i2 Learning Evaluation Report




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Executive Summary

This report is an evaluation of i2 Learning's pilot implementation of the "STEM Immersion Week" initiative at one large, urban middle school in the Northeastern United States. The school's experience was comprised of a one-day professional development session for teachers, closely followed by the teacher-led implementation of i2 Learning course curricula with sixth grade students. The Immersion Week (May 19 – May 22, 2015) was designed to engage teachers and students in exciting real-world STEM projects to expand the learning experiences available to students in traditional public school settings.

The concept of the STEM Immersion Week emerged from i2 Learning's success in operating summer Science, Technology, Engineering and Mathematics (STEM) programs for students entering Grades 5-8 (otherwise known as "i2 Camp"). At the request of i2 Camp's schools, parents, teachers, and students, the i2 Learning course curricula was adapted for school environments, and the project was launched in one public school district in Spring 2015.

This report captures the implementation of the STEM Immersion Week, as it was enacted during the regular school day. Key questions include: 1) What aspects of the i2 Learning programmatic approach were successful? 2) How was the i2 Learning approach received? and, 3) What recommendations can be made to strengthen the quality of the i2 Learning approach, as it continues to develop in its second year?

To explore these questions, the external evaluation team from the Center for Technology and School Change at Teachers College, Columbia University, gathered data based on the desired goals and outcomes of the program. Data collection strategies included site visitations, classroom observations, conversations with teachers, and pre-post teacher questionnaires.

Overall, the analyses revealed high levels of student engagement across all participating students. While the STEM Immersion Week created new demands for teachers, the participating educators were generally positive about the i2 Learning approach after completing the STEM Immersion Week experience, and most reported that they were looking forward to continuing i2 Learning activities. The following are the key findings from the data:

1. **Several *programmatic features* emerged as meaningful to the i2 STEM Immersion Week.**
    a. The Engineering Design Process (EDP) provided a consistent structure for student exploration across courses, as well as an instructional strategy for scaffolding student problem-solving efforts.
    b. The i2 Learning curriculum provided opportunities to reinforce core content (e.g., from the teachers' existing mathematics or science curriculum) from a STEM perspective.
    c. The hands-on STEM learning experiences engaged students in problem-solving and provided structured opportunities to work collaboratively in teams.
    d. When probing questions were used in the classrooms, observers noticed that it facilitated student problem-solving and deepened student understanding.

2. **Participants in the i2 Learning program had a *positive response* to the STEM Immersion Week experience.**
   a. The teachers reported that they found the hands-on aspect and the collaborative planning time of the i2 professional development to be very helpful.
   b. The teachers were generally enthusiastic about the program after the implementation in the classroom.
   c. Evaluators observed students to be very engaged and excited to participate in the collaborative, hands-on STEM activities.

Overall, the evaluators found that the i2 courses engaged students in problem-solving and created openings for students to make conceptual connections across the STEM disciplines. The school setting presents a new—and promising—environment for the implementation of the i2 Learning approach.

Overview

The goal of i2 Learning is to engage middle school children in authentic learning environments in Science, Technology, Engineering and Mathematics (STEM) through stimulating hands-on activities. The curricula of i2 Learning broadens children's exposure to STEM concepts through a series of challenges. Previously, the i2 Learning program has been offered in summer camp sessions. This evaluation reports on the use of the i2 Learning curriculum in one urban middle school. Ultimately, across all i2 Learning settings and courses, the program seeks to excite children about Science, Technology, Engineering, and Mathematics and professions related to STEM fields.

In May 2015, the i2 Learning curriculum was used for four days in a public middle school. Teachers attended one day of professional development focused on the course content of their assigned course. The program was implemented across the entire sixth grade, with all the students and teachers participating. The sixth grade was broken down into thirteen sections (five sections of *Engineering Prosthetics*, four sections of *Engineering Ice Cream*, and four sections of *Architects of Time*). Students were involved in program activities for six periods of a nine period school day for each of the four days. Two teachers were assigned to each group of approximately 25 students and taught one specific course for the entire four-day period. Three courses were taught during this time period: *Architects of Time, Engineering Ice Cream, and Engineering Prosthetics.*

Observers attended one day of the three days of professional development and two days of the four days of in-school implementation of the program. Pre and post questionnaire data was also collected from the participating teachers. This evaluation report summarizes findings from all of these data sources.

