pre-post formative assessment, surveys, writing	Content knowledge in core academic disciplines: e.g., Science: Earth and Energy Essentials								
Computer-mediated / online learning		Curriculum units in Learning Management System support completion of 3 Unit Performance Assessments (UPA) to proficiency. UPAs are designed to allow students to demonstrate proficiency to standards and unit's essential questions. Periodic standardized assessments. Documentation and reflection of learning in digital portfolio.			Team-based curriculum: units differentiated by area of responsibility, expertise, and department. Students collaborate to create a product, service, or technology that solves an authentic problem.				Team showcase of Challenge Projects	Pre-post formative assessment, surveys, writing; reflection of learning
Computer-mediated / online learning		UPA 1	UPA 2	UPA 3						
Computer-mediated / online learning	Asynchronous and synchronous tools for collaboration: forums, wikis, blogs, discussion boards, 3D virtual worlds, Internet video calls, digital media products									
Computer-mediated / online learning	Orientation to Digital Portfolio	Student selects work for submission to portfolio, reflects on learning, and receives feedback from teacher, peers, and adults (parents/mentors).								
Face-face classroom work	Orientation to program including challenge project, blended learning, LMS, digital portfolio, experiential learning, career pathways, student success plans	Student 1	Students demonstrate proficiency to standards for UPAs and development of 21st century skills: • information literacy • collaboration • communication • innovation/creativity • problem solving • responsible citizenship		Students 1, 2, 3, who have demonstrated proficiency on UPAs form the class team and begin to develop solutions to the program challenge				Authentic assessment of student work by a panel of business, industry, and academic professionals using standardized guidelines and rubrics	Students debrief and reflect on learning leveraging technology and 21st century skills
Face-face classroom work		Student 2								
Face-face classroom work		Student 3								
Face-face classroom work		Student 4			Student 4 joins team upon demonstration of proficiency					
Face-face classroom work		Student 5			Student 5 joins team upon demonstration of proficiency					
Face-face classroom work		Student 6			Student 6 continues to work on individual proficiencies and participates in team activities in consultation with teacher					
Experiential learning	Authentic assessment of student work by a panel of business, industry, and academic professionals	Workplace tours, meetings, guest speakers, classroom visits			Online and onsite mentoring by business, industry, and academic professionals. Biweekly progress reports and responses.				Showcase and public display of student work evaluated by business and academic professionals	Further mentoring and internship opportunities explored
Experiential learning		Onsite Meeting 1	Virtual communication: internet video calls (e.g., Skype); 3D virtual worlds	Onsite Meeting 2	Virtual communication: Internet video calls; 3D virtual worlds		Onsite Meeting 3			

STEM21 in Practice

A CASE STUDY FROM THE FIELD

At the start of 9th-grade, Miguel was a low-performing English language learner attending a large urban high school. All three of his STEM21 Academy teachers noticed that Miguel consistently chose to do the least work possible and barely passed his courses as a result. He lacked motivation, had limited subject-area knowledge, and struggled significantly with teacher-directed instruction. When his teachers introduced the annual Challenge Project, Miguel began to change his behavior. He participated more in class, completed assignments at home more regularly, and began to ask more questions.

The project asked students to "create and implement a new product or service that addresses the theme of Responsible Design." Miguel had to work with his team members to:

- identify a specific issue or topic.
- investigate the topic through research, experimentation, and data analysis.
- develop an innovative solution (product or service) that addresses the issue.
- demonstrate application of the product or service.
- document and communicate the project using digital media.

Additionally, for their Earth and Energy Essentials class, students were also asked to integrate the conservation or responsible use of one or more natural resources into the project.

Miguel and his team felt it was important to choose a problem relevant to their community, and they settled on mosquitos. They decided to create the "Water Hornet," named after their school mascot - a solar-powered, battery-operated device capable of creating motion in still water to prevent mosquitoes from laying eggs.

With a project of this scale, the team needed to departmentalize. Daniel, their math teacher, was surprised to see that Miguel showed great interest in creating a sophisticated spreadsheet that could be used to input data and connect to state data on mosquito distribution to generate predictions. The formulae required a keen understanding of the point-slope form of a linear equation, a concept Miguel had previously struggled to master. Now, he rose to the challenge, becoming proficient with point-slope form and developing a deep understanding of concepts that his team applied to their project.

His science and technology teachers noticed that Miguel began to take on a leadership role when he was in their classes too. With adept tactile skills, he helped to build a prototype device and made significant contributions to the project's website. All three teachers agreed that Miguel was consistently demonstrating high-quality work and leadership among his peers.

This project represented a major shift for Miguel. With an assignment that felt relevant and a new team-based context, he finally felt motivated to take ownership of his learning.

Study Design

QUANTITATIVE IMPACT STUDY DESIGN

Participants: For our intervention group, we recruited 9th-grade students who had registered for STEM21 Academy programs in 11 schools (10 in Connecticut, one in Massachusetts). We recruited a comparison group from students enrolled in comparable 9th-grade science courses in the same schools who had similar demographic backgrounds to students in the intervention group. All together, our initial sample included 500 9th-grade students (233 in the intervention group and 277 in the comparison group).

Our baseline analyses demonstrated that STEM21 Academy and comparison groups were not equivalent at the outset in terms of their 21st century and inquiry skills and TerraNova science scores. (They were, however, equivalent in terms of engagement.) Therefore, we created matched subsamples from our initial participant set to measure the impact of the STEM21 program on science achievement and skills growth. Subsample 1 included 216 students from two cohorts (2011-2012 and 2012-2013 school years) with equivalent baseline scores on the TerraNova science achievement assessment. Subsample 2 included 128 students from the 2012-2013 cohort with similar baseline scores on our skills and engagement assessments. (Subsample 1 could not be used to assess 21st century skills and engagement, as those data were not collected in the 2011 to 2012 school year.) More details about the creation of the matched subsamples are described in the analytic strategies section below.

Data collection process: We collected data twice: once at the beginning of 9th-grade and again at the end of the 9th-grade. Each time, participating students took a 40-minute online survey that included items from three different survey instruments. Then, within a week or so, students took a 40-minute TerraNova Science assessment in paper-pencil format. We received parental consent and student assent prior to the survey and TerraNova administration.

