Rebuilding Smart and Diverse Communities of Interest through STEAM Immersion Learning

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Abstract - **A STEAM-based approach to education is presented that encompasses science, technology, engineering, and math (STEM), with the addition of "the Arts" as a means of reversing continuing declines in science, math, and reading scores in U.S. secondary schools and to better prepare future STEAM scholars and professionals. This is despite the significant emphasis U.S. schools have placed on STEM curricula for nearly the past 20 years. The 2014 New York State Department of Labor report states, *the President's Council of Advisors on Science and Technology (PCAST) has indicated that the United States needs at least one million more STEM workers than is currently available*. The report also cites that 75 percent of students who graduate with a STEM-related degree do not take STEM jobs; however, the need for STEM careers is 2.5 times higher than other fields within New York State. A case study of Project Fibonacci® is presented whose approach is one of immersive learning that emphasizes math within a STEAM context, holding focused STEAM educational forums, and establishing *centers of excellence* in STEAM education. This may offer additional benefits beyond traditional STEM-only approaches. There is an upward trend towards STEAM-focused curricula driven by the decline in academic scores, which provides more challenges for our youth to compete in the global workforce; and recognizing that STEAM builds upon math as the interconnection between the science and art disciplines, thus expanding career opportunities and experience that ensure a well-rounded citizenry. We are rediscovering the need for balancing the cognitive and logical sides of the brain with the creative force to engender an agile, growth-driven nationwide community.**

Index Terms – STEAM, Immersion learning, problem-based learning, Project Fibonacci®, Communities of interest.

INTRODUCTION

Of paramount importance is the need to enhance our nation's student proficiencies in STEM skills and to address potential flaws behind current teaching methods. The basic tenets of an interdisciplinary learning methodology that was implemented to expand the STEM concept to include an "A" for the arts is defined below as a potential solution to this issue. This approach was a variation of a program design that pulled students and educators out of traditional classroom settings to accomplish the following:

- Connect them directly with industry experts;
- Take them into real-world contexts and work settings;
- Expose them to authentic pieces of artwork (sculptures, paintings, photographs, music, improvisation, etc.);
- Solve real-world problems (presented as final projects);
- Engage them in project-based learning.

Why would we want to expand STEM to include the arts? How does math fit into this paradigm shift? What benefits can we expect by redefining STEM in this way? In order to answer these questions, let us first consider at a high level the present state of STEM programs in the nation.

In recent years, billions of state and federal dollars have been provided to schools throughout the nation to improve STEM skills. However, overall student proficiencies continue to erode in the areas of the sciences, mathematics, reading, and writing. China and Japan continue to lead in STEM while the U.S. continues to underperform. President Obama has articulated a clear priority for STEM education: within a decade, American students must "move from the middle to the top of the pack in science and math".

Next, women make up more than 50 percent of the U.S. population, yet in the STEM fields they are under-represented. Based on statistics from Newsweek during the third quarter of 2015, they comprise only 30 percent of full professors, while 26 percent of college presidents are women [1]. Similarly, in medicine they comprise 35.5 percent of all physicians and surgeons and only 16 percent are medical school deans. The desired goal would be to achieve a closer parity between females and their male counterparts especially in STEM fields.

A 2015 Pew Research Center study [2] shows that the U.S. ranks 27th in science, 35th in math, and 17th in reading scores internationally. The 2015 PISA study found that American students were below the international average in math and about average in science and reading [3, 4]. The PISA is an international assessment that measures 15-year-old students' reading, mathematics, and science literacies every three years, according to the website of the National Center for Education Statistics.

It would appear that efforts to improve individual STEM skills have not provided the anticipated positive results. There is an inability of U.S. students to integrate and apply knowledge across the various STEM disciplines and their many sub-content areas. There needs to be a paradigm shift in the way STEM programs are implemented or delivered and how their success is realized.

How Can STEM Education Be More Effective?

