IMSA© FUSION: Preparing Students for Future Scientific Expertise
by Michelle Kolar, Dora Phillips, Liz Martinez, and Laurie Sutherland

Author Bios:

Michelle Kolar, Executive Director, Professional Field Services, Illinois Mathematics and Science Academy, holds a Bachelor of Science Degree in Biology from Western Illinois University and a Masters in the Art of Teaching degree from National Louis University. Ms. Kolar's career in STEM education began in museums where she spent over ten years working at internationally renowned organizations such as, the Shedd Aquarium and The Field Museum. Ms. Kolar leads the development, implementation and expansion of IMSA's STEM outreach initiatives. She may be reached at mkolar@imsa.edu, phone (630) 907-5879.

Dora Phillips, IMSA Director of Statewide Educator Initiatives, holds a Bachelor of Arts Degree in English/Secondary Education from Tulane University and Master of Education in Instructional Leadership from Loyola University Chicago. Ms. Phillips spent much of her early career working with the Chicago Public School system as a teacher and administrator in alternative educational programming. She has extensive experience in building programs offering opportunities for students from diverse backgrounds to achieve increased education success. She may be reached at dphillips@imsa.edu, phone (630) 907-5858.

Liz Martinez, IMSA Fusion Lead Curriculum and Professional Development Specialist, holds a Bachelor of Arts Degree in Elementary Education from National College of Education and Master of Education in Curriculum and Instruction from Concordia University. Ms. Martinez taught middle school science for 30 years in multiple socioeconomic and academic settings, has held several association board seats, and has partnered with university and corporate science leaders on a variety of educational projects. She may be reached at emartinez@imsa.edu, phone (630) 907-5874.

Laurie Sutherland**,** IMSA Special Assistant to the President, holds a Bachelor's Degree in English/Secondary Education from Nazareth College and a Master of Science Degree in Curriculum and Instruction from University of Rochester. Ms. Sutherland's early career includes teaching in New York and Los Angeles, including an academic program for high potential minority youth at The Johns Hopkins University Center for Talented Youth, and also in higher education at Waubonsee Community College and College of DuPage. She has worked at IMSA for 15 years in STEM program administration and development. She may be reached at sutherla@imsa.edu, phone (630) 907-5970.

The authors acknowledge two IMSA staff members who assisted with research for this article:

Brian Grublesky, Statewide Educator Initiatives Program Manager
Robyn Lee-Diaz, Statewide Educator Initiatives Partnership Manager

The Illinois Mathematics and Science Academy is located at 1500 Sullivan Rd., Aurora, IL 60506.

Abstract
Illinois adopted the Next Generation Science Standards (NGSS) on February 19, 2014 with implementation scheduled to begin in the 2016-17 school year. This article explores (1) the national and statewide need for STEM college and career readiness based on current data; (2) the research on best practices in STEM teaching and learning; and (3) the work of the Illinois Mathematics and Science Academy (IMSA) to create IMSA Fusion, a science, technology, engineering and mathematics (STEM) educational program that is aligned with NGSS and utilizes research-based best practices to serve Illinois educators and students.

The introduction of the Next Generation Science Standards, following closely on the heels of the Common Core State Standards, provides an opportunity for a national discussion on STEM (science, technology, engineering and mathematics) readiness in America. Dixon and Moon suggest what is at stake: "To maintain a healthy society capable of either collaboration or competition with international counterparts, the U.S. must continue to prepare students who are capable of becoming experts in science." (2014, p. 334) Although the implementation of Common Core State Standards across the country focused our attention on national standards in education, many have felt that the conversations regarding science education have lagged behind those in mathematics and English.

National Educational Trends
According to the U.S. Department of Commerce Economics and Statistics Administration (2011), STEM fields will become our largest area for future employment and will necessitate a workforce that is literate in science, technology, engineering and mathematics, "STEM occupations are projected to grow by 17.0 percent from 2008 to 2018, compared to 9.8 percent growth for non-STEM occupations…STEM workers command higher wages, earning 26 percent more than their non-STEM counterparts." It is unfortunate that although the national unemployment rate is still roughly 6% there are an estimated four million unfilled jobs in STEM fields because of a lack of adequately trained workers. Not coincidentally, the U.S. ranks 47th out of 144 countries in mathematics and science (Harlan, 2014). If the United States is to be a global economic presence our students must graduate from high school as not only college ready, but STEM ready as described in the Next Generation Science Standards (Achieve, Inc., 2014): "The nation's capacity to innovate for economic growth, and the ability of American workers to thrive in the global economy depend on a broad foundation of math and science learning, as do our hopes for preserving a vibrant democracy and the promise of social mobility for young people that lie at the heart of the American dream." (Carnegie).

