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# Preparing Students for Careers That Do Not Yet Exist

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## Setting

The Illinois Mathematics and Science Academy (IMSA), as a self-described "teaching and learning laboratory for imagination and inquiry," has a history of pursuing innovations closely aligned with the vision and framework of the National Science Education Standards. Innovations include both methods and materials for inquiry-based student instruction as well as for delivering professional development for pre-service and practicing teachers. Instructional innovations described include yearlong student inquiry and research projects (SIR), self-paced physics instruction, student-driven energy and engineering projects, instruction in innovation and entrepreneurialism, and a host of student-led outreach activities to "ignite and nurture creative, ethical, scientific minds of students throughout Illinois and beyond." Highlighted practices for improving the effectiveness of current STEM teachers as well as training and inspiring prospective STEM teachers included IMSA's Teacher Candidate Institutes, Golden Apple Scholars and signature programs of Problem-Based Learning and IMSA FUSION.

In addition to describing these successful innovations, this chapter contains specific results and a constellation of evidence for each program, which serve to demonstrate the efficacy of IMSA's efforts in four areas: (1) improving students' deep conceptual understanding of critical STEM concepts; (2) promoting students' advanced studies and pursuit of STEM careers, including becoming mathematics and science educators; (3) changing teacher practices; and (4) developing a culture in which students not only become advanced "power users" of scientific principles but retain a commitment to IMSA's mission of "advancing the human condition" long after they leave school. The chapter concludes with recommendations for organizations and institutions seeking to replicate these and similar practices as well as advancing and scaling these practices through generative networks and pioneering technologies.

## Context

The internationally recognized Illinois Mathematics and Science Academy was created by the State of Illinois in 1985 to provide a "uniquely challenging education" to Illinois' top math-

ematics and science students in grades 10–12. The Academy was also charged to serve as a "catalyst ... to transform mathematics and science education" throughout the state. IMSA currently enrolls 650 academically talented Illinois students in its advanced, residential college preparatory program, and every year it serves hundreds of educators and thousands of 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. While career preparation programs in schools emphasize traditional skills, career preparation at IMSA adheres to a far different philosophy, based on constructivist learning principles, a bold mission, and standards that go far beyond learning specific skills and leave students well prepared for the 21st century, including attainment of the competencies and skills outlined in the work of Zhao (2009) and Wagner (2010).

Now, some 25 years later, IMSA still prepares students for careers that do not yet exist. The Academy's mission, belief statements, and core competencies are the foundation on which students first acquire the habits of mind to construct the advanced knowledge and skills and fashion the mindset of expert learners that will enable them to succeed in careers that they may end up creating for themselves. While novice learners may be adept at acquiring information, IMSA's graduates have learned how to learn, generate new knowledge, be self-directed learners, ask and answer challenging questions, and both find and solve problems that impede the healthy development of the human condition.

## Ties to Standards and Reform Efforts

IMSA has historically listed its core competencies for teaching and learning as inquiry-based, problem-centered, integrative, and competency driven. While these competencies have been evident at IMSA for 25 years, along with an emphasis on collaborative learning practices in which students are required to engage in meaningful dialogue, group research, and healthy debate as they work in teams on assigned projects, weekly math assignments or generative performance assessments, they actually form much of the basis for the conceptual framework for the new science education standards: "The new framework specifies eight science and engineering practices that students should learn and use over the course of their schooling. Examples include asking questions and defining problems, analyzing and interpreting data, and engaging in arguments with evidence. The previous standards included practices in its model of 'inquiry-based learning,' but the new framework is more specific about the practices that students should learn and use" (NRC 2011).

As detailed in the next section, inquiry, modeling, and debate—the pillars of the new framework—are found in every IMSA science class and as such are exemplars for schools seeking to pursue the forthcoming standards. In fact, IMSA has long distinguished the importance of teaching *real* science as opposed to *school* science, as we believe that preparing students for STEM careers requires experiential learning. Real science involves students thinking, collaborating, experimenting, and even failing. IMSA students develop an uncommon resilience as well as the ability to learn from mistakes, ask the challenging questions, and identify the critical resources in solving the most challenging problems. Students are not only prepared for careers, but they are prepared to create careers and to succeed in jobs that may not yet exist. This concept of pursuing real science is echoed in the language of the National Academies framework: "The framework

calls for a full integration of the practices of science with the ideas and concepts. That is, students should learn the ideas of science through actually doing science" (2011).

