

Integrated STEAM Education through Global Robotics Art Festival (GRAF)

CJ ChanJin Chung

Lawrence Technological University, cchung@LTU.edu

Abstract – Robotics is all about STEM and art is tightly coupled with all the S. T. E. M. components. A robotics art festival integrating robotics and arts was launched in Michigan in November 2013 to foster interest and engage students in STEM success. Pre-college students entered computer programmed interactive robotics projects in categories: visual arts and performing arts. 13 teams participated in the inaugural event from 2 U. S. States, Canada, and Mexico. Projects demonstrated creative applications of STEM subjects into art projects. Student survey results show that integrating arts with robotics was an effective hands-on paradigm that even brings beauty, joy, fun, and creativity while learning STEM subjects and computing.

Index Terms – STEAM education, TEAMS education, robotics education, robotics arts

BACKGROUND AND INTRODUCTION

Since Judy Ramaley, director of the National Science Foundation's Education and Human Resources division, coined the acronym STEM combining Science, Technology, Engineering, and Mathematics in 2001 [1], the term has been used worldwide. However, recently some people are arguing “STEM is not enough” [2] and there is a movement to turn STEM to STEAM or TEAMS by adding A (Arts) to STEM. Art is, according to the dictionary definition, “the expression or application of human creative skill and imagination” [3]. Why are we trying to add arts to STEM for education? The author believes that it is not natural to introduce STEM concepts without arts, because the art is already tightly related to each of the STEM components. Mathematics and art have a long historical relationship from the ancient Egyptian's golden ratio to modern fractal art [4]. Artists and scientists are more alike than different [5]. There are many direct connections between engineering and art such as in architectural engineering and industrial design fields. Leonardo da Vinci is a well-known Renaissance artist and engineer, and a prime example of the nexus between art and engineering [6]. Interconnections between arts and technologies are becoming more important. For example, see how Apple, under the direction of Steve Jobs who was obsessed with artistic design, created technologically compelling products that are useful and beautiful.

Based on the aforementioned facts, observations, and trends as well as robotics education experience through

Robofest – various autonomous robotics competitions emphasizing computer science learning [7, 8, 9] and RoboParade - an indoor parade of autonomous robotic floats [10, 11], the idea of GRAF (Global Robotics Art Festival) was conceived.

INTRODUCTION TO GRAF

Robotics, especially computer programmed autonomous robotics, is all about STEM. The idea of GRAF is to integrate arts with robotics to provide effective and interdisciplinary STEM learning environments where students will have an unforgettable fun experience by creating robotics art projects using a universal language, art [14]. The goals of GRAF are to attract more students to pursue STEM fields, to prepare them to excel in advanced education, and to promote creativity.

This annual event is open to student teams from 4th through 12th grade. Judges select champions of robotic artists in visual and performing robotic arts categories. Examples of visual robotic arts include interactive kinetic sculptures, kinetic canvases, and robotic painters (robots that draw). Examples of performing robotic arts include a robot dancer, a group of robot dancers that synchronize their moves, robot fashion show, robot skit, robots that play music, and robotic musical instruments that can be played by humans or help humans play music. Robots must have computational components programmed by students and must be integrative by employing sensors.

INAUGURAL GRAF 2013 AND PARTICIPATION DATA

From spring 2013, we encouraged existing Robofest and RoboParade teams to participate in the new program through informational meetings and introductory robotics workshops. In July 2013, a week long robotics music camp was offered.

The inaugural GRAF (Global Robotics Art Festival) event was held on November 23 at Macomb Community College, Warren, Michigan. Two registered teams dropped out, but a total of 39 students in 13 teams came from Michigan and Ohio, Canada, and Mexico. 79% were young students in either elementary or middle school and Figure 1 shows their grades. 28% of the participants were female students as shown in Figure 2, which is far higher than the female college student participation rate, ~15%, in college engineering programs [12]. Average team size was 3, which provides an ideal learning environment to develop both

independence and collaboration for the “TEAMS (or STEAM)” paradigm.

GRAF JUDGING RUBRIC

To select the best teams, we asked 12 Judges to score each item in Table 1 on the scale of 1 through 5 as defined below.

