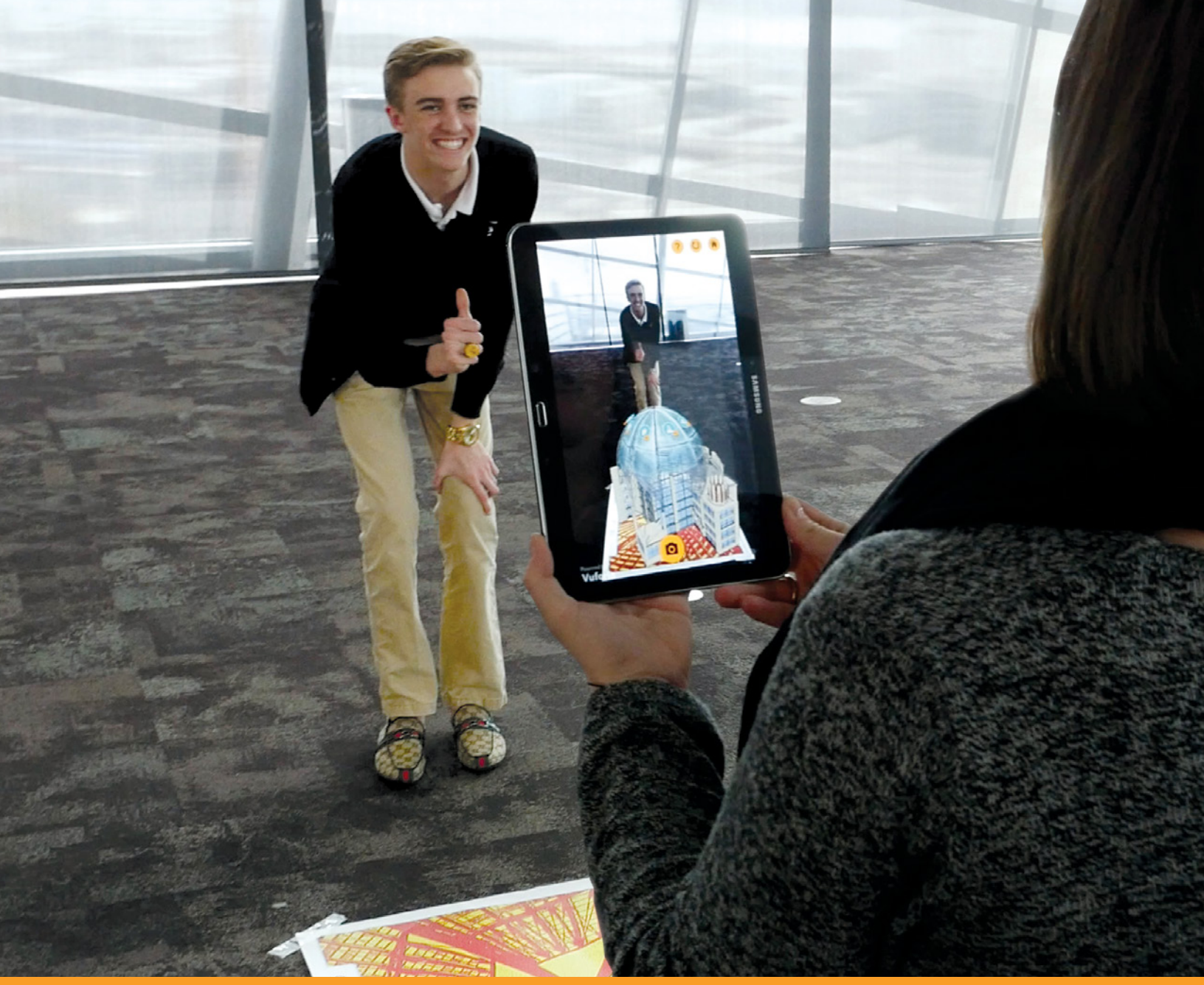


STEAMing Ahead
with Mobile Learning

Project Evaluation Study Results

A cooperative project of

SD Public Library

San Diego Public Library Foundation — Help minds grow.

e3 Civic High — engage • educate • empower

Qualcomm® Wireless Reach™

STEAMing Ahead with Mobile Learning

Results of the Project Evaluation Study

Prepared by Project Tomorrow® for the San Diego Public Library Foundation

"This was a great experience. This could be the new way of learning for the next generation of students like me."