The chair of the committee that developed the standards framework, Dr. Helen Quinn, provides her own insight, as well as examples as to the importance of inquiry, debate, and modeling:

> Quinn's committee, comprised of university scientists and education scholars from across the country, said educators should deemphasize "discrete facts" and refocus on "a limited number of core ideas and crosscutting concepts." Every student should have a chance to work with the ideas, make connections and experience how science is actually done. For kids to really understand an idea, they have to work with that idea. So what you need to do is have fewer facts and more development of ideas," she said (Kenrick 2011).

In an interview with Glenda Chui (2011), Quinn elaborates on the importance of inquiry:

> The current national education standards push for science as inquiry... What the research on learning shows is that students learn better when they have a context in which to put those facts, where the facts are developed in a coherent fashion and where they get to understand what science is by engaging in scientific practices...
>
> For example engaging students seriously in arguing from evidence—so students are the ones drawing the conclusions and saying how does this evidence support or not support a particular explanation that was given for what's going on. Another one is using models ... teach kids how to think about a problem rather than learning a lot of Latin names for parts of the cell. How to think about cells and how they function is more important. When we just memorize things we have no real understanding of, all of us tend to forget them. (Chui 2011)

Additionally, IMSA's curriculum is not textbook-driven. Rather it is driven by a small set of Standards of Significant Learning that emphasize students attaining deep conceptual understanding of key concepts. To attain this deep understanding, students develop habits of mind in which they learn how to learn, make connections among big concepts and ideas, develop thoughtful questions, and engage in healthy debate. Again, the idea of pursuing a few core ideas and integrating ("cross-cutting") them is both aligned with and precursor for the new framework:

> We had a set of criteria for what constitutes a core idea for science learning. It's not just what are the core ideas of the discipline, but what are the core ideas of the discipline that are important for students to learn about in K–12? For example in physical science, the core ideas are matter and energy and forces and interactions; those are the ones everyone would expect. But then another one is waves and their relationship to information technology. That's for kids to understand that physics and chemistry have applications, and understand how these things play out in things they see in their everyday life (Chui 2011).

The National Academies report states, "One aspect of this coherence is the emphasis on deepening students' knowledge of core ideas systematically over multiple grade levels. Another aspect of coherence is the integration of a common set of practices and crosscutting concepts across the disciplines of science and across all of the grades" (2011).

## Major Features of the IMSA Program

### *Inquiry-Based Collaborative Student Instruction*

Arguably the best preparation for future careers is IMSA's instructional model. The core competencies of inquiry-based, problem-centered, integrative and competency driven teaching and learning are expected of all teachers and are a daily part of student instruction. Observations using the Power Walkthrough model and student surveys given at the end of every course have confirmed that these methods are both engaging and inspiring to the extent that they have shaped students aspirations, sparked their imagination, and taught them how to think critically and creatively.

Moreover, in most classes at IMSA students sit at tables with their peers and not in individual desks, because instruction is designed to engage students in meaningful, sustained collaboration with their classmates. Whether completing weekly "problem sets" in mathematics, preparing a presentation in a history class, or conducting a science experiment, students work in teams, and often their assessments are based both on their team's product and their individual contributions to it. Given that the ability to work in teams is frequently cited as a key 21st-century skill for career success (Partnership for 21st Century Skills 2003) this collaborative model assures students learn both the benefits and challenges of working in teams.