Instruments and measures: To measure program impact, we used three instruments:

1. **Academic engagement** was measured using an adapted version of the Academic Engagement instrument (Weinstein, Schulte, & Cascallar, 1983), combined with seven items from the motivation scale of the Learning and Study Strategies Inventory. Students reported on the degree to which they stayed on top of class assignments, came to class prepared, set high expectations for themselves, and persisted in the completion tasks and achievement of good grades. We modified the original items to specify the examined subjects. For instance, the original item "Even if I am having difficulty in my course, I can motivate myself to complete the work," was adapted to "Even if I am having difficulty in a science course, I can motivate myself to complete the work." The seven items were tested in both science and mathematics domains, for a total of 14 items. The reliability of the survey was .86 for both pre and post data. (A scale is considered reliable when Cronbach's alpha is higher than .7).

2. **21st century skills** were measured using a survey instrument incorporating six 21st century skills and 14 inquiry skills derived from NCREL's enGauge standards, the ISTE NET-S standards, and the Partnership for 21st Century Skills framework. The researchers developed a self-report scale to examine students' strengths in information literacy, collaboration, communication, innovation and creativity, problem solving, and responsible citizenship. Students were asked to rate their level of perceived skill on 12 tasks and behaviors (e.g., "Evaluating the validity of data or evidence collected from a STEM product," or "Determining an innovative solution to a STEM challenge"), using a seven-point Likert scale (1="extremely poor;" 7="excellent"). The reliability of this scale was .92 (Cronbach's alpha) for pre and post data.

3. **Science achievement** was measured using the 9th-grade TerraNova assessment, a standardized, norm-referenced test that assesses student understanding of science theory and application with emphasis on understanding core concepts and applying scientific inquiry skills, including the scientific method. The TerraNova subtests are considered reliable instruments; the reliability alpha for the grade 9 test is .82, as reported in the Technical Bulletin compiled by CTB/McGraw-Hill.

We also collected student demographic data, including participants' gender, race/ethnicity, free/reduced lunch status, special education status, and English language learning status. We then created a combined variable represent-

Table 2. Description of Matched Samples

DEMOGRAPHIC	CHARACTERISTIC	SUBSAMPLE 1 (%)	SUBSAMPLE 2 (%)
Gender	Male	45	45
	Female	54	54
Ethnicity	African-American	14	24
	Asian-American	3	3
	Latino	16	23
	Pacific Islander	1	0
	White	64	48
	Other	3	3
Socioeconomic status	Free/reduced lunch recipient	43	49
Other characteristics	Special education	7	3
	English language learner	1	1

ing a student's "underserved" status—with racial/ethnic minorities, females, and low-income students defined as underserved. We also noted each school's SES composition (less than or more than 50 percent receiving free/reduced lunch). The students' underserved status, special needs status, and their cohort and schools' SES composition served as covariates in the analytic model.

Analytic strategies: We used a hierarchical linear modeling (HLM) to estimate the impact of the STEM21 Academy on student engagement, 21st century skills, and science achievement after one year, controlling for baselines tests, cohort, special education status, students' underserved status, and school SES composition. Unlike other regression techniques, HLM simultaneously accounts for variations between schools and individuals, even over time.

QUALITATIVE STUDY DESIGN

PART 1: TEACHING AND LEARNING

We conducted semi-structured interviews with 9th-grade students from each of the participating schools to better understand the impact of blended instructional strategies on their experience as learners. We interviewed an additional three 10th-grade students from each participating school and held focus groups with STEM21 teachers to confirm and further elucidate interview results.

Interview questions focused on students' and teachers' perceived impact of the four core components of STEM21 Academy's blended instructional approach: technology-enhanced learning, experiential learning, digital portfolios, and proficiency assessments. Participants were first asked if any portion of the course implementation had an especially significant impact on their learning. The next set of questions addressed each of the four components directly. Follow-up questions were used to clarify or further develop responses.

We developed our interview protocol using a taxonomy of ethnographic questions and vetted questions through a peer auditing process, exploratory focus groups, and a series of 15-minute pilot interviews with students in spring 2012. Results of these tests were used to revise and improve the final interview protocol.

During spring 2013, we conducted 15-minute interviews with three 9th-grade students from each of the 12 participating schools (a total of 36 interviews). All students were new to the STEM21 Academy program that year. To support and triangulate our data, we conducted 12 additional 15-minute interviews with 10th-grade students; these students had been in the program for two years and could therefore provide a longer-term perspective on the program. In addition, we held six focus groups with STEM21 Academy teachers in 2012 and 2013.

All interviews were recorded and transcribed verbatim, and interviewees had an opportunity to correct transcripts for accuracy. Field notes were used to maintain an audit trail. Interviews were conducted until we reached data saturation.

We conducted a content analysis of interview data, using NVivo software to search for word and phrase patterns and categories. Recurring regularities in the data were organized into the construct categories, and that data was triangulated by data source (teachers and students) and data method (interviews and observations).

{ We conducted semi-structured interviews with 9th-grade students from each of the participating schools to better understand the impact of blended instructional strategies on their experience as learners. }

Table 3: STEM21 Academy Implementation Fidelity Indicators

TEACHER PROFESSIONAL DEVELOPMENT INDICATORS	GRADE-LEVEL INDICATORS	PROGRAM-LEVEL INDICATORS
• Participation in Summer Academy (Year 1: all teachers; Years 2-4: first-year teachers only) • Participation in two coaching sessions annually (Years 2-4) • Participation in one end-of-year reflection session (Years 2-4)	• Percent of students completing the digital portfolio • Percentage of curriculum units completed by teacher • Percentage of students attending three experiential meetings and the Innovation Expo • Participation of students completing five forums in one technology class and one science class	• Summer Institute: 28 hours of quality professional development including 21st century skills -or- • Make-up session: 6 hour session for individuals unable to attend the Summer Institute • Participation of each teacher in two coaching sessions (Years 2-4) • Participation in one end-of-year reflection session (Years 2-4) • At least 51% of students in study from underrepresented groups as defined by gender, minority status, and SES • Expected number of students participating in high school program (Calculated at 20 students/grade/school/year) • Eight courses in 12 schools implemented as planned (Year 4) • Six courses articulated with College of Technology (Year 4)

Note: Changes in specific development indicators over time are identified in parenthesis.