9th grader, e3 Civic High

Contents

Introduction to the Project and Evaluation Study

High wage jobs in high demand sectors in the San Diego region demand that today's students develop familiarity with a new set of career ready skills, including those most often associated with the use of science, technology, engineering, arts and mathematics, also known as STEAM resources. In the past two years, the Economic Development Corporation (EDC) started discussions about K-12 STEAM education initiatives to help sustain economic growth in the San Diego region to support these important industry sectors.[i] A 2011 study by the U.S. Department of Commerce found that during the past decade, growth in jobs demanding these skills was three times greater than other non-STEAM related occupations[ii]. The report also predicted that such jobs would grow at a faster rate than others would in the coming years. However, a 2011 Manpower survey found that more than half of American employers were struggling to find workers to fill key jobs that required advanced science and math skills.[iii]

More than half of the nation's 14 to 18-year-olds use a library to do homework (Gates Foundation Study).[iv] With the opening of e3 Civic High on two floors of the new Central Library @ Joan Irwin Jacobs Common (Central Library) there existed a unique opportunity to develop an augmented reality pilot program at the new library to encourage and support STEAM learning with the students at the high school. The $185 million, 492,500 square foot, nine-story, San Diego Central Library opened in September 2013 and immediately became both a learning and cultural center for the San Diego metropolitan region.

A striking element of the Central Library structure is the 113 feet high steel lattice dome that is larger than the Capitol Dome in Washington DC. Understanding that today's students are interested in learning that is contextually relevant, the STEAMing Ahead with Mobile Learning project was designed to take advantage of the unique architecture of the library dome to provide 9th grade students at e3 Civic High with an enriched learning experience. Using Qualcomm® technology, the project focused on leveraging augmented reality content that utilized mobile, context-aware 4G technologies to allow the students to interact with digital information embedded within the library's physical environment focusing on science, math, engineering and art related content. Similar to augmented reality used by construction teams to visualize a building prior to construction, students learned about the construction of the new library while learning the STEAM concepts associated with each structural element.

The overarching goal of the STEAMing Ahead with Mobile Learning project therefore was to successfully demonstrate how the integration of technology and extended learning through augmented reality helps prepare students for high wage, high potential jobs, and excites and encourages those students to explore their new school environment within a fascinating and dynamic learning experience.

This report documents the evaluation results with both quantitative and qualitative data collected from the students and teachers involved in the pilot implementation of the STEAMing Ahead with Mobile Learning project in fall 2015. Driving the design and implementation of the study methodology was a set of core research questions:

1. How does the mobile/augmented reality learning experience increase student engagement in science, technology, engineering, art or math concepts?
2. Does that increased engagement result in increased interest in a career in those fields?
3. What lessons learned can be derived from the project that can inform the further development of digital library resources or outreach efforts into the community around the use of augmented reality in the library?

About the Project Partners

The STEAMing Ahead with Mobile Learning project was a collaborative effort between the San Diego Public Library Foundation, San Diego Public Library, e3 Civic High, and Qualcomm® Wireless Reach™. Additionally, Trigger, a digital agency specializing in augmented reality, mobile application and game development, designed and developed the AR app experience with help from e3 Civic High and the San Diego Public Library. Project Tomorrow designed and implemented the project evaluation study.

About the San Diego Public Library Foundation

The San Diego Public Library Foundation strengthens communities by supporting excellence in the San Diego Public Library system through philanthropy, advocacy and outreach.

About the San Diego Public Library

The San Diego Public Library serves the informational, educational and recreational interests of San Diego through 35 branches, the Central Library in downtown San Diego, the READ/San Diego literacy program and an online presence. With 6.6 million annual visitors, the library is the largest cultural institution in San Diego that offers free programming.

About e3 Civic High

e3 Civic High which opened in fall 2013 is a charter high school serving the needs of approximately 500 students, many of whom are from low income families in the metropolitan San Diego area. The mission of e3 Civic High is to prepare students for college, career and life-long learning through project-based instruction, cutting edge technology, and expansive research facilities via our exclusive location within the San Diego Central Library, and active civic engagement in the downtown community.