Literature Review

The Nation's five-year plan for STEM education includes a concentration on providing equitable STEM learning experiences for students, and a focus on building the capacity of teachers to support STEM instruction (Holdren, 2013, p. 8). To this end, the creation of high-quality STEM curricula is essential, as it improves access to STEM Learning and models successful approaches to authentic STEM education (National Research Council, 2011). As the U.S. government increases investments in STEM (The White House, 2015), curriculum providers will increase the number of STEM resources available to teachers. Yet, what constitutes "high-quality" STEM learning experiences? And, how can stakeholders support the adoption of innovative instructional materials?

Identifying High-Quality STEM Learning Experiences

It is our Nation's goal to "increase STEM literacy for all students" (National Research Council, 2011, pp. 5). To do so, our education system must "evolve from learning for STEM literacy to using STEM literacy for learning" (Zollman, 2012, p. 12). High-quality curriculum materials embrace STEM as a "meta-discipline" that includes "skills, abilities, factual knowledge, procedures, concepts, and metacognitive capacities" (Vasquez, 2014, p. 11; Zollman, 2012, p. 12). High-quality STEM experiences for students also embrace "transdisciplinary" approaches to instruction, where deeper understandings arise from hands-on, real-world problem-solving opportunities (Vasquez, 2014).

Understanding the Adoption of Instructional Materials

Our shifting notions of STEM education create new demands for teachers, as they begin to understand STEM learning and start reconceptualizing learning environments and adopting new curricula materials in their classrooms. Moving away from disciplinary approaches to STEM—toward multidisciplinary, interdisciplinary, and even transdisciplinary approaches—will require renewed efforts in training to prepare teachers to make these instructional shifts (Vasquez, 2014).

The challenge for STEM curriculum providers is to foster professional development experiences for teachers and administrators that support sustainable change. Key considerations from the literature suggest that what is needed is "more in-depth engagement than is typically provided in the standard workshop given to teachers at the beginning of an initiative" (Penuel, Fishman, Yamaguchi, & Gallagher, 2007, p. 928; Loucks-Horsely & Stiles, 2001, Putnam & Borko, 2000). While a guided curriculum provides context for the discussion and a mechanism for instructional change, professional development must be connected to a larger vision for reforming STEM pedagogy (Penuel et al., 2007). Moreover, outside curriculum developers must respect the professional expertise of teachers, and provide opportunities for teacher input (Stacy, 2013). Flexible curricular approaches that understand and value teachers as professionals will demonstrate better success than traditional, scripted materials (Sparks, 2004).

Curriculum providers who understand the context of schools, and accommodate the individual needs of teachers and students, are promising partners in the STEM education journey. The goal of providing equitable STEM learning opportunities across settings requires "expanding access to new opportunities for learning, for continuing and deepening learning, and for designing learning opportunities that deeply connect with and reflect (and therefore invite) the lived experiences of children and young people" (Penuel, Lee & Bevan, 2014, p. 2). The challenge is to identify successful STEM resources that can support such learning opportunities for teacher and student learning.

Methodology

Three members of the evaluation team from the Center for Technology and School Change (CTSC) observed various aspects of the program implementation. Two members observed one full day of professional development (8:30 am - 3:00 pm) with teachers from the *Engineering Ice Cream* course. Two members of the evaluation team observed classes throughout the entire school day on the second day of curriculum implementation at the school, and one member of the team observed the fourth (final) day of the program implementation.

The observations were captured using a protocol developed by the evaluation team. In addition, researchers wrote field notes, and held informal conversations with teachers. The open-ended question responses on the teacher Pre and Post questionnaires were also used as part of the data collection for this report. The CTSC evaluation team subsequently analyzed the data iteratively, to identify themes and patterns.

Findings

The findings presented below document i2 Learning's pilot implementation of the "STEM Immersion Week" program in one public school setting. The i2 Learning approach provided new opportunities for the school to experience authentic approaches to interdisciplinary STEM instruction.

Working together, the i2 Facilitator and the teacher teams explored specific i2 courses, and made preliminary adaptations for their students and their school context. Teachers then worked with students using the i2 Learning curricula over four days in May 2015. Overall, the evaluators found that the i2 courses engaged students in problem-solving and created openings for students to make conceptual connections across the STEM disciplines. The school setting presents a new—and promising—environment for the implementation of the i2 Learning approach.

Finding 1: Several programmatic features emerged as meaningful to the i2 Learning STEM Immersion week

Finding 1a: The Engineering Design Process (EDP) provided a consistent structure for student exploration across courses, as well as an instructional strategy for scaffolding problems. The EDP was an integral part of each course. Teachers facilitated student work through the eight-step EDP: identify, investigate, imagine, plan, create, test, improve, and communicate. The cyclical nature of the EDP created an opportunity for students to develop their growing understandings of targeted STEM concepts. Students and teachers capitalized on design failures, and demonstrated excitement to rethink and improve. Evaluators consistently noted that students were deeply engaged in the design process.