PART 2: FIDELITY OF IMPLEMENTATION

We assessed implementation fidelity in the 12 participating schools through the ongoing collection of: (a) professional development data records; (b) attendance records, portfolio grades, Unit Performance Assessments, and records of on-line forum use; and (c) professional development agendas and observations. We developed a metric, ranging from "low fidelity" to "high fidelity," using these data sources to assess the degree to which the blended instructional program was implemented as intended at the individual teacher level, within the grade level, and across the program.

We developed categorical indices (e.g., teacher attendance in summer professional development, students completing the digital portfolio) to establish implementation benchmarks for each treatment classroom, grade-level, and school. We assigned weights to each indicator appropriate to the relevance and importance of that factor in program implementation, and used the combined indicator scores to generate a construct-level score. Each construct score was categorized into levels of implementation fidelity (low, moderate, high), with our threshold for "adequate implementation" of most categories set at completion of 65% or more of relevant activities.

Our research team also conducted observations of eight 9th-grade classrooms, using the Electronic Quality of Inquiry Protocol (EQUIP) and the Classroom Practices Record (CPR) as tools for organizing observations. The EQUIP is a four-point observational rubric designed to measure the number of instances and quality of inquiry-style instruction. The CPR measures higher-order thinking and questioning in the classroom. Each 9th-grade classroom was observed two times, with preliminary data obtained during spring 2012 and comprehensive data collected during 2012-2013. These qualitative data were used to confirm our fidelity measures.

Findings

QUANTITATIVE RESULTS:

Impact Of STEM21 Practices On Student Engagement, 21st Century And Inquiry Skills, And Science Achievement

At the end of 9th-grade, students who participated in the STEM21 Academy for one year demonstrated significantly higher scores on the TerraNova science assessment and marginally higher levels of 21st century skills than comparison students. We found no statistically significant difference between student groups in terms of engagement in science and mathematics. Underserved students in the STEM21 Academy performed better on the science assessment than underserved students in the comparison group. Small sample size prevented an analysis in engagement and 21st century skills for underserved students. Table 4 summarizes the quantitative results.

STUDENT ENGAGEMENT

At the end of 9th-grade, students in the STEM21 Academy group reported an average level of academic engagement of 5.03 (SD=1.06) on a 7-point scale (1="not at all true of me"; 7="very much true of me"). The average engagement level in the comparison group was 5.04 (SD=.90), indicating very similar degrees of engagement in both groups. Our statistical analysis suggests that the STEM21 Academy did not engage students in science and math better than traditional classrooms.

21ST CENTURY AND INQUIRY SKILLS

At the end of 9th-grade, students in the STEM21 Academy sample and the comparison sample rated themselves an average of 5.37 and 5.07 respectively on our skills survey, indicating that students from both groups believed they had acquired a mid-to-high level of 21st century skills.

The score difference between the two groups was marginally significant (p =.06), taking into consideration other factors that might contribute to students' 21st century skills acquisition (e.g., their baseline skills, student demographics, and school SES composition), the STEM21 Academy group students scored .29 standard deviations higher on 21st century skills than the comparison group. Accord-

Table 4. Descriptive Statistics of Engagement, 21st Century and Inquiry Learning Skills, and TerraNova Science Measures

		N	MEAN	SD	95% CONFIDENCE INTERVAL
Engagement	Comparison	64	5.04	0.90	[4.82 5.27]
	Intervention	64	5.03	1.06	[4.77 5.29]
	Total	128	5.04	0.98	[4.87 5.21]
21st Century skills	Comparison	64	5.07	0.84	[4.86 5.28]
	Intervention	64	5.37	0.85	[5.16 5.59]
	Total	128	5.22	0.86	[5.07 5.37]
TerraNova Science	Comparison	116	683.67	48.51	[674.75 692.59]
	Intervention	100	695.80	41.61	[687.54 704.06]
	Total	216	689.29	45.75	[683.15 695.42]
TerraNova Science	Underserved Comparison	90	683.51	47.59	[67.54 693.48]
	Underserved Intervention	75	693.75	44.21	[683.58 703.92]
	Total	165	688.16	46.22	[681.06 695.27]

Figure 4: Average self-reported student engagement and 21st century skills at the end of 9th-grade