### *Student Research*

Student research is a cornerstone of IMSA, beginning with Methods of Scientific Inquiry (MSI) as an introductory course sophomore year and extending to Student Inquiry and Research (SIR) junior and senior year. Given that developing habits of mind is the most important aspect of career preparation, in MSI students design and conduct hands-on experiments, make observations, analyze data, draw conclusions, and communicate evidence-based principles. These scientific ways of thinking and knowing become the foundation for their IMSA experience. MSI is a one-semester course that is required of all IMSA sophomores. The course explicitly addresses three broad areas encompassed by the nature of science: data acquisition and analysis, experimental design, and written and oral communication. Activities support the development of basic skills across the science disciplines and promote an understanding of scientific inquiry and the nature of research. Student learning objectives include:

- To enhance student learning and understanding in the following areas: data acquisition and analysis, experimental design, and written and oral communication.
- To develop students' skills and levels of understanding and proficiency in the following Standards of Significant Learning (SSLs):
  - Construct meaningful questions that advance learning
  - Observe precisely and record accurately
  - Critically evaluate information and reasoning

- Find and explain connections among things and ideas
- Construct and support judgments based on evidence
- Write and speak with power, economy, and elegance
- Recognize the parts that make up complex wholes

Students develop the skills necessary to conduct an inquiry project through a variety of learning activities that deepen with time. These activities support the development of research skills, as well as demonstrate discipline-appropriate scientific thinking. After building appropriate inquiry and research skills, students work with a partner to define and conduct their own inquiry investigations and report the results of that investigation in the form of research papers, poster presentation, and oral presentation. Students work with their partner to complete the poster and oral presentations, but the final research paper is written individually.

The Student Inquiry and Research (SIR) program is IMSA's flagship program. No classes are held on Wednesdays so students can pursue a yearlong annual research project of their choosing with a mentor in the field. In SIR we partner with distinguished researchers; hundreds of students are bused to prominent laboratories, universities and museums to conduct investigations on diagnostics, nanotechnology, particle physics and more. Each August, approximately 85% of IMSA's juniors and seniors have identified their mentor and their project. The vast majority of this research is in the hard sciences, whether working on quarks at Fermilab, researching congenative heart disease in premature infants at the Loyola University Medical Center or advanced chemistry in the laboratories at the University of Chicago. Other students pursue studies in mathematics or in the social, behavioral or economic sciences and a few explore challenging issues in the arts. SIR is a graded experience, with students being assessed on their proposal, abstract, their research log, final paper and capstone presentation to a group of peers, staff and professionals. The reflections of graduating seniors indicate how much they value their experience. For example, in a letter to his State Senator seeking continued funding for IMSA, P. J. Patel wrote: "They challenge us to think like the scientists and develop knowledge based on understanding and not on memorization. All of my science classes were coupled with extensive laboratory experiences, which have allowed me to participate in real-world research at Northwestern's Feinberg School of Medicine."

These titles of projects the past three years indicate both the diversity and complexity of SIR projects as well as students' commitment to achieving IMSA's mission of "advancing the human condition":

- Nanoparticle Silver-Applied Filters as Water Filtration Solutions
- Engineered NanoBio Conjugates for Brain Cancer Therapy
- BA-D1: A Novel Treatment for Type 2 Diabetes
- A Genome Wide Association Study of Carotid Artery Plaque
- A Western Legal Shift to Incorporate Indigenous Intellectual Knowledge
- Mass Incarceration and Its Effects in Society
- An Analysis of the Patient Protection and Affordable Care Act and Its Effect on Physician Compensation and Health Insurance Companies

- Design of Genetic Sequences Encoding a Matrix Metalloproteinase-2-Degradable Synthetic Recombinant Protein
- Density Functional Theory Study of the Influence of VOx Promotion on the Mechanism of Alcohol Synthesis on Rhodium Catalysts
- The Effect of *Egr2* on the Cell Markers Lag3, 41BB, and CRTAM in the Anergic carEGR2 flox/flox TH1 T-cell Clone

In keeping with the theme of preparing students for careers that do not yet exist, six IMSA students recently completed two yearlong SIR projects working with students in China and researchers at the Chinese Academy of Sciences, Beijing University of Astronautics and Aeronautics, and Peking University. One group pursued converting the grass *Miscanthus* to butanol and another explored the design of wind turbines for "gentle breeze" environments. Students met via videoconference every three or four weeks to share data, discuss findings, test prototypes, and the like. During the course of this international collaborative research they connected frequently outside the videoconferences and were not only successful in producing a final project but also in developing close cross-cultural relationships, another of Zhao's (2009) 21st-century skills. Given that global problems will require global solutions, these students are well positioned to become leaders in international research careers.