- 5:** Strongly agree - excellent, advanced, exemplary, or amazing
4: Agree - good, accomplished, or proficient
3: Neutral - average, intermediate level, or acceptable
2: Somewhat disagree - attempted but needs work
1: Disagree - little attempted or needs lots of help

The rubric was pre-announced as a part of the rules to teams when they registered.

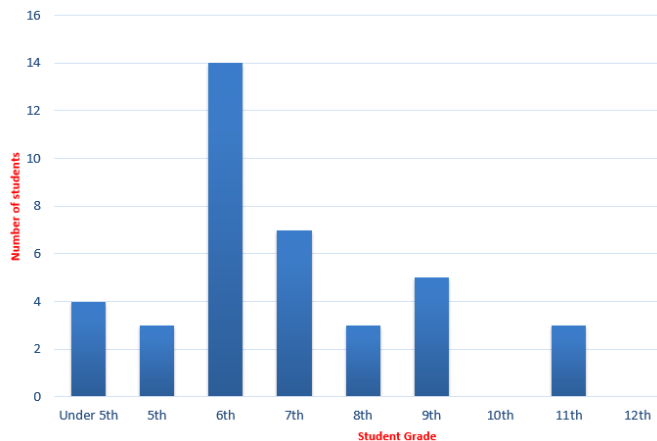


FIGURE 1
PARTICIPATION GRADES

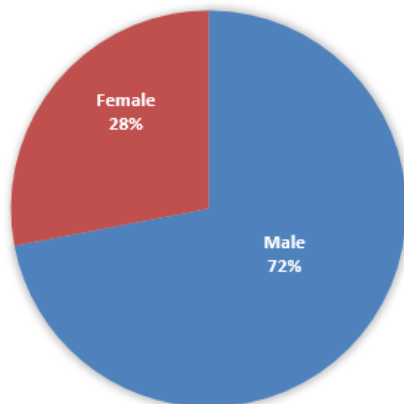


FIGURE 2
GENDER RATIO

GRAF 2013 TEAM PROJECTS AND WINNING TEAMS

As visualized in Figure 3, more students were interested in the visual arts category by showing something beautiful with robots. 62% of teams chose visual arts robotics projects, while 38% chose music, dance, or play related projects. Some teams introduced projects combining both visual and performing arts aspects.

TABLE 1
GRAF JUDGING RUBRIC

Category	Sub Categories	Weight
1. Artistic concepts / aspects	Students applied art concepts and/or aspects to the robotics project	10%
2. Project creativity & innovation	The project idea was wow and unique. The project was artistically creative.	9%
	Students integrated art in an innovative way.	8%
3. Interactions	The robot(s) interacted with other robots, humans, and/or environment.	8%
4. Project demo performance (robot)	The official public robot demonstration was free from problems, and <i>artistically</i> impressive.	10%
5. Project presentation (humans)	Project presentation was clear, well organized, and delivered effectively. Student attitude toward spectators was courteous. Students reacted professionally when the robot did not perform as expected.	8%
	The team has evidences of promoting their project to the public. (For example, posters, brochures, blogging site, and/or online video)	3%
6. Math & Science learning	This project applies some concepts of math and science and Students have knowledge on the math and science concepts they applied.	8%
7. Team work	Specific member roles were clearly introduced. Work division is done well and balanced. Each team member seems to know as much as the other team member. Teamwork and team spirit was evident. Shows respect to other teams. Good citizenship.	8%
8. Robot design	I inspected and tested the robot. The robot mechanical design was creative, user-friendly, and sturdy. (If the whole robot hardware was made by others, give score of 1)	7%
	The project is complex (not simple).	3%
9. Programming	I asked students who were involved in programming to explain a part of the programming code. They totally understood the code and seemed like they wrote the program. The code is well organized and commented.	8%
10. Team independence	I believe the whole project (hardware and software) was done by students, not by adult coaches, parents, mentors, or other professionals.	10%

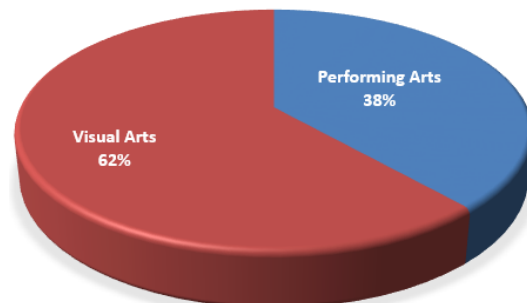


FIGURE 3
PARTICIPATION CATEGORIES

I. Performing Arts Projects

Team *Courageous 1* introduced a piano playing robot and a robotic guitar instrument (see Figure 4). The piano robot had creative mechanism with 3 motors to control 6 fingers. The guitar robot made different tones while sensing the finger location with an infrared distance sensor. 91.7 FM Ann Arbor, a part of the NPR (National Public Radio) digital network, aired a part of “Jingle Bell” that the robots played. This team won 1st place in senior division Performing Arts category.