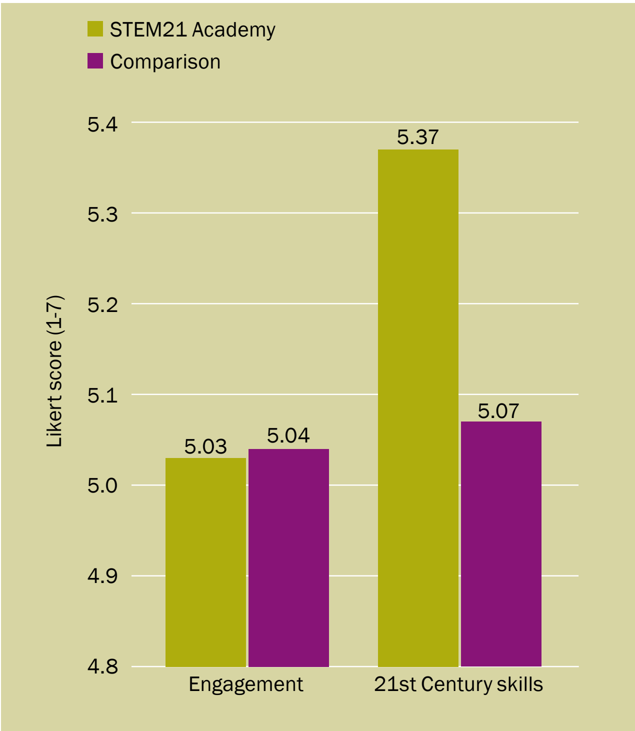
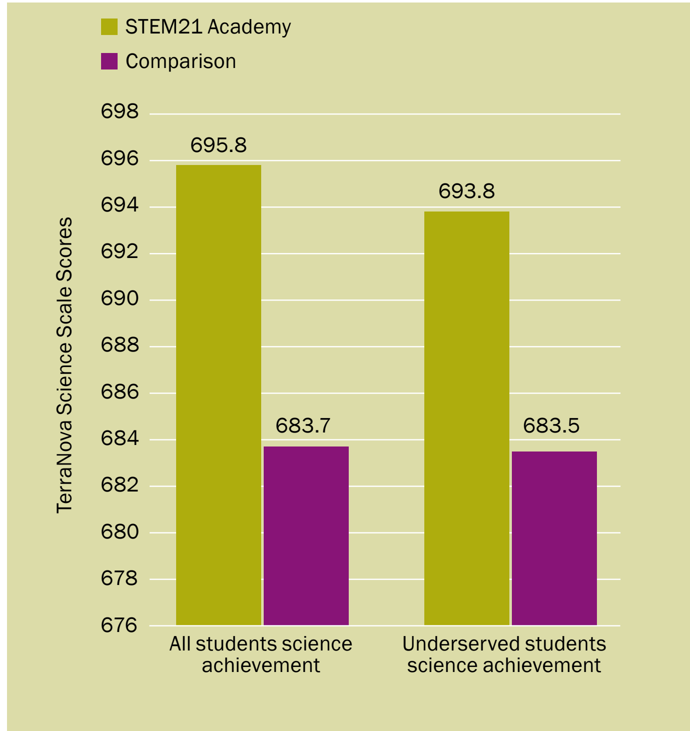


Figure 5: Average TerraNova scale scores for students at the end of 9th-grade



ing to Lipsey, et al. (2012), the median effect size of high school intervention on student outcomes of specialized topic is .29 standard deviations, and the mean effect size is .34 standard deviations. In short, the STEM21 Academy was somewhat more successful in improving student 21st century skills than the comparison classrooms. (See Figure 5 for details.)

SCIENCE ACHIEVEMENT

At the end of 9th-grade, students in the STEM21 Academy group scored higher on the TerraNova science test than students in the comparison group: a mean score of 695.80, compared with 683.67 (TerraNova scale scores range from 0 to 999). The result of statistical analysis confirmed that the difference between the two groups in science achievement was statistically significant ($p < .05$). Accounting for other factors, such as students' demographic information, previous TerraNova scores, cohort and school SES composition, the STEM21 Academy group students scored .25 standard deviations higher on TerraNova science than the comparison group. The median effect size of a high school intervention on standardized test scores is .04 standard deviations, and the mean effect size is .03 standard deviations (Lipsey, et al., 2012). Our results, therefore, suggest a meaningful effect of the STEM21 program on student achievement.

UNDERSERVED STUDENTS

Results for underserved students revealed similar patterns. That is, underserved students in the STEM21 Academy group scored higher on the TerraNova test than underserved students in the comparison group (a mean score of 693.75, compared with a mean of 683.51). The difference between the two groups was statistically significant ($p < .05$). Accounting for other factors, such as students' previous TerraNova scores, student demographics, and cohort and school SES composition, we found a meaningful effect size of .23 (Cohen's d).

These results indicate that the STEM21 Academy program was better able to meet the learning needs of underserved students than traditional classrooms. (See Figure 5 for details.)

QUALITATIVE RESULTS:

Perceived Impact and Fidelity of Implementation

GENERAL PERCEPTIONS OF STEM21'S IMPACT

When asked an open-ended question about the elements of the STEM21 Academy program that most influenced them as learners, the largest number of 9th-grade student responses (20%) emphasized how the program contributed to their success. Examples of the successful outcomes they discussed included increased engagement, a positive learning experience, altered future intentions related to careers or academic interests, and increased achievement. By contrast, very few (4.9%) student responses related to learning challenges, such as disengagement or a negative learning experience. These results indicate that STEM21 Academy students strongly believe the student-centered learning process supports their academic success.

Interview data was coded and organized into the following thematic categories: overall learning success, improved engagement, and personal skill development.

Overall learning success: Students said that their experience in STEM21 resulted in increased knowledge acquisition, enhanced skills in areas such as critical thinking and communication, the development of independent learning habits, improvement in content retention, and an increase in confidence. These topics represent half (50%) of all responses in the overall perceptions category. Sample comments included:

"The way that they teach you how to dig deeper and how you are the one that figures it out for yourself—you definitely remember—it becomes a lesson you learn forever."

"It really allows you to expand on your creativity. It gives you a much more, almost a more individualized learning."

Improved engagement: The second most common category of response was related to different facets of engagement. Students mentioned overall enjoyment, fun, liking or loving the courses, increased interest in course content, creativity, appreciation of the up-to-date curriculum, commitment to further participation at the next grade level, and enthusiasm regarding the uniqueness of the non-traditional instructional approach. This category represents a third (32%) of all feedback. Sample comments included:

"When you learn something new and it interests you so much, you want to learn more and more, and it's a building block that compacts all your knowledge together and you can do things you never thought were possible."

"Really fun, hands-on stuff. It's always changing. It's a little bit of a challenge but if you are really into it, you'll get a lot out of it."

"In these courses, you go on and learn by yourself and you connect with other kids and I love the courses!"

Personal growth and skill development: The third most frequently occurring comments related to personal growth. Eighteen percent of responses related to this category. Comments addressed:

- STEM21 Academy's emphasis on team work and the use of interpersonal skills required for successful teamwork,
- increased communication capabilities resulting from consistent personal and professional interactions,
- enhanced friendships and a sense of "family" within the class environment,
- development of a sense of interdependence with peers,
- increased leadership ability,
- appreciation for the presence of an open, non-judgmental learning environment, and
- increased student-teacher interaction.

Sample comments included:

"My confidence has built up tremendously over the course of this year and it has been amazing."