## *Self-Paced Physics*

A faculty research project designed to identify why female students were far less likely to pursue electives than their male peers led to the development of an innovative introductory physics course. While the first year of Self-Paced Physics is just completed and no evidence is yet available of girls' persistence in physics, student survey results indicated that the self-paced experience was positive in terms of both student achievement and motivation for further study.

## *TALENT*

Total Applied Learning for Entrepreneurs (TALENT) focuses on student entrepreneurship in a STEM context. It is truly career preparation for entrepreneurs and innovators. The program engages students in activities that include, but are not limited to, understanding intellectual property, developing a business plan, developing products, securing funding, networking, communicating ideas, and starting a business. Taught in an evening seminar format, instructors engage students not only in developing their ideas but also in interacting with successful entrepreneurs in an array of businesses from high tech to meal preparation. One of TALENT's highlights is its Power Pitch Contest where IMSA student entrepreneurs pitch their new business ideas to venture capital investors and entrepreneurial leaders. One of the judges, John Hoesley, a highly successful entrepreneur and IMSA alumnus noted, "The ability to clearly communicate the value of your product or service and its growth potential in its early stage of development is critical to venture capital funding or seed funding. This real-world experience for IMSA student entrepreneurs gives them a head start in understanding the competitive marketplace and in preparing answers to vital questions before they seek funding."

## *Applied Engineering and the IMSA Energy Center*

Students who do not participate in SIR projects often opt to pursue the Wednesday Applied Engineering seminars and laboratories. Working in small groups, students explore branches of engineering and learn about the highly diverse opportunities within the field. They will learn to analyze given problems and through teamwork arrive at a solution. A requirement for completion is to design and build various functioning objects, ideally that will improve the quality of life. The innovative ideas and prototypes are again evidence of preparation for nonstandard and as yet nonexistent careers as well as for traditional engineering.

During past years many of the Applied Engineering projects have been in the field of energy and integrated with the IMSA Energy Center. Given the proliferation of careers in energy coupled with students' natural concerns for the environment, IMSA's mission and core belief that "we are all students of our planet," students and staff launched the Energy Center three years ago. Students authored both its powerful mission, "a collaborative pioneering endeavor to spark innovative student inquiry focused on sustainable energy sources, usage and policy," and its compelling vision, "to promote the conservation of global resources and the implementation of energy alternatives based on innovative and collaborative research within the IMSA community and beyond." To integrate the teaching of science, technology, engineering and mathematics, the IMSA Energy Center draws on students' natural concern for their environment and desire to advance the human condition. Students join engineering and research teams to work on energy issues of their own interests. Each team selects leaders and assigns roles to team members. Students learn academic science content as they encounter the need to solve problems for their respective teams. This educational process is fluid. Students are able to share their ideas by forming new teams or joining existing teams at almost any point during the school year. The energy center has specific goals, each with set of activities and deliverables. The goals are:

- Research, construct, and produce alternative energy sources and demonstrations;
- Create community awareness about energy sources, usage, and policy and the Energy Center's goals, projects, and demonstrations;
- Serve as an educational resource to school systems throughout Illinois and beyond;
- Build collaborative relationships with organizations in the private and public sectors to combine resources that lead to new bodies of knowledge, programs, and services; and
- Secure financial partners to seed and launch projects and prototypes.

## *Preparing Future Teachers: IMSA Allies*

While the majority of IMSA students pursue STEM careers, IMSA realizes that some of its best teachers are its current students. While some high schools may still have Future Teacher Clubs or classes that involve students in observing teachers, IMSA's Kids Institute and Allies programs actually enlist and prepare high school age students to teach younger students important STEM lessons. IMSA Allies are students who work as teachers and group leaders for all Kids Institute programs throughout the year. Kids Institute's design is to have kids teaching kids. The first "Kids" being IMSA students and the second being the outside students in summer camps, Saturday FUNshops, and school assemblies. On Wednesdays, Allies meet to learn about teaching pedagogy and strate-

gies about how to work with a diverse population of students. They learn how to introduce STEM concepts through demonstrations and activities and after this first quarter have the opportunity to teach or lead groups of middle school students who visit IMSA. Allies also assist in writing the curriculum for FUNshops, summer curriculum, assemblies, and field trips.