The demonstrated need for an increased STEM workforce requires that the American education system must graduate students who are STEM proficient. In order to complete this task, educators must first evaluate the capacity of high school graduates to successfully complete post-secondary STEM programs. In other words, America needs to closely examine STEM readiness.

In recent years a significant educational emphasis has been placed on graduating high school students who are "college ready" as defined by ACT scores. Each year ACT issues its *The Condition of College & Career Readiness* report which includes benchmark scores that correlate with readiness to enter a 100 level college course with a 75% chance of scoring a "C" or higher (ACT, Inc. 2014). The measurements for this definition of college readiness generally discussed are an English score of 18 and a math score of 22. However, also included in these annual reports are a science score of 23 and a reading score of

21, indicating preparation to successfully complete introductory laboratory science and social science courses. In *The Condition of College and Career Readiness National* (2014) ACT, Inc. indicates that currently 26% of students nationwide leave high school ready for college in all 4 areas; sadly, 31% leave high school meeting none of the four benchmark scores. Thus, more students leave American high schools unready for any college core course than leave ready in all four subject areas. English and reading scores are highest with 64% and 44% of students prepared, respectively. Science scores lowest with just 37% readiness to math's 43% (ACT, Inc. 2014). Clearly, American students do not leave high school STEM ready.

Illinois Educational Trends

In Illinois, 100% of students complete the ACT exam, as a mandated part of school-based standardized testing, allowing this to be a strong data point for educational analysis (ACT, Inc. 2014). Illinois students score just below the national averages with 62% English, 41% reading, 41% math, and 35% science readiness scores. Currently, only 26% of high school graduates in Illinois are ready for all subjects, in contrast with the 81% of students who aspired to a postsecondary education. When scores are filtered for students indicating an interest in a STEM major, Illinois student readiness rates increase to 72% English, 50% reading, 53% math, and 46% science with 36% ready in all four subjects. Students interested in future STEM study and careers select different courses and prepare differently for the future than their classmates.

In Illinois, English/Language Arts is taught in double blocks of study throughout many elementary and junior high schools and is required for all 4 years of high school. Given that amount of emphasis and preparation, it is not surprising that English leads the college readiness content areas as reported by ACT with 62% (2014) of Illinois students reaching the college ready benchmark. Conversely, elementary schools often minimalize science as ELA and other subjects take priority forcing science to relinquish minutes from its allotted time block. Many elementary schools are even forced to rotate between science and social studies cutting down instructional time even further. Similarly, junior high school and/or middle school science courses provide no laboratory time and thereby leave these students without hands-on science learning opportunities.

Illinois graduation requirements for math and science increased only recently, but still fall below the levels recommended by college admission departments. The science requirement increased from one year to two years for students entering high school in 2007, but does not require a lab component (ISBE). It should not be surprising given the time and lack of emphasis on science education that only 35% of ACT test takers are considered college ready in science. Although Illinois recently increased the math requirement to 3 years, Algebra II is not required as part of this increase (ISBE). The Southern Regional Education Board (n.d.) indicates that both ACT and High Schools That Work recommend Algebra II and 3 years of lab-based science as minimum requirements for a rigorous high school education. Four years of math and 3 years of lab science are recommended by most colleges for admission. Also lacking from required Illinois curricula are computer science or technology education requirements. According to MacNeill (2014), "the best way to prep for an undergraduate degree in computer science is to cultivate knowledge and skills in mathematics and laboratory science." An argument can be made for increasing both the type and rigor of coursework required for graduation in mathematics, laboratory science, and computer science if Illinois students are to leave high school STEM ready.

Rapid Change

Over the past twenty years technology has reorganized how we live, how we communicate and how we learn—and educational leaders have embraced the idea that science is pertinent in all aspects of life; classroom educators have grasped how differentiated instruction and how various students process information; and we have become keenly aware how today's students have access to more information than those of previous generations. Simply put, knowledge is no longer contained in dusty encyclopedias or confined to the brains of the erudite.