"It's really hands-on and teaches you to be more independent in your learning. It is very different from what I've had before."

"You got to be really close with a group of students so you get a nice bond. Yet you can still be independent and grow at your own level."

Additional impressions: In addition to the three primary categories, students cited a variety of other successes that they attributed to STEM21 Academy's student-centered approach. We found a consistent pattern of overall student enthusiasm toward the blended instructional approach, with the majority of students affirming their commitment to continued participation in the program. We heard such comments as:

"I would describe these courses as more modern learning…It's more on technology and it's not really old school learning."

"You'll learn to use teamwork and communication—it is a great course if you want to work for a big company in the future."

"I think the whole process of learning how to fit in and work with what you have was a good experience for us because we are going to be thrown into the new world this same way."

A number of respondents indicated that they considered the blended curriculum to be a highly relevant learning method for the 21st century, arguing that individuals in their age group would be heavily dependent on technology skills for future college and job opportunities. Additionally, some students stated that participation in these courses would give them a competitive advantage in the college or career market over students participating only in more traditional courses.

Perceived challenges: Although the breadth of responses strongly suggested that the majority of 9th-grade STEM21 Academy students planned to remain enrolled in 10th-grade, a small number of participants (approximately 10%) were less certain about the success of their learning experience in the first year of the STEM21 Academy program. Individuals who indicated a lack of interest in project participation generally attributed this lack of interest to the use of technology. Additionally, a small number of students expressed frustration with the blended curriculum, stating a preference instead for more traditional learning that places less emphasis on technology-driven assignments and outcomes.

Students also described various implementation or learning challenges, including challenges using the learning management system (LMS) to complete the digital portfolio, participate in forums, and complete other online assignments. Students discussed inconsistent performance of the LMS, sometimes attributed to system incompatibility or Wi-Fi access issues in their school. Other students perceived the LMS as too difficult to understand. Students with these concerns expressed a desire for more teacher-directed instruction and felt a lack of written guidelines exacerbated their technological challenges. These described a need for more technology support.

General perceptions of teachers and 10th-grade students: The overall perspectives of 9th-grade students were widely substantiated by teachers and their 10th-grade peers. Teacher focus groups emphasized how blended instruction resulted in more student freedom and independence and reported an increase in students' learning skills.

Comments from 10th-grade students suggested that they generally engaged in the program with a higher level of confidence and understanding than their 9th-grade counterparts. A number of 10th-grade students reported that their knowledge and confidence had increased since 9th-grade. These students attributed this increase to the development of a better working knowledge of curriculum expectations in their second year. Tenth-grade students were also more likely to describe potential long-term benefits of the program than were their 9th-grade peers. When questioned about learning outcomes, the large majority (88%) of 10th-grade respondents had a positive perception of the impact of blended instruction on both their personal growth and success with learning.

Tenth-grade students expressed fewer program challenges, saying many challenges had been resolved during their first year. Among the 22% of 10th-graders who identified challenges, only a few focused on LMS issues. This suggests that while first-year students struggle with technological issues, by the end of their second year of participation, students have successfully developed technological and problem-solving skills to overcome these issues.

Teachers also provided additional perspective on some of the challenges that emerged in interviews. Specifically, 9th-grade teachers described the challenges of implementing STEM21 Academy courses in conjunction with other district requirements as sometimes “overwhelming,” occasionally resulting in decreased ability to implement all course components or activities. A few teachers, in particular teachers new to the program, described similar challenges with the technological demands of the courses.

PERCEIVED IMPACT OF THE FOUR CORE COMPONENTS OF BLENDED INSTRUCTION

In the second stage of our interviews, students shared their perspectives of how each of the core blended instruction program components affected their learning. Each component is discussed separately.

Technology-enhanced learning: Students reported that STEM21’s approach to blending online and in-person learning supported their growth in each of the three categories previously identified: success with learning, engagement, and personal growth and development.

A majority (77%) of 9th-grade students reported a positive impact on learning and engagement, with comments like, “blended learning helps me learn,” or “I like it/love it,” and said blended learning is “good,” “great,” “different,” and “balanced.” The specific aspects of the technology-enhanced curriculum most frequently described as contributing to their learning and engagement included:

- the use of the blended learning strategies in the extended Challenge Project,
- the ability to access their classroom and projects from any location via the online portal,
- the incorporation of digital media tools (such as video editing and application design software) into the online environment, and
- a clear focus on skill development.

Although a large majority of students expressed positive impressions of technology-enhanced learning, almost a quarter of students (23%) said its impact was minimized due to challenges faced in the process. They elaborated on some of the points raised previously, identifying a need for more frequent teacher guidance and more consistent use of textbooks and note taking. A small number of students attributed their challenges to an overall lack of interest in technology.

Ninth-grade student feedback was supported by feedback from teachers and 10th-grade students. The majority of teachers described the positive impact of technology-enhanced learning on student outcomes; they expressed that their students enjoyed collaborative learning, the openness and freedom to work independently at their own pace, and the array of opportunities to work with a variety of technologies in a creative problem-solving process.

The teachers who provided less positive feedback were less experienced with the program, and we hypothesize that they are likely to have also been most impacted by the technological challenges described previously. The majority of 10th-grade students did not report challenges with the technology-based environment, likely due to greater experience with technology and blended-learning strategies.

Experiential learning: Data from interviews strongly indicate that both the smaller experiential meetings and the end-of-year Student Innovation Expo were viewed as positive opportunities for students to broaden their educational perspectives in a less restrictive environment.

A majority of students (66%) spoke positively about experiential meetings that took them from the comforts of a traditional school setting into business environments and college campuses. Experiential meetings took a variety of forms and included hands-on learning with partner organizations—for example, environmental groups that brought students into the field to conduct data collection, or a computer company that helped students develop a business website. Students described these opportunities to do real-world and hands-on work as "inspiring," critical to supporting their development of communication and presentation skills, and important to personal development. The majority of respondents also shared that the meetings enhanced their learning by offering opportunities to actively participate in scientific experiments and learn about innovative professional products. Students frequently described their participation in these meetings as improving their ability to bring fresh ideas back to the classroom and to incorporate these ideas into the design of their Challenge Projects.