Allies first spend time observing experienced teachers and group leaders. They next work as assistant teachers or co-group leaders in order to work side-by-side with experienced Allies. After the Allies and Kids Institute staff are comfortable that the students can take charge of his or her own classroom or group, they "graduate" to experienced teachers or experienced group leaders. Allies teachers are responsible for facilitating the inquiry-based, hands-on learning experience and to guide the students in their learning process. In other words, they are expected to teach the IMSA way, the way they are taught. IMSA graduates who go on to become teachers have returned to IMSA to share both their successes and frustrations. While being well prepared to become inquiry-based teachers, they have also confronted the hard reality that many schools are not open to these approaches. By and large, however, the resilience and persistence they have acquired through their IMSA experience has sustained them in their careers as they continue to be the leaders in forging a transformative model of teaching.

### *Leadership and Ethics*

While the phrase "career and college readiness" generally brings to mind the idea of skill development, two of the most important and generally neglected career preparation skills, leadership and ethics, are required monthly seminars at IMSA.

LEAD, IMSA's innovative, student-run leadership program, inspires its sophomore students through open classroom discussion, engaging and meaningful activities, real-life applications, and personal reflection to strive to become positive, ethical leaders who pursue their passions and use their individual capability to create the change they want to see in the world. IMSA believes that every student has the potential to lead and that leadership can be learned. Thus, this series of seminars is designed to take an intricate look at definitions, theories, models, and conceptualizations of leadership. Students will be challenged to think critically about leadership during peer-to-peer facilitated lectures, class discussions, hands-on exercises, and group work. Students are provided with a foundation of leadership, which includes topics such as understanding self, social justice/group dynamics, communication, and conflict resolution/negotiation.

Considerations in Ethics introduces IMSA juniors to the very real, yet often rejected notion of ethics as a field of philosophical study. At monthly seminars students are introduced to the ethical systems of philosophers including Aristotle, Kant, Confucius, Bentham, Hobbes, Rawls, and others. Following the presentations, juniors engage in activity-based breakout sessions led by senior facilitators. In addition, two presentations are given by speakers from various fields, including medicine, politics, advanced technology, pharmaceutical research, and law, so students learn that ethics are integral to career success and best learned early on.

## Professional Development

When IMSA was founded in 1985, part of its legislative charge was to serve as a catalyst for transforming mathematics and science education. IMSA fulfills this charge by not only deliv-

ering professional development and coaching in teaching the IMSA way so other teachers can prepare their students for 21st-century careers but also helping them grow and succeed in their careers. While IMSA has a host of opportunities for teachers at all levels of their career, from preservice to veteran, three programs have proven to be the most effective in changing teaching behaviors and in impacting student learning: Problem-Based Learning (PBL) Network, IMSA FUSION, and Teacher Candidate Institutes (TCI).

## *PBL Network*

Problem-based learning is focused experiential learning organized around the investigation and resolution of messy, real-world problems. PBL engages students as stakeholders immersed in an ill-structured, problematic situation and organizes curriculum around this holistic problem, enabling student learning in relevant and connected ways. PBL creates a learning environment in which teachers coach student thinking and guide student inquiry, facilitating learning toward deeper levels of understanding while entering the inquiry as a co-investigator.

To prepare teachers in the art and science of the collaborative inquiry of Problem Based Learning, IMSA has created a series of institutes for individuals, teams, schools, and districts. Teachers learn how to teach content as well as learning skills essential for students to thrive in the 21st century and developed criteria to gauge progress in those skills as identified by the North Central Regional Educational Laboratory and the Metiri Group (2003). These skills fall into four groups: (1) digital age literacy, (2) inventive thinking, (3) effective communication, and (4) high productivity. Specific skills include global awareness and multicultural literacy; self-direction, risk-taking and managing complexity; teaming and collaboration; and the ability to produce relevant, high-quality products.