Gonzalez (2004) explained, "One of the most persuasive factors is the shrinking half-life of knowledge. The 'half-life of knowledge' is the time span from when knowledge is gained to when it becomes obsolete. Half of what is known today was not known 10 years ago. The amount of knowledge in the world has doubled in the past 10 years and is doubling every 18 months." As a result, education must change both in methods of delivery of content and in cultivating skills in learners that will allow them to keep pace with a world that is constantly changing.

P21 Framework

The Partnership for 21st Century Skills (2009) was formed for the purposes of bringing together the business community, education leaders and policymakers to create a comprehensive set of skills that, along with content mastery, are what all sectors can agree are needed for student success. The P21 Framework (*Partnership*, 2009) "describes the skills, knowledge and expertise students must master to succeed in work and life; it is a blend of content knowledge, specific skills, expertise and literacies." P21 divides student outcomes into four areas:

1. Core subjects and 21st Century themes.
2. Life and career skills.
3. Learning and innovation skills.
4. Information, media and technology skills.

   The research and recommendations from the Partnership for 21st Century Skills strongly indicate that students need more than general content knowledge to succeed in today's global economy.

It is unlikely that the mandated increase of instructional hours for STEM content will occur in the near future. However, awareness that there is a need to exceed standard and transcend traditional grade level topics and concepts is currently at the forefront of education as evidenced by the ACT reports and the P21 Framework. The need for students who are STEM ready exacerbates the need for the introduction of a national set of science standards utilizing best practices for science education. According to *Assessing the Role of K-12 Academic Standards in States* (2015), the National Research Council claims that American students are educated under 51 different sets of state standards (50 states and District of Columbia). States predominately use either the National Science Education Standards from the National Research Council (NRC) established in 1996 and/or Benchmarks for Science Literacy from the American Association for the Advancement of Science (AAAS) published in

1993 as the basis for these differing standards. Both sets of standards are now more than 15 years old providing an opportunity for an updated and unified look at science standards in America.

Next Generation Science Standards for Today's Students and Tomorrow's Workforce

In order to address the need for well-prepared STEM students, Achieve, Inc designed the Next Generation Science Standards (NGSS) reflecting findings from the National Research Council with input from the National Science Teachers Association and the American Association for the Advancement of Science and with support from the Carnegie Corporation of New York (2013). These standards are based on research regarding both the nature of science and how students learn about science coupled with changes in the availability of knowledge and extensive research into 21st Century Skills necessary for success in the current and future world. The NGSS is designed to promote richness in both content and practice. In addition, the standards are coherent across disciplines and grade levels. These standards offer students an internationally benchmarked science education which will prepare them for college and introduce them to the wide world of STEM.

Literature Review

The need for a change in science education is evident. The solutions, such as NGSS and others, that are being put forth nationally and at the state level align with the educational research about best practice science teaching and learning, student motivation and best practices for teacher development.

Best Practices in Teaching and Learning

Using inquiry based methods to engage and teach science to students is grounded in educational theory as well as is "congruent with how we think people learn." (Capps & Crawford, 2013) "Inquiry based instruction resembles scientific inquiry by engaging students in instruction that parallels the work of scientists." (Capps & Crawford, 2013) Inquiry based teaching looks different than traditional teaching; it can look messy and take more time then direct methods. In the inquiry classroom the teacher role is a facilitator, helping guide students as they engage in the learning process (Anderson, 2002). The students in an inquiry based classroom are processing information, interpreting data, collaborating with others and sharing their interpretations anideas that are based on their own experiences (Anderson, 2002).

Student Engagement and Motivation

In an inquiry based classroom, students gain more ownership over their own learning, they become more engaged and intrinsically motivated to learn. Motivation is a driving factor in student engagement. Often we look at external factors to motivate students, such as grades or awards. However, we know that when students are intrinsically motivated they gain better understanding and make better connections (Herman, 2012). Daniels articulated that motivation in school can be fostered in a learning environment where students have 1) autonomy or some control over their own learning process, 2) relatedness to the content, where the learning links to real world connections, and 3) competences, when faced with rigor students have the confidence and ability to do the work (2010). All three of these factors are hallmarks of inquiry based teaching.

As students find their own motivation in an inquiry based classroom the their attitudes will change. Research by Sinatra & Pintrich demonstrates that student motivation can be a key driver in student academic success and their ability to make connections between content and experience (2003). Creating a learning experience that the students can be active and engaged in also promotes motivation (Wigfield & Eccles, 2002).