Diverging from the positive feedback were concerns regarding the mechanics of the experiential meetings. These individuals (less than a third of all respondents) noted a lack of relationship between the meeting activities and the goal of the extended Challenge Project, a lack of connection between activities and classwork, an over-emphasis on college tours, discomfort due to the required interactions with students from other districts, lack of interaction with other schools, and concerns over meetings canceled due to weather or other limitations. Teacher focus groups verified some of these concerns. Although both students and teachers appreciated the function of group work in these experiential meetings, they expressed a need for these groups to include a balance of classmates and students from other schools, which would confer an optimal balance of emotional support with opportunities for challenge and new insights. These results suggest that some students and their teachers would benefit from more guidance with experiential learning meetings.

The Student Innovation Expo is the culminating annual event at which STEM21 Academy student teams showcase their learning through their Challenge Projects. At the time of the 9th-grade interviews, the Expo had not yet taken place. Therefore, our results are based primarily on interviewer attendance at the Student Innovation Expo, subsequent field notes, and teacher and 10th-grade student input.

Ninth-grade students, who had not yet participated in the Student Innovation Expo, expressed a high degree of anticipation for the event and commitment to and pride in their final Challenge Projects. Their enthusiasm was supported by 10th-grade students and teachers, who expressed enthusiasm about the power of these opportunities to encourage collaboration, support personal and professional development, develop 21st century skills, and provide a central focus for all classroom activities. These discussions provided overwhelming evidence that the Student Innovation Expo and the related Challenge Project are viewed as critical to fostering student engagement, commitment, skill development, and content mastery. Maturation and previous experience may account for differences in responses of 9th-grade students and the more sophisticated responses of their older peers and teachers, who offered more explicit details.

Few students and teachers gave negative feedback relating to the Student Innovation Expo. Among interviewed 9th-graders, 18% expressed negative concerns, such as a need to allocate more time for student presentations and a desire for more opportunities to view and learn from the work of other school districts. The findings were similar among 10th-graders, with 14% providing at least some negative feedback. Like the 9th-graders, the most frequent concerns pertained to lack of time for project preparations, or time allocated for presenting at the event.

Digital portfolios: The digital portfolio, an online environment where students collect and share their work, was described positively by the majority (81%) of students. Recurring themes included the three categories discussed previously: enhanced learning, engagement, and personal and skill development. Students also praised the digital portfolio as a useful gauge of what they learned in an academic year and a resource with potential future value if treated as an expandable online resume for college and career applications. Digital portfolios were described as excellent tools for reflection, for providing insight into how an individual's work measures up against the work of their peers, and for providing a means to display what a student has learned throughout their high school experience and beyond. Many students described the portfolio as a good frame of reference for tracking their progress within a course as well as a useful tool for reviewing course content for exams and the end-of-year Challenge Project.

Nearly a fifth of respondents (19%) expressed negative perceptions of the digital portfolio. The challenges they described included a lack of understanding of the role of the digital portfolio in the learning process, problems navigating the links needed to access the portfolio, and a lack of teacher direction or knowledge in some schools. Several students stated that the portfolio was "busy work;" they felt the act of putting work in two places—the portfolio and the location where the work originated—was redundant. It is worth noting that students that perceive the portfolio as nothing more than "putting work in two places" clearly did not have a strong understanding of the purpose of the portfolio.

Results from teacher focus groups offer a possible explanation for the challenges expressed by students. A number of teachers explained that student buy into the portfolio requires understanding of the benefit it provides. A few hypothesized that more mature students, with a greater understanding of the need to prepare for life after high school, generally demonstrated greater appreciation of the portfolio. Responses from both students and teachers revealed 10th-graders as generally having a stronger understanding of and appreciation for the portfolio.

Proficiency assessments: STEM21 Academy's Unit Performance Assessments (UPAs) measure students' mastery of concepts and standards in each curricular unit, leading toward a final, end-of-course Challenge Project presented at the Student Innovation Expo.

Student perceptions of the smaller-scale, in-class UPAs were varied and appeared to be related to their familiarity with the term "Unit Performance Assessment" as well as their awareness of pre-designated unit topics. Some students were not aware that they had participated in the assessments or remembered covering some topics but not others. It is worth noting that students indicated that the use of UPAs became less frequent as the end-of-year Expo approached. Students who did remember the proficiency assessments reflected positively about the role of the UPA in increasing collaboration. Students did not perceive that the UPAs given early in the year were relevant to the Challenge Project goals.

{ ...both students and teachers shared very positive perceptions of the long-term, proficiency-based Challenge Project. }

Teacher feedback supported student perceptions. Teacher focus group responses suggest that many teachers chose to use their own school's or region's teaching rubrics, or exchanged them intermittently with the UPAs. Teachers also indicated that the UPAs were not easily aligned with their course requirements, being either too basic or complex to meet their students' needs. A number of teachers expressed concern that some of the UPAs lacked rigor and relevance, thus explaining why they had not implemented UPAs consistently. While their feedback on UPAs as a whole was mixed, teachers noted that specific UPA labs or assessment topics had a positive impact on student learning.

In contrast, both students and teachers shared very positive perceptions of the long-term, proficiency-based Challenge Project. The vast majority of students perceived the Challenge Project to be a highly valuable part of their learning experience. They overwhelmingly agreed that the project supported learning of course content and helped them develop skills in independent thinking and research, writing, presenting, oral communication, critical thinking, creativity, leadership, tolerance, and compromise. Students also described how these new skills helped them engage and learn more effectively in other subject areas.

Most students expressed deep investment in and commitment to solving the Challenge Project as well as pride in what they had created. They emphasized the “real-world” value of their projects; a number of respondents described inventing products or services that they felt would improve vital concerns related to the environment, personal safety, quality of life, health, or energy efficiency. Students expressed ownership of specific project tasks, and recognized that successful completion of a Challenge Project required interdependence among students. Nearly all respondents stated that collaboration and teamwork were the most important skills learned while completing their Challenge Projects.