FIGURE 4
PIANO ROBOT AND ROBOTIC GUITAR

Team Creative Canucks created two robots as seen in Figure 5 on a play with a winter theme. The team narrated while the robots performed and danced. This team won a Judge’s Choice award.

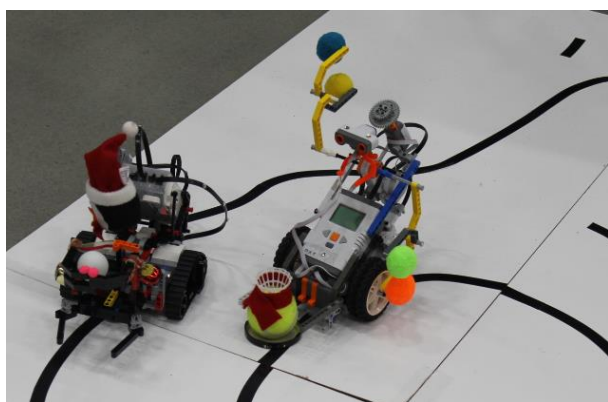


FIGURE 5
CREATIVE CANUCKS DANCE TEAM

Team Five Girls’ robotics art project (Figure 6) was with two robots that were programmed like they were in a band. One robot moved as if it were playing the guitar and the other one moved as if it were playing drums.



FIGURE 6
TEAM FIVE GIRLS

Team Atomaton designed one robot (Figure 7) to move and perform as if it were the DJ, and the second robot danced on the dance floor to the music.

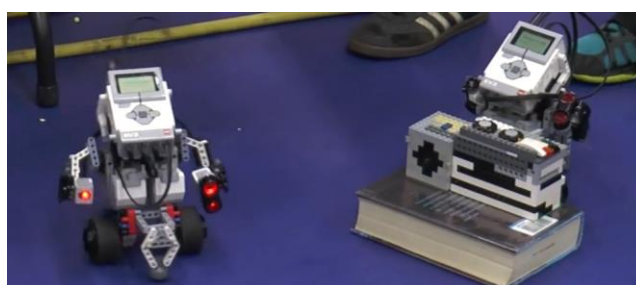


FIGURE 7
TEAM ATOMATON

Team RoboCruisers introduced a believed-to-be the world’s first robot playing a recorder. 3 motors were synchronized to control two pumps to provide powerful enough air into the recorder windway. When the robot was playing “Mary had a Little Lamb” on a recorder, the other robot duck was dancing to the music synchronized by Bluetooth signals. This team won 1st place in junior division Performing Arts category. See Figure 8 below.

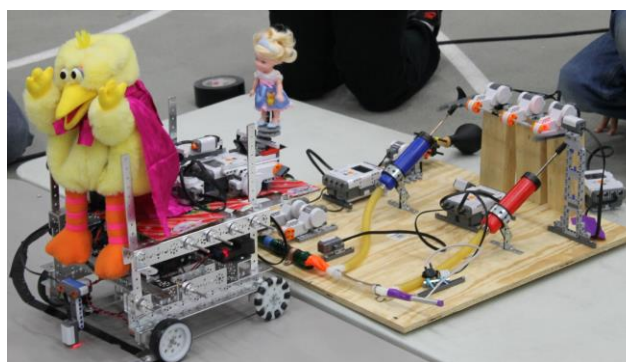


FIGURE 8
RECORDER PLAYING ROBOT AND A ROBOT DUCK DANCER

II. Visual Arts Projects

Team Moodpainter developed a robot system with a database that will draw a shape by spraying different color paint according to a person’s mood determined by the music

played on a foot keyboard. See Figure 9. This team won 1st place Sr. Visual Art category.