Due to the advancements made in technology, the stage is set for a flourishing global society. Teachers and students need to be concerned with global competition. New teaching models are essential if students are to fill the jobs of the 21st Century and be competitive in a global economy. The mindset of continuing to use the same traditional teaching models in the STEM disciplines with minimal impact on student knowledge and application must change if the U.S. is going to lead globally. All U.S. students must have the necessary interdisciplinary skills that prepare them for today's global work environment and make them aware of how the application of the multi-faceted disciplines relates to the real world. New, meaningful life-long learning models must develop students' opportunities to acquire and apply knowledge outside the traditional classroom setting. The old model of passive learning is obsolete; teachers must use methods that incorporate the realistic skills needed to be competitive in a world economy.

Based on the continued atrophy of U.S. student's STEM proficiencies, it is evident that the present methods of instruction, disconnected from real life problems and applications, are the root of the stagnation in STEM education. The current method of teaching STEM in isolation and ignoring the relationship to other educational disciplines, has resulted in the inability for students to be front-runners in STEM aptitude and 'agility'. Any kind of a paradigm shift must overcome the pitfalls of test-driven, declarative knowledge-based, segregated, academic only/ workplace disassociated approaches. A shift to an interdisciplinary or integrated curriculum provides students opportunities for more relevant, less fragmented, and more stimulating learning experiences [5, p.186].

A key ingredient in establishing a commanding edge in education in a world economy is to put emphases on the professional development of teachers by "unleashing" them to explore diverse STEAM professional workplaces and settings. This must include learning prototypes that are grounded in real-world application and that help them to understand how these skills relate to 21st Century jobs. New instructional models must address the multi-faceted learning masteries needed to prepare students to be competitive and equipped to meet the challenges of a new labor force.

"Problem-based and project-based learning" are two models that should be offered to students. Problem-based learning presents the occasion for students to learn through hands-on experience and identify and offer solutions that necessitate the integration of knowledge to tackle real-world problems. This interaction improves motivation and engagement and helps the student to enhance self-confidence and retention of the subject matter. Guidance provided by teachers makes students aware of the importance of life-long learning skills.

Another important instructional strategy, a variant of the problem-based learning model, is "project-based learning." This is a teaching model that is goal-oriented, highly team-driven, applies various learning strategies, and allows students to gain knowledge beyond the traditional rote learning of the classroom. The strategies used in this model promote an active engagement of students through vigorous investigation of highly complex questions. Students learn to team build, develop critical skills, explore ideas, make mistakes, and innovate. Learning in teams approximates today's work environment in that it draws upon the strengths of individuals. It enables learning from one another, and provides opportunities for students who are not high achievers to become team leaders. The relevance of their studies emerges by employing such strategies. Through their projects students take ownership of their learning by taking active roles in questioning, thinking, creating, inventing, and drawing connections between their studies and the real world.

Serious consideration must be given to a new approach that bridges the gap in STEM. Math is an important enabler in STEM that helps learners connect to the arts domain and bridge the various STEM disciplines. There are studies that show a strong correlation between the arts and an increase in academic performance, decision-making, social responsibility, creativity and, cognitive development [6-9].

The National Academy of Engineering has stated that today's engineers need to be more than individuals who simply "like math and science". They must be "creative problem-solvers" who help "shape our future" by "improving our health, happiness, and safety" [10-11].

Math is more than working with numbers; it provides the foundation for art. Art and architecture use math to create illusions fooling the eye to see a surface take on movement and depth using shapes, perspective and color. Art applies math principles as seen in the beautiful architectural designs attained from the amazing pyramids of Giza, to our incredible sky-scrapers and to many other art forms such as Da Vinci's *Mona Lisa*. Additionally, musical rhythms are accomplished through time intervals of sounds based upon math that resonates with our own body rhythms. Math is an essential component to science and art with a strong connection to creativity.

In 2015, several Upstate New York educational, governmental, commercial, and non-profit institutions formed a coalition to launch an experimental, immersion-learning pilot program called Project Fibonacci® [12]. To test the benefits of incorporating the arts into STEM, a week-long STEAM event was held in 2016, designed to integrate various STEAM disciplines and active learning within an immersive learning context. That is, students (called STEAM "scholars") engaged in a week-long series of learning opportunities alongside local educators and community business members. Collectively, the week's events introduced scholars to the applicability of STEAM disciplines including the importance of teamwork, leadership, decision-making, and creative thinking. The event was fashioned and intended to stimulate both sides of the brain and to work in cooperation on problems that simultaneously involved both science and arts elements.