Students also discussed the role of the Challenge Project in enhancing personal growth - in particular the development of self-confidence. Students and teachers attributed the growth in confidence to the opportunities they had to take on such challenges as interviewing industry professionals or public speaking.

Students described relatively few problems with the Challenge Project. Their most common concern was the time conflict between needing to complete end-of-year assignments and exams as well as their projects. A number of students perceived Challenge Projects to be aligned with course requirements, while others expressed concern that they fell behind in their studies due to the time requirements of the Challenge Project. A small number of respondents mentioned lack of time for project development.

IMPACT ON AT-RISK AND UNDERSERVED STUDENTS

Researchers decided that asking students or teachers about their ethnic background or socioeconomic status could limit the discussion or be seen as offensive. As a result, no detailed demographic data is available on interview participants. We do know that during 2012-2013, 71.7% of all STEM21 Academy study participants were identified as underserved based on their socio-economic status, gender, and/or ethnic background. We can infer that there was a similar distribution among interview participants. Since our qualitative data indicates an extremely high positive perception of the impact of blended instruction on student learning, engagement, and personal development, we expect that these results can be understood to apply to both underserved students and their peers.

While we did not parse demographic data for this portion of the study, interviewer notes identified frequent references to technological challenges in the urban schools represented in our sample. Students in these schools were also far more likely to express challenges related to a lack of access to curriculum resources, stemming from a lack of computer access at home and less than ideal access at school. Additionally, interviewers noted lesser engagement in the interview process from some students in the urban schools; when these students were queried for more detailed responses to questions, they often stated that they didn’t know the answer. Interview data from urban schools generally contained less breadth and depth of information.

VARIATION OF IMPACT BY OTHER STUDENT CHARACTERISTICS

In an attempt to understand whether STEM21 Academy's blended instructional approach had a differential impact on students based on other personal characteristics, the research team reviewed interview and focus group results, field notes, and student demographic data. Student interview and teacher focus group results across the years of the study strongly suggest that students who benefit the most by STEM21 Academy participation are those who expressed interest in and readiness for a different kind of learning experience. Students who responded most positively to the program were:

- not highly bound to the traditional instruction techniques of lecture and note taking,
- not intensively concerned about the impact participation in a non-Advanced Placement/honors course might have on their chances of college acceptance,
- interested in working hard on a project and taking responsibility for their own learning,
- comfortable with hands-on education,
- interested in and comfortable with the use of technology in learning, and
- less successful and/or comfortable in a traditional academic setting.

Although these personal characteristics can be found across demographic groups, they are most likely to be found among students who have been less successful in a traditional school setting and may, therefore, occur more frequently among populations that are typically underserved by schools, including low-income students, English language learners, students with disabilities, and racial minorities.

Supporting these findings, students and teachers alike perceived that those who were most likely to be successful in the STEM21 Academy were those who were willing to "take a risk" and "break out" of the traditional educational setting, interested in technology and hands-on learning, and open to committing to an intensive work experience. Both students and teachers describe the curriculum as "intense," "a lot to learn," and requiring students to take ownership of the material.

IMPORTANCE OF TECHNOLOGY AND OTHER RESOURCES

Our interview and focus group results indicate that successful STEM21 Academy implementation requires adequate access to a variety of working technology, both at home and in the classroom. Additionally, the heavy technological requirement of these courses requires that either the classroom teacher, or an easily accessible school staff member, have the technological ability to troubleshoot issues as needed. The most common technological concerns described by teachers and students included a lack of software compatibility between school computers and software required by the Academy courses and the need for a technology team to support access to the websites. Both teachers and students also described minor issues with the LMS, including design restrictions that limit flexibility and website links that may not be updated.

It is also worth noting that participation in experiential meetings and the end-of-year Student Innovation Expo requires fiscal resources (e.g., funding for travel and possible overnight stays), commitment of district leadership and parents (especially to support time spent away from the classroom), and willingness from staff, parents, and students to forgo AP/honors courses.

FIDELITY OF IMPLEMENTATION

As discussed in the study design section of this report, we rated implementation fidelity on several indicators for each of our focal areas: teacher professional development, classroom implementation, and program-wide implementation. Analysis of implementation fidelity allows us to see what is happening in a program as it is being implemented. The potential impact on classroom teachers, schools and program staff of variations in implementation can be large. We set a 65% threshold as our definition of adequate implementation for each construct. Summary results are presented in Table 5.

During 2011-2012, the threshold of 65% fidelity was achieved at the teacher, classroom, and program levels. During 2012-2013, fewer 9th-grade teachers than expected attended the summer professional development session. As a result, fidelity of teacher professional development was not achieved at the 9th-grade level. However, fidelity thresholds for classroom implementation and program implementation were met. It should be noted that additional professional development in the form of in class team teaching and coaching was provided, as well as online technical assistance.

IMPLICATIONS OF FIDELITY RESULTS

We found that measuring implementation fidelity requires an extremely clearly defined program model. As our program staff developd a more clearly defined model, we improved the program in the process. In collecting fidelity data, we were able to clearly identify the STEM21 Academy's four primary program components (technology-enhanced learning, the digital portfolio, experiential learning, and performance assessments). Establishing this clear definition increased our ability to describe and explain the model to other researchers and program staff. It also helped us to identify appropriate data collection instruments to use for measuring implementation fidelity.

The collection of implementation fidelity data was also instrumental in helping program staff identify aspects of the program that were not being implemented as expected. This knowledge was used throughout the two years of the study to identify additional program support schools might need or to recommend changes in the implementation process. Using specific implementation data, program staff could identify teachers and other staff who were not performing as intended, using this information to provide support to these individuals, revise the program, or replace individuals who were not willing and able to implement the program as required. This access to data has greatly improved our ability to ensure that activities are implemented throughout participating schools as intended. Assessment of implementation fidelity has been an extremely worthwhile experience for the STEM21 team as a whole. Use of a rigorous assessment of implementation fidelity has improved our program, developed our research capacity, and strengthened our awareness of the relationship between research and program development. We have found the process to be invaluable.