A key feature in inquiry based teaching is that it is active. Students learn best in certain classroom conditions; these conditions are active environments where students are not passive learners, but generators of information. Active learning produces results in student achievement. Through longitudinal study one sees that students who had the opportunity to perform their own science experiments, instead of reading about them or watching demonstration, learned more (Burkam, Lee, & Smerdon, 1997). Nadleson et al, articulated the need for students to also have authentic learning experiences that are grounded in inquiry (2013). Authentic inquiry based learning takes more time then traditional teaching, as students grapple with ideas collaboratively and generate potential solutions. Knowing that it takes more time, it is of concern that in most elementary classrooms time for science is actually declining (McMurrer, 2008). Understanding the factors in this decline is imperative to change the trajectory of science engagement at the elementary school level (Nadelson et al, 2013)

Teacher Preparation and Development

Ensuring that students have access to the types of learning they need to meet the standards of NGSS is key. Most teachers are not prepared with the tools to teach in this way and most school structures are not conducive to non-traditional teaching methods. NGSS is best met with inquiry-based instruction which is "a complex mixture of skills, knowledge, and creativity and can be challenging to implement" (Nadelson et al, 2013). Teachers as facilitators of learning have to manage the diversity of student paths as they may vary in their learning processes. Science inquiry requires "scaffolding students in framing questions, grappling with data, creating explanations, and critiquing explanations....prospective teachers need to understand and practice these strategies, before they can feel an honest confidence in their ability to carry out this kind of reform based instruction." (Crawford, 2007) Teacher professional development needs to have components that mimic these practices and promote growth in the teacher. As learners, teachers need time to understand their content and practice in order to hone their craft. In addition, they need support and resources as they go through this learning process. The ability for a teacher to teach science is grounded in their understanding of the content as well as their personal beliefs about science (Crawford, 2007). Development of teachers, both in-service and pre-service, will need to change to allow for new ideas and innovations in the classroom. Teachers of NGSS and inquiry need to be prepared or professionally developed to create those conditions where students can explore. IMSA suggests that schools model practices of other specialized STEM schools as a means of developing teacher expertise in these inquiry based methods (Kolar & Sondel, 2010)

IMSA Fusion Program

The Illinois Mathematics and Science Academy (IMSA) was established by the Illinois General Assembly in 1985 to "provide excellence in mathematics and science education" (105 ILCS 305). Nobel Laureate Dr. Leon M. Lederman and Governor James R. Thompson led the effort to create the institution. IMSA houses a top selective enrollment residential high school serving Illinois students and a field services team formed to "stimulate further excellence for all Illinois schools in mathematics and science"

(105 ILCS 305). Over the past 28 years, IMSA as a teaching and learning laboratory has gathered evidence of the conditions that promote STEM learning. IMSA combined this information with external research on habits and practices yielding two main findings, echoed years later by the National Research Council (2007):

1. Students learn science by actively engaging in the practices of science.
2. A range of instructional approaches is necessary as part of a full development of science proficiency.

   Such reports by the National Research Council informed IMSA's program design for elementary and junior high students to become better prepared for rigorous secondary STEM coursework.

With the support of the Illinois General Assembly, IMSA Fusion was created in 2000 to address the need for a rigorous hands-on, minds-on program for pre-secondary students. It began with 7 off-campus sites and has grown to 165 programs in 110 partner schools throughout Illinois. It is recognized among the top programs in the nation by Change the Equation, a corporate-led initiative, to identify and expand effective STEM teaching and learning to best prepare for a powerful and diverse STEM pipeline for the global future. It is also recognized as one of the top K-12 STEM programs in America by the Bayer Corporation.

Illinois schools in under-resourced communities are identified as potential "Fusion school partners." These communities are rural and urban and have large populations of low income families and in some cases tend to have large numbers of minority students who are historically underrepresented in STEM fields or are rural schools with little access to STEM activities. IMSA Fusion provides access for these students to quality STEM enrichment.

Teacher Professional Development

The school-based enrichment program is offered either as an after school program or as an embedded program during the school day. These two models allow schools to adopt the program implementation to best suit their school's needs, for example a school may offer it to students in grades 4-8 in single or multi-grade groups. Each program selects two teachers who each receive 40 hours of professional development from IMSA Fusion teacher professional developers; that is, 40 hours of STEM professional development per school year per teacher -with additional support that ensures each teacher can develop as an IMSA Fusion facilitator. This includes pedagogical training that focuses on facilitating inquiry-based, student-centered activities that create conditions for students to grapple with real world problems.