## *IMSA FUSION*

IMSA FUSION offers exciting, hands-on, minds-on STEM activities for 20–30 talented students in grades 5–8 who attend weekly program sessions at their school, taught by teachers in their school who were prepared by IMSA staff. In fact, the professional development of teachers is the primary focus of IMSA FUSION. Teacher workshops provide rich content background, quality curricular materials and lab kits, and extensive training and practice in inquiry-based instruction. FUSION employs IMSA's recognized core competency of developing and delivering curricular materials and teaching approaches that are competency-driven, problem-centered, inquiry-based, and integrative. The effect on teachers and their students is profound. Writes one of the FUSION teachers:

> I have seen students grow intellectually and become better thinkers over the past two years as a result of the FUSION program. FUSION students approach open inquiry with more success than students who are not in the FUSION program because they have more confidence in solving problems. FUSION has given me experience in inquiry-based teaching and learning which has carried over into my classroom teaching. I have used lessons from the FUSION program in my regular classroom. The program has increased the expectations of our students. FUSION has inspired me to pursue a Math and/or Science endorse-

ment. FUSION lessons have also given me ideas on how to incorporate math and science lessons together.

### *Teacher Candidate Institutes*

Teacher Candidate Institutes (TCIs) are two-week (8–10 day) programs designed to offer preservice education candidates an opportunity to encounter a wide range of instructional activities from planning and design to implementation and assessment in a mentored environment. The TCIs focus on STEM content and are meant to increase the comfort level and facility of teacher candidates in the critical areas noted above. The TCIs also introduce candidates to IMSA's constructivist approach to pedagogy, with an emphasis on inquiry, problem-centeredness, and integrated ways of teaching and learning. Ideally, the participating candidates have completed classroom observations, but have not yet done student teaching.

Teacher Candidate Institutes are divided into two distinct phases. The first, or training, phase, lasts three to five days, and is taught either by IMSA faculty and staff alone or in collaboration with faculty and staff from the partnering college or university. Candidates are introduced to IMSA's approach to mathematics and science teaching and learning through study and discussion of the core attributes of the competency-driven, problem centered, inquiry-based, integrative curriculum during a POP (Pedagogy, Orientation and Planning) workshop. They are then familiarized with the content to be delivered to the students with whom they will work. Content instruction is delivered for candidates in the same way it is for experienced teachers who are involved with IMSA's outreach programming. Candidates work through all activities that will be taught to the students during the second phase of the Institute, debriefing as they go. They conclude the IMSA-led section of the training phase by planning the rollout of the instructional unit with students. If time permits, they practice-teach to each other under the guidance of IMSA mentors.

## Evidence of Success

While most high schools measure success in terms of test scores, IMSA uses these as a secondary measure to an array of metrics including student awards, publications, and placement in national and international competitions; alumni's pursuit of STEM careers and contributions to "advancing the human condition;" and SIR projects. Also, given the Academy's legislative charge to serve teachers and students throughout Illinois, data are collected for PBL, IMSA FUSION and TCI Institutes.

### *Student Achievement*

While test scores are not IMSA's most important metric, the students excel on standardized tests. Data for a recent graduating class show the following mean scores:

- ACT Composite: 31.5 (national average = 21.1)
- SAT Reading: 666 (national average = 501)
- SAT Math: 721 (national average = 515)
- SAT Writing: 663 (national average = 493)

Also, although IMSA does not offer AP courses, 85% of students who tested last year scored 3 or higher on examinations. AP examinations were administered to 292 students. 125 students took the Calculus BC AP examination and had a mean score of 4.53 out of 5. Moreover approximately 25% regularly are named National Merit Finalists.

Students regularly place highly in state, national, and international competitions as individuals and as teams. For example, students are regularly selected as semifinalists for the Intel and Siemens competitions; in the last three years, three students have been on the U.S. Physics and Chemistry teams; and several students have published papers of their SIR projects in distinguished publications such as *The Astrophysical Journal Letters, The Journal of Physical Chemistry, Learning and Leading with Technology, Nature, Neuroscience Research Communications* and *The Science Teacher.* Within the last two years, IMSA's math team has won the state mathematics contest and Scholastic Bowl championship and a team of four has placed first in the International Mathematical Modeling Competition.

## *Alumni Longitudinal Study*

The Academy conducts regular surveys of graduates. Results show that more than 60% of IMSA's graduates pursue STEM careers. Several of these are high profile, as IMSA alumni were on the founding teams of PayPal and YouTube, lead authors in developing Microsoft Outlook and Explore, and literally the pioneers of the internet leading the development of Mosaic and Apache. Recently, two graduates were lauded for discovering new planets and exploring "waltzing black holes." All of these, and hundreds of others, are engaged in careers that did not exist when they entered IMSA their sophomore year and are a testament to the power and success of an inquiry-based education.