About Qualcomm Wireless Reach

Through Wireless Reach, a strategic initiative that brings wireless technology to underserved communities globally, Qualcomm works with partners to invest in projects that foster entrepreneurship, aid in public safety, enhance the delivery of health care, enrich teaching and learning, and improve environmental sustainability. To date, Wireless Reach has funded over 100 programs in more than 40 countries, with almost 40 of those programs focusing on education. Education programs are designed specifically to address the barriers to adoption of wireless technology in the classroom, including needs for digital content and assessment, infrastructure, privacy and security, and professional development for teachers.

About the Study Participants

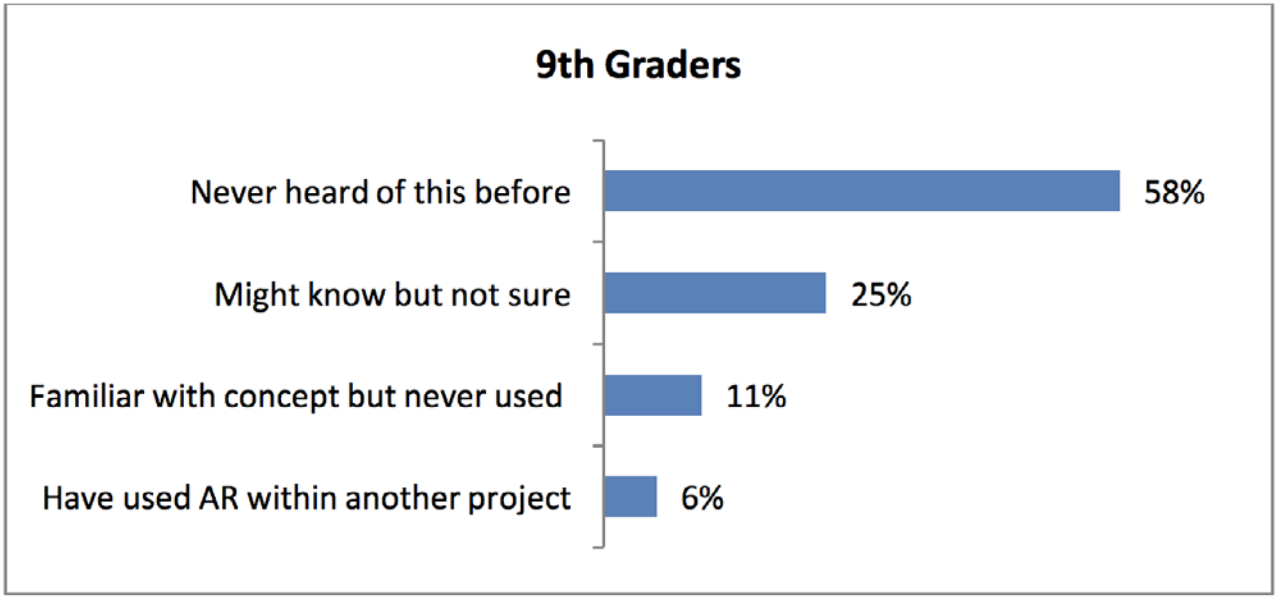
The STEAMing Ahead with Mobile Learning project was specifically designed to introduce the 9th graders at the high school to the unique architecture of the library. The goal with this selection was to provide students in their first year of high school with a memorable learning experience that would connect the resources of the library with core concepts in science, technology, engineering, arts and math. As part of the project implementation, 9th grade students used 4G enabled Samsung Android tablets to access the augmented reality content about the construction of the Central Library Dome.

The technology profile of the e3 Civic High students in this study was very similar to the profile of other high school students around the United States. Like their peers nationwide, 69 percent of the students view their technology skills as average when compared to their classmates (comparative to data from the Speak Up 2014 national research results). Eight in ten use a smartphone and 49 percent have personal access to a tablet outside of school. The students also reported using a wide range of different technologies to support learning at school. Those activities included:

- Taking tests online (70 percent)
- Using online textbooks (62 percent)
- Using a mobile device to take photos of class assignments or textbook pages (59 percent), looking up information online (50 percent) or reading online books or articles (46 percent)
- Watching online videos to help with homework or studying (36 percent)

Relative to this project design, student familiarity with the term "augmented reality" prior to the mobile learning experience was very limited as would be expected for 9th graders. Chart 1 illustrates the depth of student knowledge about augmented reality. Only 6 percent of the students reported familiarity with the concept through use in another project or activity.