Each educator is also immersed in two different curricula areas annually that extend beyond traditional classroom content. By providing teachers with designed activities and a kit containing all of the materials they need to facilitate learning with their students, IMSA Fusion creates the conditions for these educators to guide students through these content-deep, rigorous and fun hands-on STEM learning opportunities.

Additionally, the goals for Fusion teacher professional development include the enhancement of the knowledge and skills of current educators in science, mathematics and technology. Teachers gain valuable content and pedagogical knowledge as they practice the skills developed during professional development sessions while teaching the activities specifically designed to advance these skills to their students. Included are:

1. Writing reflections about their own teaching and their students learning throughout the year.
2. IMSA Fusion team members observing every participating teacher as they facilitate lessons providing concrete feedback for continued improvement.
3. Administrators observing teachers in their traditional classrooms and providing insight about the changes they recognize occurring because of the Fusion training.

The 2013-14 IMSA Fusion evaluation was conducted by the Center for Evaluation & Education Policy (CEEP) at Indiana University and reported impressive results: over 90% of IMSA Fusion principals felt that this IMSA program enhanced their teachers' regular classroom instruction.

Curriculum

IMSA develops the STEM enrichment curriculum for Fusion specifically to address two central findings: 1) curricular topics are experiential and 2) they are delivered through a range of instructional approaches. All learning experiences are driven by the four attributes of IMSA's Core Competency: competency-driven, inquiry-based, problem-centered, and integrative. These attributes serve as design principles for the development, implementation and assessment of all IMSA curricula. As this curriculum is presented in Illinois public schools, it is aligned to the appropriate standards, currently Common Core State Standards (CCSS) and NGSS. While exploring STEM content, students learn to be innovative and entrepreneurial by using 21st Century Skills, such as collaboration, critical thinking, communication and problem-solving. Students work in groups to explore solutions to problems by using creative, analytical and critical thinking skills.

Student Engagement

Another valuable curricular feature is the highly integrative nature of the Fusion program. Unlike the typical science class, students work across disciplines in each activity. Students examine the history of a concept, conduct the experiment, graph the result and communicate the discovery. In each curricular unit, students work through the engineering design cycle and are intentionally taught that failure and frustration are ingredients in the formula for success. It is vital that student activities mirror real world experiences integrating multiple areas of knowledge and skills, allowing students to advance evaluation and modification skills as they work through iterations of various projects.

IMSA Fusion goes beyond the classroom content by providing students the opportunity for hands-on, minds-on learning in real-world STEM fields in Illinois. We need to develop these students if we are to support and sustain Illinois' STEM workforce. In response, STEM career fields are researched in order to extrapolate interesting areas of study that will teach math and science practice standards andem allow students to develop habits of mind, which ultimately allow them to learn various contents in richer, more meaningful ways. Fusion exposes students who are interested and motivated in STEM to the large variety of careers available within various STEM fields, introducing them to interesting options and identifying pathways for study through secondary and postsecondary schooling.

Lessons Learned and NGSS

Over the past 15 years, the implementation and evaluation of the IMSA Fusion program has provided lessons that support the need for and success of science standards epitomized by the Next Generation Science Standards. Expanding on the original two Fusion best practices—1) curricula topics are experiential and 2) delivered through a range of instructional approaches—Fusion has evolved and embedded four foundational attributes throughout the program that enable student STEM success. All students need:

1. To understand and use scientific explanations.
2. To conduct experiments and gather evidence.
3. Time to struggle, reflect and connect lessons learned with teachers facilitating learning through varied instructional strategies.
4. To share science.

NGSS is organized into three dimensions: 1) practices, 2) crosscutting concepts and 3) disciplinary core ideas. For the purpose of this article, we focused our alignment between the four foundational Fusion beliefs and the NGSS practices dimension. Next we illustrate these connections by sharing one activity created as part of our Synthetic Biology curriculum (see Case Study I).

IMSA collaborated with the BioBuilder Education Foundation team of scientists and educators from MIT to identify appropriate content and practices for 4th and 5th grade students. Using this information, IMSA developed a curriculum that exemplifies our four attributes and aligns to the eight practices of NGSS.

Fusion Belief 1. <u>Students need to understand and use scientific explanations</u>. This is not the memorization of facts, but is an understanding developed as students increase awareness of the way the world around them works through a scientific filter. Often younger students are given incomplete or incorrect information to answer their questions instead of being encouraged to investigate answers. IMSA Fusion introduces scientific content through inquiry-based teaching methods.