Quantitatively, 60% of IMSA graduates have earned degrees in STEM fields and are now scientists, doctors, engineers, researchers, teachers, and leaders in other fields. Approximately 25% of alumni are employed in technology, mathematics, and engineering; almost 20% in medicine and other sciences; and more than 10% in business and finance. IMSA alumni have founded more than 30 new companies and created countless jobs.

A current longitudinal study of STEM specialty schools (Subotnik, Tai, and Almarode 2011) examined survey data from IMSA graduates and gifted and talented students who did not attend IMSA. The results showed that students who had research experiences in high school (e.g., MSI), who undertook an apprenticed mentorship or internship (e.g., SIR), and whose teachers connected the content across different STEM courses were more likely to complete a STEM major than their peers who did not report these experiences.

## *Problem-Based Learning Network (PBL)*

Data from multiple sources, including independent observations and surveys conducted by external reviewers have provided affirmative evidence for the following:

- PBL has a positive impact on student learning.

- IMSA's PBL model develops metacognitive strategies in students. (Pierce and Gerdes 2005) on IMSA's PBL drive Summer Sleuths program shows a significant increase in metacognitive statements initiated by students.
- Participants' students show a positive change in content knowledge, attitude and/or behavior (critical thinking, self-directed learning, collaboration). The independent evaluation study (Oyer 2005) on Fox Valley PBL Initiative shows that student impact increases (20–40 percentage points) as teachers gain more experience in PBL strategies.
- IMSA's introductory PBL workshops/institutes are effective in increasing teachers' knowledge and skills of PBL as well as increasing PBL teacher strategies in their classrooms.
- Educators trained in PBL implement PBL strategies and skills as part of their regular classroom practice and report that it makes a positive difference in student learning (Oyer 2006).

## *IMSA FUSION*

In 10 years, IMSA FUSION has grown from a program serving 7 schools to more than 80 schools and in 2010–11, served over 200 teachers and 2,000 students. It was selected as one of the "Best Practice" K–12 STEM Education programs in the nation in September 2010, by the Bayer Corporation's Making Science Make Sense initiative for our proven track of helping girls and underrepresented minorities to participate and achieve in STEM. One reason this award was given is that IMSA FUSION is a data-driven and researched-based program that tracks program impact using the following tools:

1. Survey of Enacted Curriculum to measure teacher professional growth and impact
2. High School Transcript Study to measure long-term impact on students
3. Constituent Surveys to provide qualitative data of program impact
4. Site Performance Observations to measure program teaching and learning

Longitudinal program research demonstrates that the majority of FUSION alumni elect to take advanced coursework in math and science in high school and, in fact, attain above average grades in these courses. Data collected through the Survey of Enacted Curriculum show gains in FUSION teacher professional growth in the use of hands-on instructional strategies and approaches that develop student communication and demonstration of content understanding. In addition, teachers report that they are provided with the skills, support, and resources to use the best practices, inquiry-based, and real-world teaching that our students need to be 21st-century learners, bringing new, more effective instructional skills to their classrooms year after year. Program surveys taken by FUSION students, parents, teachers and principals indicate significantly strong perception of the benefits and value that FUSION brings to schools.

Data are tracked internally at the Illinois Mathematics and Science Academy as well, to show that IMSA FUSION has been a very significant pipeline for IMSA. Since 2005, 41 former FUSION students have graduated from IMSA. As of this past fall, 2010, more than 13% of the

current students in IMSA's residential high school program participated in FUSION in their middle schools.

IMSA FUSION also increases access to STEM programs for underrepresented minorities and low-income students. Over the past five years, a little less than 50% of the FUSION participants were Caucasian, approximately 25–30% African American, and less than 20% Hispanic. The rate of participation by Asian students has increased from 2% to 10%. In this coming school year, 64% of the students in our new partner schools are underrepresented minorities. In 2010, the rate of students eligible for free and reduced lunch averaged 55%. For 2011–12 the average rate of low-income students in FUSION schools will increase to 62%. Twenty-one FUSION schools will have low-income student populations at or above 75%.