The Immersion Learning Model

The goals of the Project Fibonacci® initiative were: (i) to test ways of reversing the declining trends in our nation's high school level science, math, and reading scores; (ii) set the foundation for an effective workforce education plan and economic driver for new business start-ups that would build upon the upstate region's strengths and interests; (iii) create a new ecosystem that could attract and retain the youth talent in the region; (iv) enable educational and long-term career opportunities for students in high school and colleges/ universities; (v) strive to rebrand our region and catalyze it for sustained growth and expansion through diverse STEAM businesses, opportunities, and the formation of communities of interest; and (vi) design a STEAM campus concept that would blend many STEAM activities all operating under a single framework.

The first phase of the pilot project successfully culminated in the one-week STEAM conference. This was partially project-based, strongly team-based, and showcased a number of high profile keynote speakers who were able to directly engage with the conference scholars and educators, providing for a unique motivational and mentorship opportunity. The event concluded with a STEAM project fair where teams presented their ideas to their peers, conference staff, and community members. Topics included: how to promote the creation of STEAM businesses; influencing STEAM curricula in schools; influencing federal policy to support STEAM initiatives; and pursuing entrepreneurial career paths.

The STEAM scholar demographic included 101 high school and college students and ten educators of various subject areas and grade levels. Most scholars were from across New York State. The conference brought together a diverse group of students (67% high school, 30% college-level, 2% home schooled, 1% military bound) including those at risk of dropping out of high school.

STEAM group facilitators, who were New York State certified educators, functioned as mentors to help focus and clarify the students' learning and career aspirations. Facilitators exposed students to regional academic and career resources.

STEAM scholars were motivated by discussions with world-class speakers and were immersed in learning across multiple STEAM topics. Learning activities included such things as understanding the science, engineering, art, and architecture of building a geodesic dome as might be constructed on another planet, to the technical, expressive, and aesthetic arts of film making. The educators learned the significance of the relationship between the courses they teach and the real-world connection to skills expected in today's business and job markets.

In addition to the speakers and workshops, tours of venues associated with learning, scientific research, art, and music stimulated *beyond-the-box* brainstorming and provided insights into educational and career opportunities offered regionally. The scholars were encouraged to cultivate an entrepreneurial mindset that would help foster new business ideas built around proven STEAM models.

The pilot program was deemed highly successful as evidenced by the significant positive feedback received from the attendees. Approximately 92 percent of the scholars hoped to return the following year and expressed that the experience was a highly positive one, enhancing their realization and awareness of the importance of STEAM. The majority stated that the experience was "life changing" on multiple levels. One piece of critical feedback was that scholars generally wanted more interactive, hands-on workshop activities. As expected, we learned that not everyone has aspirations to work in STEM-only fields. Some changed their college plans after being exposed to the many diverse STEAM tracks and after better understanding that one can be good at multiple things, harkening the scientists and artists of the Golden Age of the Renaissance.

The key lesson learned is that we must emphasize interactive, project-based activities built around various STEAM topics, and provide enough time for scholars to synthesize what they learned.

Inspiration for STEAM Tracks

Recall that our approach was intended to reinforce the underlying concept of the mathematics that weaves through all STEAM disciplines. Stated another way, the sciences and mathematics influence the arts and vice-versa. It was envisioned that by emphasizing the mathematical concepts "underneath the hood", the scholars would gain a better appreciation for the importance of embracing mathematics as one step in reversing the declining math scores of our U.S. students. We used the metaphor of Fibonacci mathematical sequences and the Golden (Divine) Ratio as a basis for this. The Fibonacci sequence is a series of numbers where each number is found by adding up the two preceding numbers. Starting with 0 and 1, the sequence goes 0, 1, 1, 2, 3, 5, 8, 13, 21, 34, and so forth. The Golden Ratio is generally expressed as a fraction. For example, taking two successive numbers a and b (corresponding to two contiguous segments) in the sequence, then $(a + b)/a \cong a/b \cong 1.618$, a transcendental number, similar to the transcendental number π (3.1415…) found in trigonometry and geometry.