Case Study: Synthetic Biology Belief 1

Students need to understand and use scientific explanations.

In our Synthetic Biology example activity, 4^{th} and 5^{th} graders pop microwave popcorn recording observations at various intervals. They are then able to graph it and begin the analysis and interpretation processes. Next, students are introduced to the scientific explanations for phases of cell growth: lag, log and stationery. Actual cell growth data is given to students to compare to their data so they may look for any patterns. Throughout this entire time, students are encouraged to and taught how to ask questions: What occurred? Why did the pattern emerge? Will it remain unchanged?

Students take this knowledge regarding cell growth and transfer it to baker's yeast. They are responsible for engineering optimal growth given the materials available, identifying problems and adjusting procedures as they progress. Throughout this activity, students utilize NGSS practice number one: asking questions (science) and defining problems (engineering**)**. In order to be able to transfer knowledge and practice from one concept to another, students must learn the history of science and demonstrate proficiency with the principal laws, theories, and models of science. However, we believe that students learn deeper and can connect concepts more successfully when they construct their own meaning as part of the process.

Fusion Belief 2. <u>Students need to conduct experiments and gather evidence</u>**.** This belief encompasses NGSS practices two through five:

1. Developing and using models.
2. Planning and carrying out investigations.
3. Analyzing and interpreting data.
4. Using mathematics and computational thinking.

The importance of experiential learning for science cannot be emphasized enough. Watching demonstrations and videos and reading about previous experiments are not sufficient. Evidence is the foundation of STEM disciplines. The National Science Teachers Association (2004) declared, "In the process of learning the strategies of scientific inquiry, students learn to conduct an investigation and collect evidence from a variety of sources, develop an explanation from the data, and communicate and defend their conclusions." Building proficiency requires that students learn to generate and evaluate evidence in order to create and refine models and experiments. Students need guidance as they learn to narrow questions, decide what to measure to support the inquiry, and to design processes to collect appropriate measurements. They need to master mathematical and computational tools and systems as they collect and analyze data.

Case Study: Synthetic Biology Belief 2

Students need to conduct experiments and gather evidence.

Students in the 4th and 5th grades who experience the Synthetic Biology curriculum will collect, graph, analyze and interpret data on popcorn popping to find that it represents the lag, log, and stationary phases of growth of many microorganisms. They will then use this model to develop and test a protocol to study the growth of baker's yeast. Finally, they will have an opportunity to compare the data from the two different experiments. Both activities are economical and accessible, yet the process and results will lay the foundation for connecting to other concepts within the curriculum. These other ideas include proteins, programming, parts and standardization, lab techniques, and application of synthetic biology.

Fusion Belief 3. <u>Students need time to struggle, reflect, and connect lessons learned with teachers facilitating learning through varied instructional strategies</u>. Science learning is deep and builds upon other concepts—failures and successes. We believe that students need to be able to fail in order to learn. Completing only the successful experiments of others will not provide as deep of a learning experience as students will experience as they struggle to construct explanations and design solutions (NGSS practice 6). Most STEM advancements arose over time from multiple experiments that did not work, trying to explain why things did not work, and as a combination of input from multiple fields. In fast-paced classrooms with so many concepts to "cover," depth of learning can be sacrificed to speed of learning. Teachers need to facilitate lessons that are integrative (both within and among disciplines), tap into students prior learning, allow students to "fail," and include time for debriefing.

Case Study: Synthetic Biology Belief 3

Students need time to struggle, reflect, and connect lessons learned with teachers facilitating learning through varied instructional strategies.

To develop the Synthetic Biology activity, we understood that students tend to be more familiar with microwave popcorn than with Baker's yeast, which is why the experiences begin with popcorn; however, trying to construct an explanation of why it pops is more difficult. Providing open ended questioning and time for students to explore their ideas to develop their constructs about why it pops will help students gain an enduring understanding. Most students know little about yeast, their need for growth, and are unfamiliar with equipment used, so it is inherent that errors will occur that will result in less than favorable results. Experiments and solutions will need to be redesigned and retested to determine if optimal results have been achieved. Each time students are responsible for recording what they did, what the results were, analyzing and interpreting the data, and sharing these with their peers. Students are not penalized for failures and teachers use a variety of strategies to assist with student comprehension. In this model, teachers facilitate learning by asking open-ended questions, differentiating to students' abilities and experiences, and giving students time for the repetition of practices needed to reach mastery.