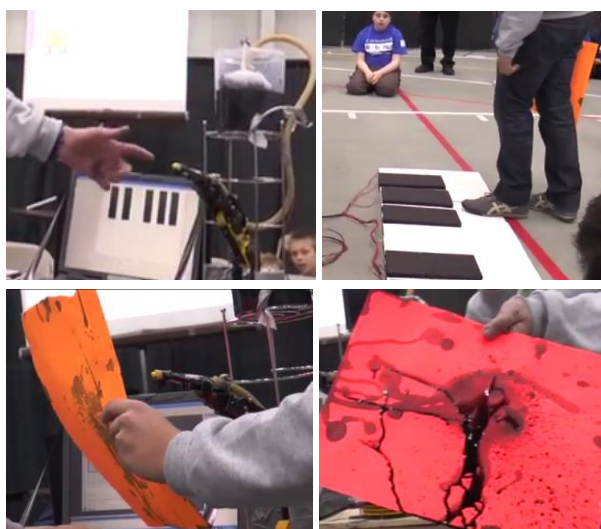


FIGURE 9
MOODPAINTER

Team ALL2JESUS created a robot that displays kinetic art patterns by using 16 servo motors and distance sensors. The robot changes the pattern whenever it detects a new spectator or by using a built-in timer. This team won a Judge's Choice award. See Figure 10.

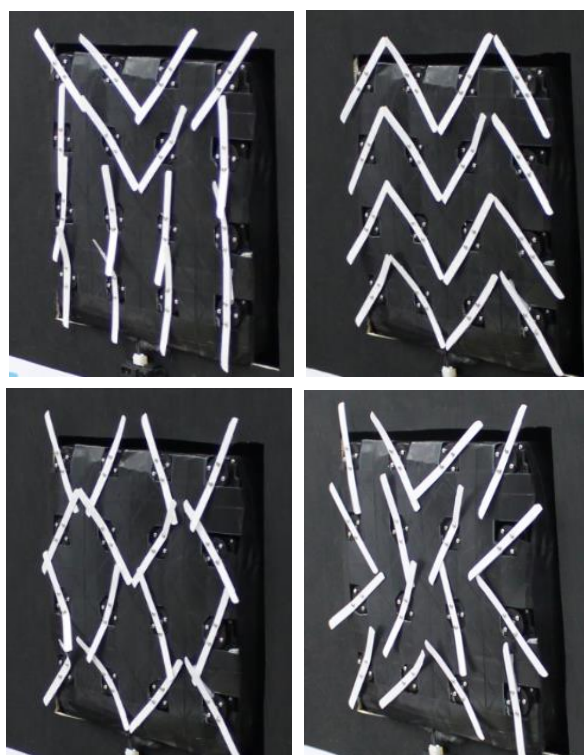


FIGURE 10
KINETIC ART PATTERNS

Team The Supernovas created a robot, Franc (See Figure 11), which is designed to paint letters based on pre-entered

coordinates. Franc painted the official logo for the Global Robotics Art Festival (GRAF). This team won 1st place in Jr. Visual Arts category. Figure 12 is the official GRAF logo painted by the robot.

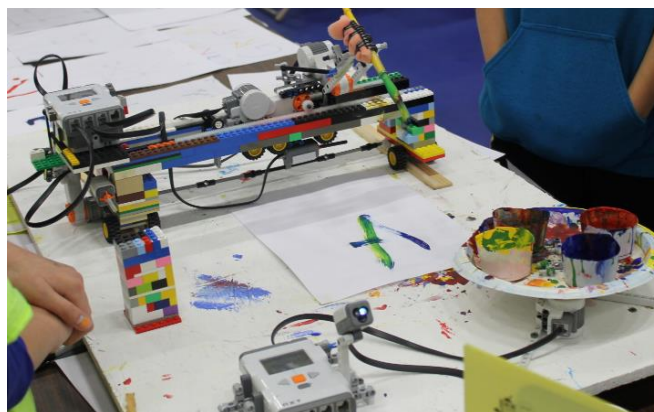


FIGURE 11
LETTER DRAWING ROBOT



FIGURE 12
GRAF LOGO DRAWN BY THE LETTER DRAWING ROBOT

Team Spruce Goose made a mechanical kinetic sculpture that abstractly depicts a cam shaft, in an artistic way, playing a LED light show activated by IR distance sensors. This team won Judge's Choice Award. See Figure 13.