This mathematical characteristic is present virtually in everything in science, engineering, technology, architecture, art, photography, music, nature, medicine, financial forecasting, meteorology, the cosmos, and even in the proportions of the human body. The Golden Ratio is pervasive in the designs of Greek, Egyptian and Roman architecture. This provides the fundamental inspiration, and an effective metaphor, for Project Fibonacci®.

We also drew much of our inspiration on scientists and artists of their time who personify the underlying Fibonacci principles of emergent patterns interconnecting virtually everything in the universe. These include such luminaries as Leonardo da Vinci, Michelangelo, and even legendary people of the modern era like Albert Einstein who was a musician and a scientist. To that end, the STEAM tracks for the one-week conference were shaped as follows:

- Fibonacci and the "Big Math" of the Cosmos
- Fibonacci in Medicine & Human Physiology: Integrating Cognitive and Creative Sides of the Brain

- Fibonacci in Art, Graphics, Photography and Nature
- Fibonacci in the Art of Music and the Science of Sound
- Fibonacci in Science, Engineering, and Computing

Within these tracks were specific sets of subtopics, workshops, and field trips that resonated with the above main tracks and topic themes. A dedicated curriculum committee consisting of industry and academic partners worked to develop specific tracks, and was responsible for curriculum development, content enrichment, and scheduling. This included the incorporation of a daily exercise regimen each morning consisting of jogging, yoga, stretching and modified martial arts drawing upon the holistic concept of a healthy mind-body-spirit to maintain the scholars' attention span and cognitive performance.

Perhaps one of the most important ingredients in the unfolding of the curriculum was the inclusion of an eclectic group of motivational keynote speakers who each embodied various aspects of the sciences and the arts. In its first year, the program included high-profile speakers who spoke on a variety of topics that included: the NASA space program to Mars and beyond, the mathematics of nature and the human body, communicating science to the layman through the art of improvisation, the art and science of music production, the art of architectural engineering, and many other related topics all with threads of mathematics woven throughout.

Some of the most notable positive feedback from the STEAM scholars had to do with being inspired and transformed by the speakers themselves, and for the chance to interact directly with them, hearing their stories and learning important life lessons. This led to a memorable experience and left a long-lasting impression on the scholars.

Additionally, a college and career fair was held during the conference. Local companies, colleges and universities set up exhibits for recruitment and outreach to the STEAM scholars as well as to the general public.

EXAMPLES OF STEAM TRACKS

One of the tracks involved a series of interactive workshops devoted to themes on the *art of music and the science of sound*. The workshops were intended to elucidate the interconnection between the two domains through a common mathematical framework while at the same time, appealing to everyone's natural affinity for listening to and analyzing musical rhythms.

These workshops were considered to be one of the most popular tracks as they actively engaged students in becoming part of an *in situ* experience. They were able to directly interact with the instructors and others in the composing of music, as well as delve into effective methods of listening and interpersonal communications. The scholars were taught to focus on 'listening' to the underlying musical tones, beats, rhythms and repeating [emergent] patterns in order to better understand how these can be leveraged to promote positive energy, team building and communication skills.

These workshops illustrated the Fibonacci math as it relates to sound patterns in voice, percussion, keyboard and stringed instruments, including the fundamental and harmonic tones present in many popular songs of the past one hundred years. The idea was to exemplify the depth of such rhythms in music that contain the Fibonacci sequence and show how math plays an integral role in music composition.

For example, in part one of a rhythm and percussion workshop, participants were given a percussive instrument and assigned a particular rhythmic pulse. Each was added in one by one culminating in a multi-layered percussive orchestra of increasing complexity. The instructor then used hand gestures to control volume, rhythmic speed, and level of complexity while participants had to listen closely and assure smooth transitions in order to effectively 'communicate' the sound. Part two consisted of a lecture regarding the importance of rhythms in both traditional and modern societies as a form of communication. Next, participants were given phrases to recite and repeat, first vocally, then with their instrument.