Table 5: Fidelity of implementation results

	GOAL FOR 2011-12	% IMPLEMENTED WITH FIDELITY 2011-12	GOAL FOR 2012-2013	% IMPLEMENTED WITH FIDELITY 2012-2013
Teacher PD	65% of schools with high teacher participation	80% of schools showed high fidelity **Above threshold**	65% of schools with high scores for teacher participation	58% of schools showed high fidelity **Below threshold**
Classroom Implementation Fidelity	65% of schools with high classroom fidelity	71% of schools showed high fidelity **Above threshold**	65% of schools with high scores for grade activities	66% of schools showed high fidelity **Above threshold**
Program	Program has score of > 2 out of 4	Score=4 **Above threshold**	Program has score > 4 out of 6	Score=6 **Above threshold**

Summary and Discussion

Our mixed-method study of the STEM21 Academy's blended instructional model resulted in four major findings:

- Participation in the STEM21 Academy *significantly increased student achievement* in science and *marginally increased their 21st century and inquiry skills.*
- One year of STEM21 Academy exposure *did not result in a significant increase in academic engagement.*
- Students and teachers *overwhelmingly reported positive impacts on student learning* through STEM21's blended instructional approach.
- Students were most positive about the experiential learning components of the program and *extended Challenge Projects.* There was a less favorable feedback related to the program's unit proficiency assessments.

The first set of findings are consistent with other research that found that project-based learning, another student-centered approach, is effective in teaching 21st century skills (Moylan, 2008; Bell, 2010) and leads to increased achievement in science (Kanter & Konstantopoulos, 2010). We found that all students, and, in particular, underserved students in the STEM21 Academy, earned higher science achievement scores than students in the control group at the end of one year. This is consistent with prior literature that found that students in a blended learning environment perform better than students who learn the same material either exclusively online or in a traditional classroom setting alone (Heterick & Twigg, 2003).

Our results regarding student engagement are only partially supported by other studies. DeGeorge-Walker and colleagues found that a blended learning environment and information and communication technologies enhanced student engagement and achievement after one semester of an undergraduate course (DeGeorge-Walker, et al., 2010; Lou, et al., 2011). DeGeorge-Walker and colleagues used a qualitative, self-selected interview approach to understand engagement patterns, while we used a quantitative measure. The differing data-gathering and analytic approaches could account for the difference in findings. Our own qualitative results, meanwhile, indicate a large increase in student engagement through STEM21 Academy participation. Both 9th-grade students and teachers described all four components of the STEM21 Academy as enhancing student engagement in learning. The difference between our quantitative and qualitative results regarding engagement may result from a difference in the areas of engagement that we explored. In our quantitative analysis, we examined more general indicators of engagement, such as doing class assignments, consistently attending class, setting high expectations, and completing tasks. In our qualitative approach, we asked students and teachers specifically about the four instructional components of technology-enhanced learning, experiential learning, digital portfolios, and proficiency assessments.

The difference in the findings could also be attributed to the delayed effect of the treatment. Some scholars argue that changes in personal factors, such as self-efficacy, take longer than changes in behavior (e.g., a choice of task, persistence, effort, and acquisition of skills) (Lou, et al., 2011; Schunk & Pajares, 2002). For instance, Lou et al. found that participation in a learning behavioral model showed a positive influence on students' behavior in terms of cognition and behavioral intentions, and they hypothesized that those changes in behavior would precede eventual changes in personal factors.

Our interviews indicate that the specific elements of blended instruction that had the greatest impact were those associated with project-based and real-word learning (i.e., Challenge Projects, experiential learning). This mirrors the work of Schneider, Krajcik, Marx, and Soloway (2002) as well as the work of Hmelo-Silver, Duncan, and Chinn (2007), which demonstrates that project- and inquiry-based work increases achievement. STEM21 Academy's Challenge Project provided opportunities for students to learn rigorous content and develop transferable skills through projects that were largely self-directed and collaborative. Students expressed preference for these extended projects when compared to shorter-term performance assessments. Although the Unit Performance Assessments were designed to scaffold the knowledge and skills required for the challenge project, greater value was placed on the Challenge Project. This was most likely due to the authentic nature of the project, the ability to learn in context, opportunities to connect with experts in the field, and chances to demonstrate expertise in an area of choice.

Overall, our quantitative findings support the use of blended instruction to reduce the achievement gap for underserved students. This is consistent with other research that has found that 9th-grade, low-achieving students from minority backgrounds who used computer-assisted technology in the classroom outperformed their counterparts in classrooms without such technology (Shirvani, 2002).

Our qualitative data reveals, though, that successful implementation of blended instruction requires students to access a variety of working technology, both at home and in the classroom. This finding points to the importance of providing support for the technology interventions that take place in blended contexts (Graham, 2006). That is, parents and districts must have the necessary funding and infrastructure to support the technology requirements of a blended program, and, if necessary, provide at-home access for students who would not otherwise have access. This may be considered as a limitation of blended instruction, in that it may not be as cost-effective as completely online or completely face-to-face instructional approaches. However, access has become more ubiquitous and the majority of students, even in low socioeconomic settings, have availability to devices that can provide connectivity. A recent Pew Research Center survey found that teen students (ages 12-17) in urban centers have nearly the same access (94% access, 74% mobile access) as their counterparts in suburban (96% access, 72% mobile access) and rural (99% access, 79% mobile access) environments (Madden, Lenhart, Duggan, Cortesi, & Gasser, 2013). The greatest disparities remain for those with low household income, regardless of urbanity (89% access, 66% mobile access). Schools can leverage strategies like Bring Your Own Device to potentially remediate and help leverage funds that provide access to students in a cost-effective manner (Costa, 2012).

Conclusion

The 21st century increasingly mandates the use of technology. As a future investment, it will be critical to provide technology tools to students in all settings, particularly to those from low socioeconomic backgrounds. As teachers search for instructional strategies that have an impact on achievement, they should consider practices that increase student interaction and provide more opportunities for authentic learning. Technology-enhanced environments can be a powerful setting for leveraging authentic, student-centered learning opportunities that connect students to their communities and provide extended learning challenges that result in gains in achievement and engagement.

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