Chart 1: Student Pre Survey Results - familiarity with the concept of "augmented reality"



Similarly, only one-quarter of the students (27 percent) reported that they already knew a lot about the Central Library Dome. Students' lack of prior knowledge about the dome was further supported by the fact that 83 percent of the students could not accurately state how many "sails" or overlapping lattice structures made up the dome. However, when asked about familiarity with other large domes, the students indicated that they had visited other dome structures such as those within the Botanical Building in Balboa Park in San Diego (78 percent), the Museum of Man in San Diego (44 percent) and the Love Library at San Diego State University (28 percent). This exposure to other large domes presented a unique opportunity for the students to activate prior knowledge when experiencing the augmented reality content about the Central Library Dome.

Additionally, 61 percent of the students expressed interest in learning more about the dome with the students' highest interest in how technology was used to design the structure and artistic symbolism of the dome. The students' natural curiosity about their environment set the stage for the augmented reality learning experience.

"I hope to learn what the dome represents and why did they build the dome on top of the library."

"I would like to learn about the technology that was used because I've always wanted to see how things start out. I would also like to learn about the art. For example, who came up with the idea of making it into a dome and not a regular shape."

"I want to learn more about the symbolism and importance of the dome along with its history. Learning about the dome can teach me about my school."

About the Learning Experience

On November 30 and December 1, 2015, the 9th graders had the opportunity to use the 4G tablets to access the augmented reality content about how the Central Library Dome was built. To maximize the experience, the teachers brought their students to the 9th floor of the library to the outside deck so that they could both virtually and physically observe the dome. The augmented reality content is divided into 6 sections, with each section representing a different academic area. The academic areas included:

- Humanities: cultural aspects of the dome
- Science: designing the dome for weather in San Diego
- Technology: how designers used computers to design the dome
- Engineering: building techniques used in constructing the dome
- Art: symbolism of the dome
- Math: shape of the dome

Within each academic content area, the students could read narrative text, watch a video or review photographs, diagrams or charts. Each section also included a quiz to assess student comprehension about that academic content area. Upon successful completion of all six areas, the students could take a "selfie" photo of themselves on the Central Library Dome.

Key Study Findings

The key findings from the STEAMing Ahead with Mobile Learning project implementation include:

1. The majority of the 9th grade students agreed that using the 4G tablet with the augmented reality content increased their engagement in learning about the Central Library Dome.
2. The students ascribed many benefits to the learning experience including increased enjoyment in learning, ability to work on the content with their classmates, and being more interested in the dome structure and architecture than they first envisioned.
3. Four out of 10 students said that they were more interested in exploring a STEAM career field after having this mobile learning experience.
4. The teachers participating in the project believe that the mobile augmented reality environment could be used successfully to impact student learning in many other academic areas with a closer alignment with curriculum.

Detailed Study Findings

The detailed study findings leverage the reflections of both the students and their teachers on the learning experience to understand the impact of using 4G mobile devices with augmented reality content to support student learning. Three specific types of outcomes are addressed through these findings: the level of interest and engagement in learning, the valuation of the learning experience, and how that learning experience affected student interest in a STEAM career field.

1. How did the experience influence students' interest and engagement in learning?

A majority of the students who participated in the mobile learning augmented reality experience (55 percent) said that their engagement in learning about the various aspects of the dome increased because of the experience. This was a surprise for 50 percent of the students who initially did not think that the subject matter, the design or construction of the dome, would hold their interest. Additionally, one-quarter of the students would like to learn more about the dome, and 23 percent noted that they have already shared information learned about the dome with others who did not have the same experience. The sharing of information about the dome with others after the experience is a strong indicator of high engagement in the learning process. This heightened level of interest and engagement in the dome is most likely the result of three key factors in the learning experience:

- The use of the 4G tablets offered the students opportunities to both self-direct the learning experience and when desired, to collaborate with classmates for shared learning opportunities.
- The content was contextually relevant and provided strong linkages between the various academic areas.
- The variety of augmented reality tools built into the content enabled different types of learners to find ways to engage with the content that was compatible with their own learning style.

For the students who said that the experience increased their engagement in learning, almost twice as many as the overall student population were able to name correctly the number of "sails" or overlapping lattice structures on the dome. This further indicates the strong connection between student engagement and enhanced knowledge acquisition.