It is hoped that when people participate in a workshop session such as this, they will take that energy back to the workforce with them and be energized in what they do or create. This teaches them to think 'teamwork' in terms of consonance (constructive) versus dissonance (destructive) based on their rhythmic understanding of how sounds, beats and patterns emerge and can effectively be communicated. That applies directly to how we function at home, in the classroom, workplace, or in other social settings.

A second example draws upon the *art of improvisation as an enabler for communicating complex scientific concepts* in lay person terms. Indeed, stage improvisation (improv) techniques are being used today to help scientists and medical practitioners communicate with the general public. The overall concept is not a new one. Improvisation has been used since the 1990s in the corporate world to help executives and employees communicate more effectively through working on listening skills, collaboration and teamwork. This merits some background discussion on why it is an important tool in STEAM learning.

The point of improvisation is to communicate an idea. Per Robert Kulhan, founding member of the improv troupe *Baby Wants Candy* and the founder and president of Business Improv, "Improvisation isn't about comedy, it's about reacting – being focused and present in the moment at a very high level" [13].

The same attributes about improvisation, which are attractive to the business community and have led several colleges and universities around the world to adopt improvisation training as part of their curriculum, are also valued and integral to teaching and communicating science in the 21st Century. These include the Columbia Business School at Columbia University, Duke University's Fuqua School of Business, Wharton School at the University of Pennsylvania, MIT Sloan School of Management and Harvard Business School, among others. Improv's dynamic relationship with academia is not just relegated to the business world, but also to the so-called "hard sciences," and that work is notably being done at Stony Brook University at their Alan Alda Center for Communicating Science.

Just as with the business world, clear and effective communication from/between scientists is a highly sought goal. The goal established by the interdisciplinary steering committee of the Alda Center, established in 2009, is not to turn scientists into improvisational actors. Rather, improvisational skills help scientists and medical professionals to talk about their work in a direct and spontaneous manner, develop a personal connection with their audience, and pay dynamic attention to that selfsame listening audience [14].

The improv games taught in workshops by the Alda Center have been taken to other institutions, including UCLA, Cornell University, and the SLAC National Accelerator Laboratory. The approach has also been used by the group ImprovScience, founded by Dr. Raquell Holmes, a cell biologist also trained in working in the fields of high performance computing and computational sciences. The stated goal of ImprovScience is to help scientists build collaborative learning and research environments, crossing disciplinary and cultural barriers to broaden the scope of their research and advance their own abilities [15]. According to Charles Limb, professor of otolaryngology at Johns Hopkins School of Medicine, "During improv, the brain deactivates the area involved in self-censoring, while cranking up the region linked with self-expression" [16].

This marks a cultural shift – whereas since 2000 the focus has been more on STEM, often ignoring the performing and fine arts that improve our standing in the world, a balance is once again being struck. Once-skeptical department chairs are now requiring students to take improvisation classes. Medical students at Stony Brook receive ten hours of training prior to graduation, and schools such as Dartmouth and the University of Vermont have become affiliates of the Alda Center setting up their own science communication programs [17].

THE "SERENDIPITY EFFECT"

The original vision of Project Fibonacci® was one that would create an ecosystem conducive to generating *creative collisions* amongst scholars, educators, and participants. This was meant to inspire and motivate people to think on a grander scale. It was designed to have the scholars and educators discover methods of artistic creativity and couple that with scientific brainstorming i.e., to think like an inventor or an entrepreneur and be willing to take risks in creating STEAM businesses for their community.

Certain topics covered in the STEAM conference such as the "math of the universe" and the underlying theories of the "multiverse" at the start, inspired moments of introspection by the scholars. This stimulated thought and debates about life philosophy, how to best serve society, and possible career interests or pursuits inspired by the "big picture" concepts of the cosmos. On a certain level, this brought out the inner artist and/or scientist in each person.