Across the different classes students were expected to reflect on their designs not only prior to starting the hands-on work but also during the hands-on work and after it was completed. Students discussed the needed revisions and revised the products as they worked. There was a great deal of student reflection heard throughout the classrooms.

Student 1: "Why don't we wrap this in the middle, so it stays cold?"
Student 2: "What material will keep it cold?"
Student 1: "Let's use tinfoil"
Student 3: "Where? On the outside?"
Student 2: "No, on the inside. I have a way to shape it correctly for the inside, let's just shape it around the outside and then use that to shape it for the inside.
Student 3: "Do we need to cover the base too? Shall we make a net?"
Student 1: "No, let's just do it separately."
Student 2: "Well if it doesn't work we can do it again."

(The *Engineering Ice Cream* course)

From observations of the preliminary professional development day, it is evident that the teachers began to develop their understanding of the EDP. Teachers had some early misconceptions regarding the differences between the EDP (a process to create new things) and the scientific method (a method to discover how things work). Teacher conversations in the professional development session suggested that the difference remained unclear for some of the teachers. Despite the confusions, the use of the provided EDP steps supported teachers in implementing the EDP in their classrooms. A number of teachers were able to share this understanding with students as they emphasized that the focus of the EDP is on the process rather than the development of a particular product.

Finding 1b: The i2 Learning curriculum provided opportunities to reinforce core content from a STEM perspective. In some of the classes there was evidence of teachers relating the student work to content areas from their curriculum and providing support for students to use that knowledge in solving the challenges.

> The teacher praised the students for their discussions, explaining that she heard good math phrases when they were troubleshooting the timers they were creating. In one group, when they realized that their timer was twice as long as it should be, they discussed how to fix it using math language. "It is twice as long so we will need to subtract one-half of the water." Another group had a timer that timed an interval shorter than a minute and a group member suggested, "We need to add sand to make the timer last one minute."
>
> (The *Architects of Time* course)

However, the evaluators did not see teachers consistently make connections between the activities and the content disciplines. The opportunity to make disciplinary connections in the interdisciplinary work was perhaps new to most teachers. Only 13% of participating teachers indicated that they taught interdisciplinary units on a monthly basis, and 40% of teachers reported no prior experience in teaching interdisciplinary lessons (n=12). The STEM Immersion Week provided a unique opportunity for these teachers to use the STEM activities to reinforce concepts from their existing curriculum and in some cases, to go more in-depth on certain ideas. The Teacher Manual and the professional development sessions can support curricular connections by providing explicit examples of places in the i2 curriculum where these alignments might be appropriate.

Finding 1c. The hands-on STEM learning experiences engaged students in problem-solving and provided structured opportunities to work collaboratively in teams. There was a great deal of evidence of student engagement across the classrooms. Students were observed to be well-behaved, on-task, collaborative, and excited to work on challenges.

Several comments from teachers indicated that the project-based work was engaging for students who normally were not so engaged. For example, one teacher noticed the active participation of a female student who was answering questions about the different design tests. After the student contributed a response for the fourth time, the teacher said, "Wow, I have not heard you talk this much all year!" (the *Engineering Ice Cream* course).

> Teacher: "What did you think about other groups' projects? Did they rise to the challenge?" Students responded, "Very creative", "Amazing." "I did not know flame angelfish could change gender." "Other groups had cool facts." "I liked their angelfish picture." "Yeah, it's really close to the model." "I learnt Piranha can break a human hand in 5-10 seconds." It also resulted in a conversation led by a quiet girl in the class, as she named and explained to the other students about 15 different types of fish she had, or had previously owned.
>
> Teachers congratulated students: "Well done; your team work was so great this week. I was very impressed with you." and "You all worked really well together- you communicated well and had to compromise sometimes and look how well your displays turned out."
>
> (The *Engineering Prosthetics* course)

The evaluator noted that the aforementioned teacher team appeared delighted with the student learning that had occurred through the *Engineering Prosthetics* course. In conversation with the evaluator, the first teacher explained: "They [the students] completely exceeded my expectations. They decided on the content they wanted to research, they worked hard researching it, and they were so creative with their displays. I wish I had videoed the aquarium and them walking around- they loved it. I never do group work, because I get so nervous about letting go of the teaching and having them do it. They really surprised me. I will definitely use more group work from now on." The second teacher added, "All students rose to the challenge- just incredible! We were very thoughtful about choosing groups well and grouped students that worked together. It definitely made a difference."