Within the augmented reality content, the entire 9th grade cohort reported that the most interesting academic areas covered were Art and Engineering. These two areas also ranked highest on where the students felt they learned the most. As noted in Table 1, students who felt that the mobile augmented reality experience increased their engagement and interest had even higher valuations on these academic areas. For example, twice as many of the more engaged students (36 percent) compared to the entire 9th grade cohort noted that they learned the most in the engineering content area. While all students ranked the art content area highly, a greater number of engaged students (32 percent) said that the art content was the most interesting to them compared to all 9th graders (24 percent).

Table 1: What content areas were the most interesting and helpful to you for learning?

Content Area	Most interesting: All 9th graders	Most interesting: Engaged 9th graders	Learned the most: All 9th graders	Learned the most: Engaged 9th graders
Humanities	11%	9%	7%	0%
Science	13%	9%	17%	18%
Technology	22%	14%	13%	18%
Engineering	**15%**	**24%**	**18%**	**36%**
Art	**24%**	**32%**	**23%**	**23%**
Math	5%	9%	6%	0%

The impact of the art and engineering content was evident in many insightful student comments.

"I learned that the dome was made to look undone to represent how San Diego is still growing through its people, education and hard work."

"It was interesting how the building was built. It was built that way for a certain purpose. They needed to build it like that so that the wind would not knock it down."

"It was a different way of learning. I liked how the Augmented Reality showed how the dome of the library around us in history and we are a part of it."

2. What types of benefits or value did the student derive from the experience?

In both the observations of the students using the augmented reality content and the students' own reflections in the post surveys, one resounding finding is that "not one size fits all" in terms of how the students used the tablets and the content. This was true in terms of how the students valued the types of learning tools embedded in the content, and described the benefits of the learning experience.

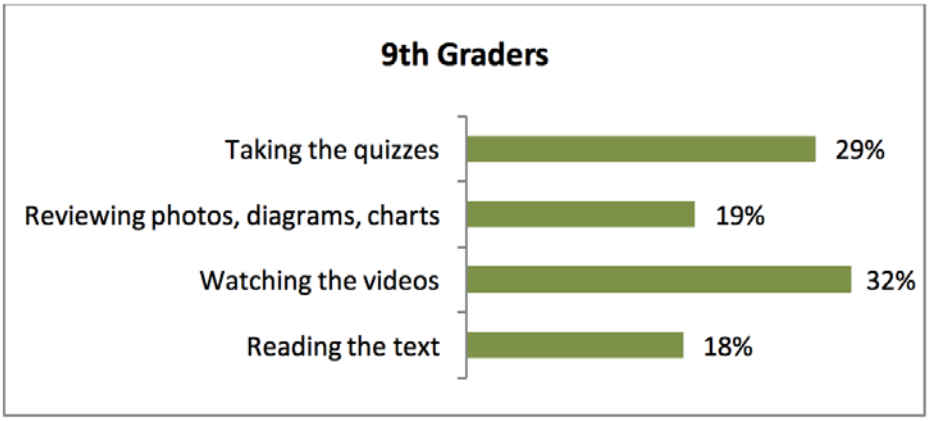
Each content area included four different types of learning modalities: reading narrative text, watching a video, looking at photographs, diagrams or charts, and taking an assessment quiz. When asked to identify the learning tool or modality that was most helpful to them, the students chose "watching a video" as their top choice. This closely follows key findings from the annual Speak Up research reports that document students' increasing interest in visual learning experiences. However, the students also highly valued the quizzes, which provided them with an opportunity to test what they have learned from the videos or readings as noted in Chart 2.

"I am a visual learner. I think that maybe watching what they were saying made it way easier for me to understand."

"I like the quiz because it helps grasp what you have learned and if you understood it or not."

"The videos helped me see a full 360 view of the library."

Chart 2: Which of these learning tools was the most helpful to you?



In the observations of the students using the tablets, we noticed that the students were often switching back and forth between answering the quiz questions and reading the text or watching the videos. The teachers were pleased to see that their students had adapted a learning strategy taught in class to this experience. The strategy, called textual evidence, encourages students to find tangible evidence within text for their answers. Additionally, the students were also activating prior knowledge to enhance the value of this learning experience, another highly valued learning strategy. Both strategies are essential for developing the type of self-directed learning skills so valued by colleges and employers.