Fusion Belief 4. Students need to share science. Science is a community of learning made even more extensive by the upgrades in technology over recent years. Students need to be able to collaborate not only in lab work by sharing responsibilities, materials, and space, but also in sharing of data, questioning other students, and defending conclusions. This belief correlates to NGSS practices seven and eight: engaging in argument from evidence and obtaining, evaluating, and communicating information.

Case Study: Synthetic Biology Belief 4

Students need to share science.

As part of our sample activity, students are asked to defend what they believe are the optimal growing conditions for baker's yeast. Their defense is based on evidence they have gained throughout their repeated experimental design, redesign, and retesting, as well as looking at growth curves of other organisms online. The class engages in a lab meeting to share results. Many skills need to occur in order for this happen. From the beginning, students work together in pairs or small groups to gather and share materials and complete experiments. Stewardship continues in cleaning up after an activity is completed. Collaboration continues in discussions. Students learn to participate in sharing of their own ideas, learning to listen to others and learning to question others' evidence and ideas respectfully. These are all important facets of students learning to share science.

Conclusion

Evaluation

The Fusion program has been externally evaluated by a variety of professionals throughout the program's history enabling us to learn lessons and adjust our focus similarly to the way we teach students to prototype. Our 2013-2014 evaluation, conducted by the Center for Evaluation & Education Policy (CEEP) at Indiana University, indicates that the Fusion program has been successful with teachers (95%), principals (100%), parents (75%) and students (79%)—all reporting that students develop a deeper interest and understanding of math and science as a result of participation. Teachers also identified a variety of areas in which IMSA Fusion improves student learning, including student abilities to:

1. Identify problems to be solved.
2. Collect, organize, and analyze data.
3. Formulate solutions.
4. Communicate orally and in written form.
5. Work with their peers to achieve common goals.
6. Integrate mathematics and science content.

Using program evaluation, educational research and partner school feedback, IMSA evaluates the program's ability to improve student success and persistence in STEM and, when appropriate, adds new values to measure the program's impact in Illinois schools.

Discussion

Science is more than a body of knowledge that students must master to be deemed scientifically literate. It is also a process for learning which teaches students to utilize critical thinking while developing, testing, evaluating, revising, and sharing claims. According to the National Research Council, "When learning science, one must come to understand both the body of knowledge and the process by which it is established, extended, refined and revised" (2007). Scientists, engineers, and mathematicians use a wide array of methods to develop theories and models and to assess and refine their work. They utilize a variety of systematic methods to collect observations, measurements and data. However, all STEM domains are rooted in a reliance on utilization of data and evidence to evaluate claims and contribute to solutions. Teaching students to effectively create, collect, evaluate and share evidence should be at the root of STEM learning from the earliest possible age. The best STEM education is deep, meaningful, hands-on, minds-on, and student-centered with wrong turns, redesign, and solutions that best fit.

Based on years of experience in STEM education, IMSA believes that the current goal of science education needs to shift from a focus on content knowledge acquisition to students working in classrooms as scientists using practices that develop their understanding of the cross-cutting concepts of science and engineering. Since the program's implementation in 2001, Illinois teachers, administrators and parents have participated and IMSA has collected evidence of increasing levels of interest, persistence and success in STEM through our model of experiential learning. We support the adoption of the Next Generation Science Standards and encourage all educational leaders to embrace the full implementation of these standards and to emphasize the importance of STEM education in all of our schools in order to prepare fully students for college and the world of work.

The internationally recognized Illinois Mathematics and Science Academy® (IMSA) develops creative, ethical leaders in science, technology, engineering and mathematics. As a teaching and learning laboratory created by the State of Illinois, IMSA enrolls academically talented Illinois students (grades 10-12) in its advanced, residential college preparatory program, and it serves thousands of educators and students in Illinois and beyond through innovative instructional programs that foster imagination and inquiry. IMSA also advances education through research, groundbreaking ventures and strategic partnerships. www.imsa.edu.

References

ACT, Inc. (2014). The condition of college and career readiness 2014 National. Retrieved from http://www.act.org/research/policymakers/cccr14/pdf/CCCR14-NationalReadinessRpt.pdf

American Association for the Advancement of Science. (1993). *Benchmarks for Science Literacy*. Cary, North Carolina. Oxford University Press.