A survey of the scholars clearly indicated that the experience made them think more carefully about what careers they really wanted to pursue, and made them more aware of the regional opportunities that exist with regard to higher education and jobs. They clearly came to understand the advantages of thinking like a "Renaissance citizen".

PARTNERSHIP MODEL

Project Fibonacci® is made possible via multiple industry-academic partnerships. Industries know what to expect of prospective employees and seek specific attributes and qualifications for a talented, well-rounded workforce. Academia knows how to instruct, but often its hands are tied by the need for compartmentalizing the STEAM disciplines. What they do deliver may not be fully palatable with their students' expectations of STEAM learning; it is not relevant to real-world work in STEAM fields; and does not lend itself to creative solutions needed for tomorrow's real-world problems, which are unknowns today.

Project Fibonacci® is attempting to develop a mindset of creative problem solving and entrepreneurial endeavor. An industry-academic partnership model provides for an effective combination to achieve such goals. In addition, the importance of building upon a proven multi-university research initiative (MURI) core model is recognized as a key component in the formation of centers of excellence in STEAM education supportive of the notion of a "feeder" to other educational stimulus and job creation activities.

RESULTS AND BENEFITS

Six days of hands-on learning heightened students' skills. Students were excited and actively engaged in researching information. Active learning demonstrated to the students that they can acquire complex concepts independently; they became aware that academic success is their responsibility. Many of the students took on leadership roles that further enhanced the soft skills sought after by employers. Students became aware of the relevance of STEAM and how the disciplines relate to the real work-world.

Active learning provided students an extraordinary learning environment. Students made on-site visits to multiple research laboratories and arts facilities, giving them a realistic view of workplace environments. Keynote speakers, workshops, guidance from mentors, and working in teams further increased their enthusiasm and knowledge of the relevancy of STEAM disciplines skills required to be competitive for 21st Century jobs.

This paper provided an overview of the Project Fibonacci® pilot program along with some key results and observations. The need for collecting in-depth statistics and metrics of the project's success after its inaugural year is recognized in order to identify areas for improvement. In an effort to quantify results and measure success in the future, the leaders of the Project Fibonacci® initiative plan to coordinate findings with Le Moyne College's Quantitative-Reasoning Center (QRC) [18]. There is ample evidence of the increasing importance of data analytics and quantitative-reasoning skills better preparing students and current professionals for jobs of the future.

CONCLUSION AND NEXT STEPS

There is a pressing need for businesses, educational institutions and community members to work together to develop and promote a clear vision that: (i) augments STEM educational programs and prepares students to be leaders in STEAM disciplines; (ii) enables the agile, modern workforce of the future; and (iii) positions the U.S. to be a leader in the global economy.

Project Fibonacci® intends to continue working with students, educational institutions, parents, community members and businesses to develop programs that **e**nhance students' exposure to STEAM opportunities. Educators are key in developing their students' proficiencies and understanding the application of STEAM skills. Educators must acquire the ability to deliver effective instruction that is linked to today's workplace and at the same time equip students with the skills to solve the problems of tomorrow.

Project Fibonacci® will establish a mentoring program drawing personnel from business, military, medical, and educational sectors to create an educational incubator. Internships and apprenticeships with research and development companies, manufacturers, and businesses are being explored to assist participants with skills that will move the U.S. to lead in a modern, global economy. Project Fibonacci® will continue to create a learning environment offering students alternatives to working within the confines of a classroom and to go beyond STEM-only agendas.

The 2016 conference was valuable in that it immersed students and educators in STEAM learning delivered by industry experts. Scholar presentations of final projects demonstrated their ability to think critically, innovate, and work collaboratively. Project Fibonacci® demonstrated that such learning can propel students forward in STEAM learning and stimulate pursuit of STEAM professions. Efforts are now underway to collect statistics and generate metrics of success as the project enters its next year.

Phase II of the Project Fibonacci® initiative will focus on creating a STEAM center of excellence. The next step in this development is to engage politicians, educators, entrepreneurs, and community members in this endeavor.

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