Needless to say, there is an abundance of anecdotal and testimonial data, but this reflection captures the gist of these by describing the impact of FUSION: Last year, an IMSA FUSION Site Support Specialist, Sharon Poynter, from the Springfield area was recognized by a young woman who had participated in the IMSA FUSION program at Grant Middle School in Springfield as a sixth grader. She was a FUSION student for one full year before she moved away for her seventh- and eighth-grade years. This student told Sharon that being chosen for the IMSA program "was the turning point" in her life because she realized she was intelligent and talented and that being part of the FUSION program instilled confidence that she never had. She worked harder in school and earned a scholarship to a Chicago area math and science high school. Currently in college, this FUSION alumna wants to continue her studies and become an optometrist. She had been raised by her mom and grandmother, and "had no college plans before her one year in the IMSA program."

Quantitative data exist that show the impact of the program on students and teachers as evidenced in the table below:

**Table 9.1.** Impact of IMSA Programs on Students and Teachers

| Teacher-Reported Changes in Instructional Practice Due to Participation in IMSA FUSION | IMSA FUSION Graduates' Enrollment Patterns in Freshmen and Sophomore High School Mathematics and Science Courses |
|---|---|
| • *Competency-driven* (standards-influenced): 94% reported an increase in the application of math and science concepts.<br>• *Inquiry-based* (student-led): 100% reported an increase in use of open-ended, student-driven, high level questioning.<br>• *Integrative* (connected): 94% reported an increase in integrative learning experiences across disciplines.<br>• *Problem-centered* (real-world focused): 100% reported an increase in the use of real-world problems in the classroom. | • 74% take advanced mathematics courses<br>• 100% take advanced science courses*<br><br>*Preliminary results based on FUSION graduates in five Illinois high school districts. |

### *Teacher Candidate Institutes*

Survey and observational data are collected for participants in IMSA's Teacher Candidate Institutes to identify if the targeted outcomes were met. The most recent evaluation plan showed:

- The indicator that "67% of participating teachers will increase their knowledge of inquiry-based practices" was met, with participants already holding some knowledge about inquiry-based practices before the program.
- The indicator that "100% of participating teacher candidates will practice their lesson presentation in phase one" was met as through observations of the participants' teaching.
- The indicator "100% of participating teacher candidates will reflect on learning in written journals in the debrief session" was demonstrated in their daily reflections in the first and/or second week.
- The indicator that "75% of teacher candidates will demonstrate inquiry-based strategies in teaching student participants" was seen in an analysis of the observation forms.
- The indicator that "75% of teacher candidates will note the use of inquiry-based teaching strategies during daily reflections" was met.

The large body of evidence of IMSA's success has been noted as IMSA regularly places among Newsweek's "best high schools in America," despite the fact that IMSA does not offer standard Advanced Placement (AP) courses because they are not yet inquiry-based. (Merrefield and Streib 2011) Also, in 2009, the Intel Foundation recognized IMSA as the Star Innovator Award Winner, its top award in the Schools of Distinction competition.

## Conclusion

As "a teaching and learning laboratory for imagination and inquiry," IMSA has developed innovative programs, practices and services to prepare students for STEM careers and to train, coach, and support teachers in schools for preparing their students for future STEM careers. The "career preparation," is not traditional in just inculcating knowledge or teaching skills. Career preparation at IMSA is about teaching students to learn, to think, to collaborate, to challenge, to take risks, and to learn from failures. This basis of career preparation prepares them to be agile thinkers, ethical leaders, and individuals of vision, action, and commitment. The system has been effective, as IMSA has produced the visionary leaders who founded PayPal, YouTube, Netscape, and Yelp; astronomers recognized for discoveries; and medical doctors and researchers who have pioneered advances in their field.

While IMSA is in one sense a unique environment—a state-funded residential public school—but as a laboratory it is tops as a proving ground for best practices which can be replicated, with modifications, for an array of settings.

If we are educating tomorrow's students for today's careers, America will never retain its international leadership in innovation and invention, much less be able to thrive economically. Career preparation begins with identifying the mindset and habits of mind students will need to excel at careers that do not exist, to be ethical leaders, and to share mission and action that will advance the human condition.

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