Anderson, R. D. (2002). Reforming science teaching: What research says about inquiry. *Journal of Science Teacher Education*, 13(1), 1–12.

Burkam, D. T., Lee, V. E., & Smerdon, B. A. (1997). Gender and science learning early in high school: Subject matter and laboratory experiences. *American Educational Research Journal*, *34*(2), 297–331.

Capps, D. K., & Crawford, B. A. (2013). Inquiry-Based Professional Development: What does it take to support teachers in learning about inquiry and nature of science? *International Journal of Science Education*, *35*(12), 1947–1978.

Carnegie Corporation of New York-Institute for Advanced Study Commission on Mathematics and Science Education. (2009). "The Opportunity Equation Transforming Mathematics and Science Education for Citizenship and the Global Economy."

Crawford, B. A. (2007). Learning to teach science as inquiry in the rough and tumble of practice. *Journal of Research in Science Teaching*, 44(4), 613–642.

Daniels, E. (2010). Creating motivating learning environments: What we can learn from researchers and students. *English Journal*, 25–29.

Dixon, F., & Moon, S. (2014). Guiding for science expertise. In *The Handbook of Secondary Gifted Education* (2nd ed.). Waco, Texas: Prufrock Press.

Gonzalez, C. (2004). Benchmarks online. The role of blended learning in the world of technology. Retrieved from http://www.unt.edu/benchmarks/archives/2004/september04/eis.htm

Harlan, Joe. (2014). Aspirin, Aspirations and The ABCs: Why America Needs More STEM Workers. Vital Speeches Of The Day. Retrieved from http://www.dow.com/company/insights/multimedia/20140310.htm

Herman, G. L. (2012). Designing contributing student pedagogies to promote students' intrinsic motivation to learn. *Computer Science Education*, 22(4), 369–388.

Illinois Mathematics and Science Academy Law. 105 ILCS 305. Retrieved from http://www.ilga.gov/legislation/ilcs/ilcs3.asp?ActID=1030&ChapterID=17

Illinois State Board of Education (ISBE), State Graduation Requirements, November 2012.

Kolar, C., & Sondel, H. (2010). Existing specialty schools as leverage for behavioral sciences research on teaching and learning in STEM fields (White paper submitted to the National Science Foundation SBE: 2020 project on future research in the social, behavioral, and economic sciences.) http://www.nsf.gov/sbe/sbe_2020/submission_detail.cfm?upld_id=287McMurrer, J. (2008). Instructional time in elementary schools: A closer look at changes for specific subjects. *Washington, DC: Center on Education Policy*.

MaNeill, M. (n.d.) Computer science online. *Science before college*. Retrieved from http://www.computerscienceonline.org/cs-programs-before-college/

Nadelson, L. S., Callahan, J., Pyke, P., Hay, A., Dance, M., & Pfiester, J. (2013). Teacher STEM perception and preparation: Inquiry-based STEM professional development for elementary teachers. *The Journal of Educational Research*, *106*(2), 157–168.

National Research Council of the National Academies. (2007). *Taking science to school: Learning and teaching science in grades k-8*. Retrieved from http://www.nap.edu/openbook.php?record_id=11625

National Research Council of the National Academies. (2013). *Next generation science standards for today's students and tomorrow's workforce*. Retrieved from http://www.nextgenscience.org/

National Research Council of the National Academies (2015). *Assessing the role of K-12 academic standards in states*. Retrieved from http://www.nap.edu/openbook.php?record_id=12207

National Science Teachers Association. (2004). NSTA position statement. Retrieved from http://www.nsta.org/about/positions/inquiry.aspx

Partnership for 21st Century Skills. (2009). *P21 framework definitions*. Retrieved from http://www.p21.org/storage/documents/P21_Framework_Definitions.pdf

Sinatra, G. M., & Pintrich, P. R. (2003). The role of intentions in conceptual change learning. Retrieved from http://philpapers.org/rec/SINTRO-3

Southern Regional Education Board. (n.d.). High schools that work: An enhanced design to get all students to standards. Retrieved from http://www.isbe.net/career/pdf/enhanced_brochure.pdf

U.S. Department of Commerce Economics and Statistics Administration. (2011). *STEM: Good jobs now and for the future* (ESA Issue Brief #03-11). Washington, DC: U.S. Government Printing Office.

Wigfield, A., & Eccles, J. S. (2002). The development of competence beliefs, expectancies for success, and achievement values from childhood through adolescence. *Development of Achievement Motivation*, 91–120.