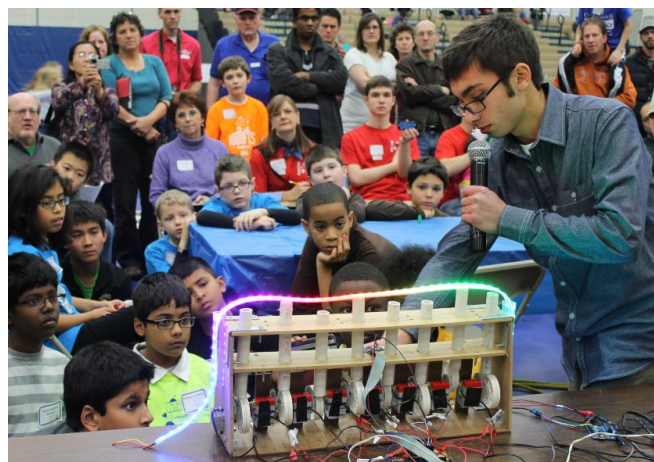


FIGURE 13
KINETIC SCULPTURE, SPRUCE GOOSE

Team Technocrats' project (Figure 14) was kinetic arts where balls went down a Lego track and were picked up by a moving rotating arm. There were multiple balls on at once, so the effect was like moving art.

Team GrafCraft designed a robot (Figure 15) that could draw various shapes. It was programmed to draw circles,

triangles, and squares, and could also draw them in a repeating pattern.

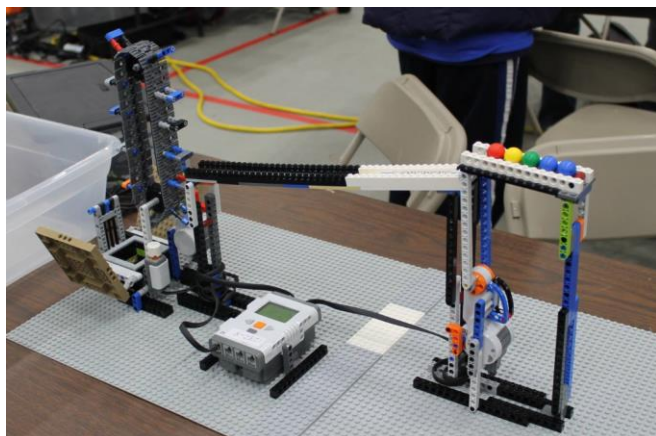


FIGURE 14
KINETIC SCULPTURE, TEAM TECHNOCRATS

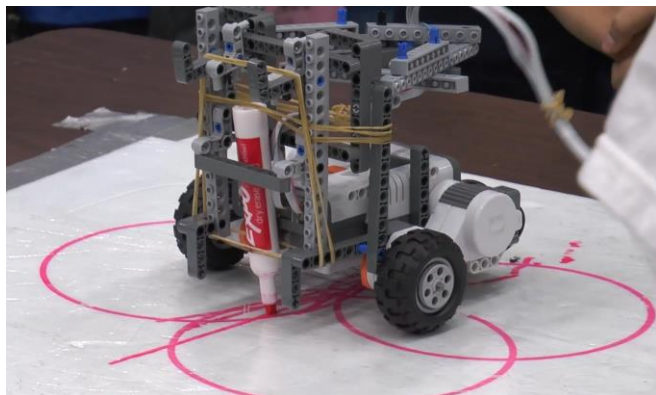


FIGURE 15
KINETIC SCULPTURE, TEAM GRAFCRAFT

Team Courageous 3 created a kinetic art project called Cyclone II (See Figure 16) with balls on roller coasters moving through tracks. When a color ball was detected by the robot, it moved the ball up high.

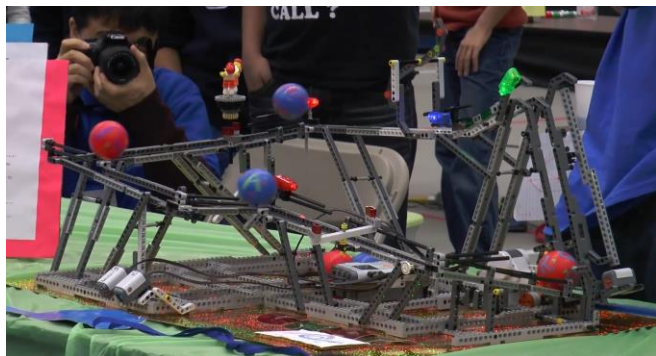


FIGURE 16
CYCLONE II, TEAM COURAGEOUS 3

Team Courageous 11 made a Domino Dog (Figure 17) that was designed to be loaded with dominoes, and as the robot moved around, it released one domino at a time, creating an artistic pattern.