Finding 1d: When probing questions were used in the classrooms, observers noticed that it facilitated student problem-solving. However, this pedagogical technique was used inconsistently across the classrooms implementing the i2 STEM courses. In some of the classrooms, teachers prompted students with open-ended questions to assist students' understanding of important concepts.

The use of probing questions supported student thinking, encouraged further inquiry, and sometimes helped students with their misconceptions. This teacher behavior was not observed in every classroom; however when it was used, students appeared to deepen their curiosity and understanding of the topics discussed.

The teachers took the group to a grassy area beside the school building. The lead teacher asked, "How can the sun help us tell time?" Students made suggestions. For example, one student said that "shadows help us tell time." The teacher probed, "But how will the shadow tell us time? Will it help us in an hour?"

The student responded to the teacher by explaining that the sun is constantly moving. The sun is on this side of the classroom building, but then it moves. They put two dowels into the ground. The teacher asked, "Does it matter if it is straight? Does it matter how big the dowel is? Think about your answer…if it is yes or no then why?" She had two students trace the dowel shadows into the ground with colored chalk and put the time they did that. The teacher then indicated they would return at multiple times to see the shadow and see the answer to their questions.

(The *Architects of Time* course)

Finding 2: Participants had a positive response to the STEM Immersion Week experience.

Finding 2a: The teachers found the hands-on aspect and the collaborative planning time of the i2 professional development to be very helpful. Patterns from teachers' opened-ended responses on the post-questionnaire indicated that teachers felt that doing the hands-on activities was the most helpful aspect of the professional development, along with the collaborative planning, and the chance to look at materials. Teachers' most consistent suggestion for changes in the professional development on the post questionnaire related to time: 1) the professional development should have been longer; and, 2) the professional development should have been conducted sooner, with more time for the teachers to prepare to teach this new curriculum.

The evaluator noted that the i2 Learning facilitator supported teachers in modifying curriculum materials for their students and to accommodate the school's four-day implementation timeline (traditionally, i2 curricula are designed as one-week courses). Feedback from the teachers both during the session and on their post-questionnaires indicated that the teachers would have liked more time to participate in collaborative planning prior to the STEM Immersion Week.

Finding 2b: The teachers were generally enthusiastic about the program after the implementation in the classroom. A total of 92% (n=12) said they would be interested in using the curriculum in the future. Despite the many challenges the teachers faced in preparing to implement this curriculum, teachers were largely enthusiastic about the experience at its conclusion. Teachers' reactions to the program grew more positive as the week went on, and as they mastered the management of materials, the presentation of new curriculum, and especially as they saw the high levels of student enthusiasm and engagement. Although they had to prepare in a short period of time, work with large classes and work with materials that were new to them, 92% of teachers (n=12) reported on the post-questionnaire that they would be interested in teaching the same i2 curriculum again. And 77% of the teachers (n=12) reported that they would be interested in teaching other i2 curriculum units.

Teacher comments on the post-questionnaire indicated that though challenging, the experience benefited their students:

- "It was a lot of work, but the end results were very rewarding."
- "It's very engaging – that's the way students learn best."
- "I enjoyed this week. Lots to plan but the activities were engaging and enjoyable."
- "I think these activities were great for our students, they enjoyed the hands on approach. I think with some modifications they will work well with our students."
- "I was able to see a different side of my students' personalities, and saw students who had been struggling all year suddenly come to life and take charge of their group."

Finding 2c: Evaluators observed students to be very engaged and excited to participate in the collaborative, hands-on STEM activities. The level of student engagement was high across the observed classrooms. Students would frequently lean forward, exclaim with excitement, and generally showed on-task behavior. The evaluator noted that students would "groan" when they had to go to other classes (electives), lunch, or when school ended for the day.

Some teachers indicated that the project-based work was engaging for students that normally were not so engaged. An example of high student engagement was shown when students completed their fish displays and viewed all the other groups' displays on an aquarium tour.

Students were enthusiastically finishing their display set-up and preparing for the aquarium tour. Each station had the group's fish displayed with detailed information about the fish alongside it. The teacher explained to the class the procedure for the aquarium tour and described how each group would walk from one group to the next. She asked students to respect each other's work. She also referred to the engineering design process and how the groups had worked collaboratively to create, test and improve their designs.

The teacher played music and a video on the Smartboard creating an aquarium-like environment. Each group moved to observe and take in their first station display. Students were eager to hunch together around the display and made sure everyone was included. They were very engaged and engrossed in discovering what the other students had done with their projects.