"Taking the quizzes helped me because I was able to do like a mini review of the text that was given. Many times though I didn't know the answer but was able to correctly answer with knowledge that was already known to me. But it still got me to reflect on what I already knew and what I learned that day."

The 9th graders placed a high value on the learning experience enabled by the 4G tablets and augmented reality content. As noted earlier, different types of students ranked the benefits differently. Overall, the 9th graders identified the following as their "top eight list" of benefits or outcomes derived from the learning experience (Table 2).

Table 2: Students "top eight list" of benefits from the learning experience

Learning benefit or outcome	% of students who agree
It was fun	72%
I liked being able to work at my own pace	55%
It made learning easier for me	48%
I liked working with my classmates on the project	48%
I was more interested in the subject than I thought I would be	43%
I liked being able to refer back to the text when I had trouble with the quiz	37%
I like how the videos complimented the text	36%
It helped me develop critical thinking skills	34%

Additionally, 39 percent of the 9th graders said that they wished that they could learn this way, using 4G tablets with augmented reality content, in other classes. The students had many ideas of other content areas that would be more engaging with this type of learning experience, including in their science and math classes. Moreover, another student thought it would be fun to learn about the Coronado Bridge using augmented reality.

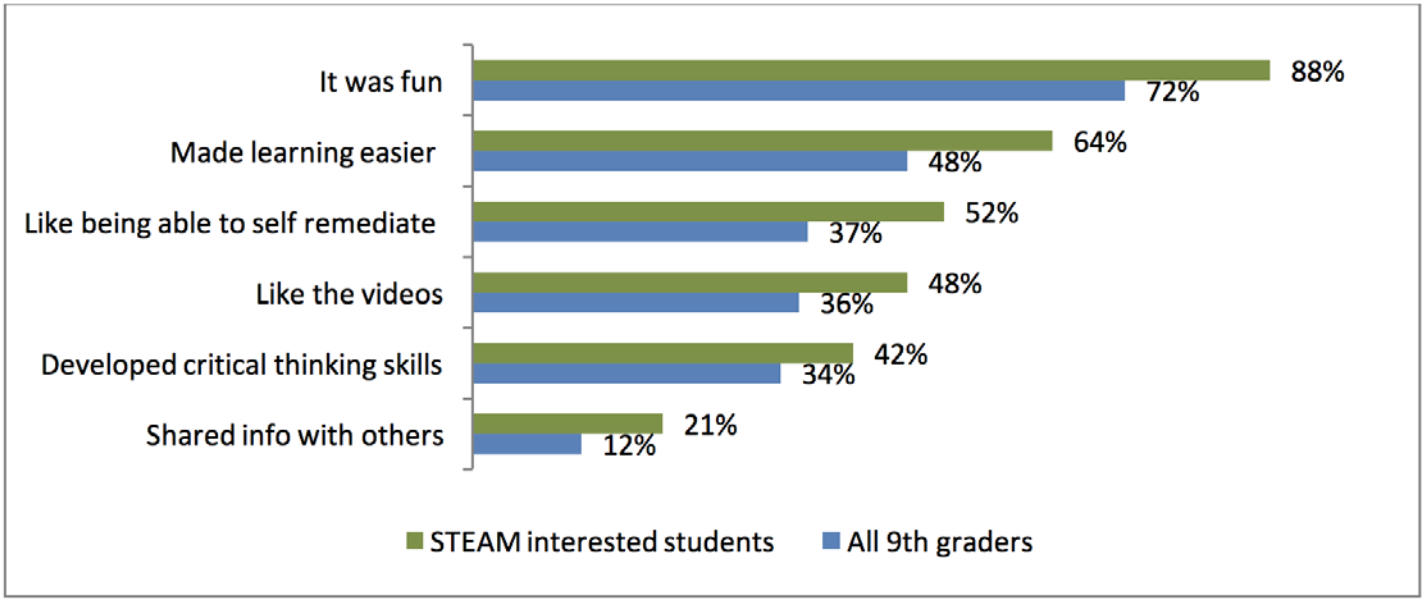
3. Did the experience increase student interest in a STEAM career field?