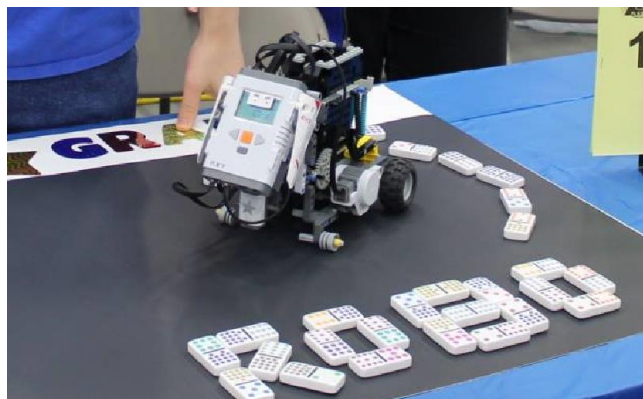


FIGURE 17
DOMINO DOG, TEAM COURAGEOUS 11

GRAF STUDENT SURVEY

In order to see the efficacy of the GRAF program for STEM learning, we asked students to answer the following questions in the scale of 1 ~ 5.

1	2	3	4	5
Disagree	Somewhat disagree	Neutral	Agree	Strongly agree

- Q1. I had fun doing robotics arts project
- Q2. I am interested in a career or job involving Science, Technology, Engineering, or Mathematics (STEM)
- Q3. Combining robotics and arts gave more motivation to learn STEM than traditional STEM only projects.
- Q4. Doing a hands-on project combining robots with arts makes me want to learn more about STEM
- Q5. I am more likely to take STEM related classes after this event
- Q6. I am more likely to take arts related classes after this event
- Q7. I would like to participate in GRAF next year too.

Figure 12 shows the average score of each survey question from 34 students who participated in the anonymous survey.

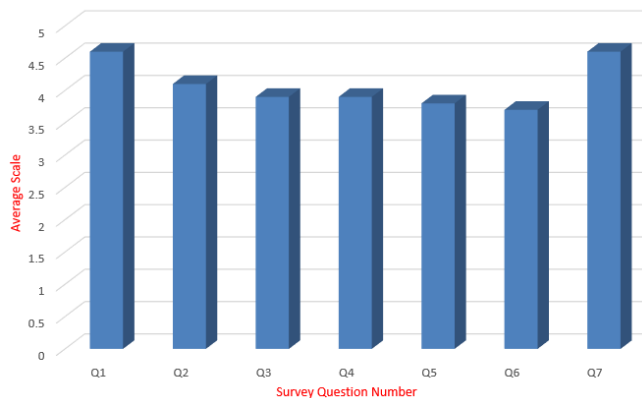


FIGURE 12
STUDENT SURVEY RESULTS

The results show that everyone had fun with the robotics arts project which seemed an effective way to get students connected with STEM subjects. The lowest score (3.7) we got was for the Q6. Students in the particular population seemed not too much interested in art only classes, since perhaps they were already actively involved in STEM classes. Students also left the following comments in the anonymous survey:

- *It was fun.*
- *This project was very enriching and interesting because besides of the robotics part, I'm a musician.*
- *I'm very impressed about all the robots. They are great.*
- *I had a lot of fun designing this project, but I would prefer a standard competition like Robofest. But I appreciate the time & effort LTU put into this GRAF*
- *I think robotics is fun. This GRAF competition was very fun.*
- *Very good organization.*
- *It was fun.*
- *More people should know about this and participate.*
- *I like everything.*
- *I am going to do more robotic arts after this event.*
- *They are fun by putting education in robotics in a fun way.*
- *It was a very good idea to mix robotics and art and I am looking forward to next year.*
- *I really enjoyed it!!*
- *Love it!!!*

SUMMARY AND CONCLUSIONS

The goal of GRAF is to get students to pursue their interest in science, technology, engineering and math, known as the STEM subjects, by using the power of universal human interest in arts. It is natural to add A (Art) to STEM, since it is tightly connected to all the S. T. E. M. components. Student projects show hands-on application of STEM and computing subjects into creative robotics arts projects that require analysis, synthesis, evaluation, and problem-solving skills. Why is integrating arts into STEM important? Because as Gullatt argues, arts are not only for (self) expression, but also for discovery [13]. Arts promote and develop creativity while feeling beauty and joy.