Students were delighted, "That's really cool!" "Like how they have decorated their fish!" "I want to see this display from another angle." Generally one person from each group would read the information about the fish to the others. Some students were taking notes and others responded enthusiastically – "Wow, this one changes gender!" and "I can't believe this fish weighs 12 pounds and can live for 7-12 years!" and "What? It's a cannibal and eats its own kind?" The teacher also told the students that they were allowed to take pictures with their phones. Most of the students were ecstatic and immediately started taking photos.

(The *Engineering Prosthetics* course)

Recommendations

Based upon the data collected, the following recommendations are provided for future implementation in school settings.

School Preparation

Administrators

- Meet in advance of professional development with school leaders to discuss, from i2 Learning's perspective, what supports will be needed for the program (including both curricular support and logistical support, such as the procurement of materials);
- Encourage administrators to engage teacher leaders in the adoption of this program at the ideation stage, and to inform teachers at least one month in advance of upcoming curriculum plans;
- Encourage administrators to provide ample time for teachers to collaboratively plan for curriculum implementation (for example, to prepare resources, to make appropriate adaptations, to align to classroom content, and to script guiding questions that build on key concepts);
- Ask at least one administrator to be present at professional development to address teacher concerns;
- Consider other scheduling demands on teacher time (testing, report cards, etc.);
- Ask administrators to inform teachers that a program evaluation team is coming (if applicable) and that the evaluation is focused on the program, not the teachers;
- Support administrators in providing name badges for professional developers, i2 staff, and evaluators (if applicable) to help the teachers identify all the new personnel in their school.

Teachers

- Provide access to professional development materials at least one month prior to curriculum implementation and where possible, provide printed versions of the materials;
- Provide professional development session at least two weeks prior to curriculum implementation;
- Encourage collaboration between and among teachers to share responsibilities equally.

Professional development

Materials

- Provide student and teacher booklets that are designed for the school setting, with no reference to camp or campers. The school version should include grade level appropriate standards (e.g., Common Core) aligned to the associated activities. Highlight suggestions such as "this would be a good time to talk about ratios," so that teachers can better connect i2 to school subject content;
- Give teachers materials sufficiently in advance of curriculum implementation;
- Provide alternative for materials that concerned teachers, such as the razor blades and hot plates.
- Copy and provide materials to teachers in hard copy format;
- Ensure that materials like URLs/links are up-to-date.

Curriculum

- Match curriculum to the number of days available for implementation;
- Meet in advance with a few school teachers to discuss how the i2 curriculum could be matched to the school grade/curriculum.

Modeling of Activities

- Relate the activities to school content subjects, using the language of the different disciplines (e.g. measurement);
- Consider the literacy demands of content and student literacy levels;
- Integrate mathematics and science concepts explicitly;
- Model discussions using probing questions;
- Spend more time on the question (from both a teacher and a student perspective): "What connections am I making?";
- Help teachers understand how their support can lead students to deeper levels of understanding in these activities. Discuss what level of teacher involvement is appropriate as students engage in the activities. Sometimes teachers just explained activities and then did not provide any support to the students or ask them any questions.

Clarify Engineering Design Process

- Encourage each class to display Engineering Design Process poster;
- Distinguish between EDP and the scientific process;
- Discuss how teachers can use probing questions to ensure that students do not use EDP in a formulaic manner. Stress the importance of process and the need for thoughtful questions to move beyond simply implementing a list of hands on activities;
- Encourage teachers to go through the cycle of prediction, cause and effect, with students routinely;
- Encourage teachers to scaffold student learning by monitoring their progress during the design process. For instance, when teachers linked activities to engineering process, sometimes they simply let students build without checking the student designs. Activities appeared most effective when teachers had a gatekeeping role;
- Suggest language for teachers to use, such as, "You may not get it the first time but that is ok – that is how engineers work." This was observed in some classes but not frequently.

Creating School Capacity

- Meet with a few teachers after implementing the curriculum in the school setting to debrief with them, and from their perspective find out: what worked with students; what didn't seem to work in their school setting; and, how to revise curriculum to be more school friendly and appropriate.

Conclusions

The students in the i2 Learning program participated in engaging and authentic EDP projects. The student level of on-task behavior and enthusiasm was extremely high. Students had unique opportunities to collaborate, innovate, and problem-solve throughout their experience in the four- day i2 Learning curriculum. By the end of the four-day experience, teachers were positive about the STEM Immersion Week. However, initially, they wanted more time to understand and prepare for the program. Recommendations from the implementation of the program include the need to provide more planning time for the teachers, as well as the need to communicate with them well in advance of the implementation of the program. A focus on connecting the i2 curriculum with the standards-based school disciplines that teachers must address could enhance the program even more and increase teacher enthusiasm for the project.

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