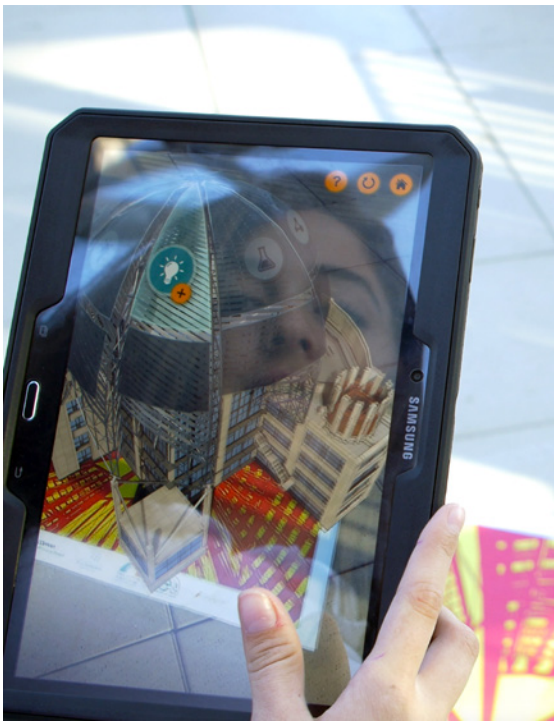
A key objective of this project was to investigate if the use of 4G tablets with augmented reality content on a contextually relevant topic would stimulate student interest in a STEAM (science, technology, engineering, art, math) career field. Policymakers, educators and business leaders are keenly interested in what triggers will work to increase student interest in these career fields. The results from this study will therefore be of strong interest to these leaders.

In the post survey students were asked about their level of interest in a STEM or arts career field. One-quarter of the 9th graders (25 percent) said they were ***very interested*** in a future career that leveraged science, technology, engineering or math; 53 percent noted that they were ***somewhat or maybe interested.*** When asked about a future career in the performing, visual or digital arts, 39 percent of the students said they were ***very interested*** in those fields; an additional 36 percent ranked their interest as ***somewhat or maybe.*** While the percentage of students expressing high interest (the "very interested" ranking) parallel other research including the Speak Up national results from high school students, the percentage of students with "somewhat or maybe" level interest in STEM fields far exceeds the comparable Speak Up data. Additionally, it represents a 26 percent increase from the student pre surveys. On the students' pre survey, 42 percent of the students identified their interest in STEM as somewhat or maybe; 53 percent had that same identification on the post survey.

While there may be several reasons for this change in student response, what is ***most significant is that 40 percent of the 9th graders agreed that their interest in a STEAM fields increased*** as a result of the STEAMing Ahead with Mobile Learning experience. For these students, the mobile augmented reality experience was a transformative event in their learning lives. When asked about the experience, 42 percent said that it increased their interest in learning more about the dome. These students also placed a higher value on several of the key benefits within the learning experience than their classmates did as exhibited in Chart 3. Additionally, while 39 percent of the 9th graders wished they could learn this way in other classes, 45 percent of these STEAM interested students said they would prefer this type of learning experience throughout their education lives.

Chart 3: Students with increased STEAM career interests highly value the mobile learning experience





This evidence supports the idea that to stimulate and nurture STEAM career interest, the learning experiences need to replicate the inherent characteristics of STEAM content and processes. In other words, students need to be able to use advanced technologies such as 4G wireless connectivity and augmented reality, and have access to contextually relevant content to explore potential career interests. The STEAMing Ahead with Mobile Learning project, a collaboration between the San Diego Public Library Foundation, San Diego Public Library, e3 Civic High and Qualcomm Wireless Reach has therefore paved new and important ground in terms of understanding how to motivate and engage students in STEAM content and career exploration.

"The things that I learned about how the dome was built were interesting to me because now I am very interested in engineering."

Ending Thoughts

Besides the key findings shared in this report, it is also interesting to speculate on the future of mobile augmented reality learning experiences within K-12 education. The demonstrated impact of this learning experience pilot on the 9th graders at e3 Civic High warrants that we further explore the integration of this technologies into education. To add relevancy to this discussion the insights of the three teachers involved in this project are especially noteworthy. From their experience, they would recommend the following for new mobile learning projects:

1. It is important to create a strong connection between the content of the augmented reality experience and class curriculum to enhance the relevancy of the learning process for the students.
2. The variety of learning tools and modalities was essential for student engagement as well as ensuring knowledge acquisition. The ways that the content is presented must support a variety of learner styles and needs.
3. The stability of the Internet connectivity cannot be underestimated, and the value of the 4G access is critical to keeping students engaged and on task with projects such as this.
4. While some students may need more guided instruction than others may, all students will benefit from having a contextual understanding of augmented reality prior to opening up the app on the tablet. Understanding this type of technology is a new workplace skill. It should be treated as such by teachers and students.
5. Teachers should think beyond their traditional course content and curriculum when exploring new areas for augmented reality and mobile learning. Increasingly students need information literacy and research skills and possibly this technology can be used to help students develop those skills, especially if your school is co-located or in partnership with a library such as with e3 Civic High.