Participation data show that the inaugural GRAF has resulted in bringing more female and young students into STEM learning compared to Robofest competition populations [16]. Survey results show that GRAF can be an effective learning environment for improving STEM fluency since students felt they gained knowledge in STEM subjects.

Due to tight budgets as well as an ever-growing list of state mandates, the priority of arts education has been lowered. Also, public sense tells that arts are beautiful, not essential. It is time for arts educators to actively embrace hands-on STEM to create STEAM or TEAMS environment.

Annual GRAF event will be continued in Michigan and future works include (1) refining the rubric by adding means to assess the engineering design process and (2) developing rigorous methodologies to measure and assess STEAM (or TEAMS) successes. In addition the author is interested in

assessing whether the GRAF students are really learning creativity more as compared to a non-art related robotics student population using Torrance Tests of Creative Thinking [15].

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REFERENCES

- [1] Jerome Christenson, Ramaley coined STEM term now used nationwide, http://www.winonadailynews.com/news/local/article_457afe3e-0db3-11e1-abe0-001cc4c03286.html, accessed Jan 9, 2014
- [2] Valerie Strauss, Why STEM is not enough (and we still need the humanities), http://www.washingtonpost.com/blogs/answer-sheet/post/why-stem-is-not-enough-and-we-still-need-the-humanities/2012/03/04/gIQAAniScrR_blog.html, accessed Jan 9, 2014
- [3] <http://www.oxforddictionaries.com>, accessed Jan 9, 2014
- [4] http://en.wikipedia.org/wiki/Mathematics_and_art, accessed Jan 9, 2014
- [5] John Maeda, Artists and Scientists: More Alike Than Different, <http://blogs.scientificamerican.com/guest-blog/2013/07/11/artists-and-scientists-more-alike-than-different/>
- [6] Bjerklie, David. "The Art of Renaissance Engineering." MIT's Technology Review Jan./Feb.1998: 54-9.
- [7] Chung, C. (2013). Unveiling 2014 Robofest Challenges, Robot Magazine, January/February 2014, pp. 48-51.
- [8] Chung, C. (2011). ROBOFEST 2010 - Little robots perform big missions for STEM, Robot Magazine, January/February, pp. 60-65.
- [9] <http://www.robofest.net>
- [10] Chung, C. (2010). RoboParade – An opportunity to develop your imagination while having fun, Robot Magazine, November/December, pp.78-79.
- [11] CJ Chung and Christopher Cartwright (January 2014), RoboParade: a Fun and Effective Way to Promote STEM Education, Proceedings of the 12th Hawaii International Conference on Education, Honolulu, Hawaii
- [12] Godfrey, E., Aubrey, T., King, R. (2010), Who leaves and who stays? Retention and attrition in engineering education. Engineering Education, 5, 26–40.
- [13] Gullatt, D.E. 2008. Enhancing student learning through arts integration: Implications for the profession in The High School Journal, April/May, 12-25.
- [14] Emily Hamner and Jennifer Cross, Arts & Bots: Techniques for distributing a STEAM robotics program through K-12 classrooms, Proceedings of the 2013 IEEE Integrated STEM Education Conference (ISEC), March, 2013.
- [15] Kyung Hee Kim, Can We Trust Creativity Tests? A Review of the Torrance Tests of Creative Thinking (TTCT), Creativity Research Journal, 2006, Vol. 18, No. 1, 3–14
- [16] CJ Chung and Chris Cartwright, Robofest 2012-2013 Annual Report, <http://www.robofest.net/2013/robofest13report.pdf>

AUTHOR INFORMATION

CJ ChanJin Chung, Professor, Department of Mathematics and Computer Science; Founder and Director of Robofest®, RoboParade®, and GRAF, Lawrence Technological University.