About Project Tomorrow

Project Tomorrow, the national education nonprofit organization dedicated to empowering student voices in education discussions, prepared this program evaluation for the San Diego Public Library Foundation. Project Tomorrow has 20 years of experience in the K-12 and higher education sector and regularly provides consulting and research support to school districts, government agencies, business and higher education institutions about key trends and research in science, math and technology education.

Project Tomorrow was pleased to have the opportunity to work on this important and interesting project with the San Diego Public Library Foundation, San Diego Public Library, e3 Civic High and Qualcomm Wireless Reach.

Appendix

Study Research Questions

The following research questions were central to the design and implementation of the STEAMing Ahead with Mobile Learning evaluation project.

1. What is students' baseline familiarity with using a mobile device and augmented reality to support learning? What prior experiences have they had that influence this project?
2. Does the project activity increase student engagement in science, technology, engineering or math concepts? Does that increased engagement result in increased interest in a STEAM career?
3. How are students using technology to demonstrate their ability to collaborate, problem solve or think critically? What role does the mobile device and/or the augmented reality environment play in that development?
4. Does the learning experience propel the students to use other library resources to support their learning?
5. What lessons learned can be derived from this project that can inform the further development of digital library resources or outreach efforts into the community around the use of augmented reality in the library?

Study Methodology

Project Tomorrow implemented a mixed methods research approach for this evaluation project collecting both qualitative and quantitative data to inform the development of the project report.

The participating students completed online surveys prior to having the augmented reality experience and then again, after the experience to capture their ideas and valuations on the learning experience. As part of this study, 106 9th graders completed an online pre survey in November 2015 and 78 completed an online post survey after the augmented reality experience in December 2015. Project Tomorrow staff observed three classes of students using the tablets and content on December 1, 2015 and conducted "on the spot" interviews with several students as they were working through the content. Additionally, on December 14, 2015, the Project Tomorrow team interviewed three teachers who were most involved with the learning experience. Based upon the analysis of the quantitative and qualitative data collected, the resulting study findings were included in this report.

The various data collection mechanisms within the study design included:

Pre and Post surveys: Staff from Project Tomorrow provided the participating teachers with a URL survey link and the teachers administered the online survey during class time both before and after the augmented reality experience.

Teacher Interviews: Following the completion of the augmented reality experience, staff from Project Tomorrow interviewed three teachers involved in this project to gain their perspective on the learning value of the experience, what is meant to their students, and how the experience and process could be improved or leveraged for other applications within the curriculum.

Experience Observation: The study team observed three classes of students using the mobile devices and augmented reality content. The purpose of these observations was to understand how students worked through the content and their level of engagement in the resulting learning process.

Speak Up Benchmarks: To provide additional context and perspective regarding the use of mobile devices within learning, the report includes where appropriate specific benchmarks from the Speak Up 2014 National Research Project findings. The annual Speak Up project collects and reports on the authentic, unfiltered views of K-12 students, educators and parents on the use of technology within a 21st century education. Since 2003, the annual research project has collected input from 4.5 million education stakeholders representing over 44,000 schools nationwide. The Speak Up national findings annually inform federal, state and local policies and programs around education issues. Speak Up is a national research initiative of Project Tomorrow.

Endnotes:

[1] http://www.sandiegobusiness.org/about

[2] http://www.esa.doc.gov/reports/stem-good-jobs-now-and-future

[3] https://candidate.manpower.com/wps/wcm/connect/6ecffb80470e244d9ac3da4a926374bc/2011+Talent+Shortage+Survey_A4_lores.pdf?MOD=AJPERES

[4] http://www.gatesfoundation.org/Media-Center/Press-Releases/2010/03/Millions-of-People-Rely-on-Library-Computers-for-Employment-Health-and-Education

[5] http://www.tomorrow.org/speakup/SU14DigitalLearning24-7_StudentReport.html

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