

2107 Premier’s Copyright Agency Creativity and Innovation Scholarship

Science, Technology, Engineering and Mathematics (STEM) education for the innovation age

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# Introduction

I proposed to investigate how Science, Technology, Engineering and Mathematics (STEM) education can be delivered effectively against the disadvantage of rural and remote isolation, through the models used in the USA, notably rural Arkansas. As a NSW Department of Education (DoE) STEM Action School, The Canobolas Rural Technology High School (TCRTHS) provides coaching to schools and teachers across the state, with a focus on those in rural and remote areas. We are the only STEM Action school in country NSW.

# Focus of Study

My critical focus questions are:

1. Is the teacher, the facilities, the practical hands-on components or the integration of STEM learning areas at the centre of the success of a STEM program?
2. Is specific teacher training needed to successfully deliver a STEM program?
3. What can we learn from the established STEM centres and academies in the USA for using STEM education to engage our students? Can the NSW STEM Action Schools play a role like this for our schools?
4. What emerging technology is essential in STEM to best prepare students for the future?

# Significant Learning

## South Central Education Cooperative – Camden, Arkansas USA

At the suggestion of Dr Scott White of the Southern Arkansas University (SAU) I travelled to Camden, Arkansas to visit the staff of the South Central Education Cooperative (SCEC). The SCEC is funded by the Arkansas Department of Education to support schools in the local district in a range of areas including STEM. Specialist teachers (like DoE consultants) work with teachers to build their capacity.

Camden has a similar context to that at Canobolas, notability a major industry and traditional employer of students and their families closing down, in this case a paper mill. STEM is seen as a way to prepare students for employment in alternative future industries. As with the Regional Development Australia (RDA) Hunter's ME Program (<http://www.meprogram.com.au/>), SCEC schools have made links with the new defence industries, working with Lockheed Martin to build rockets and rocket launching systems (<http://www.lockheedmartin.com/us/mfc/siteinformation/camden.html>). External grants for resources to support teaching and learning play a large part in education and Lockheed Martin is one of the supporting partners.

I was shown the robotics programs facilitated with primary school students, Hot Wheels cars activities and we compared notes over makerspaces and resources. Thanks to the Arkansas and Facebook Techstart Partnership, 500 Arkansas schools are being donated Occulus VR equipment, and I was walked through its professional development program.

It is clear here at SCEC that developing teacher capacity is key to successful STEM and in turn, building better outcomes for these rural and remote students. Emerging technologies like robotics and VR engage students and further increase program success.

## Magnolia Junior High School- Magnolia Arkansas,

At Magnolia Junior High School, I spoke with Brandy Browning who was starting a 9th Grade class, not long after 'testing', the Arkansas version of NAPLAN. Some of her students will be presenting their work at the SAU STEM Science Fair. Two projects that caught my attention were an investigation into the impact of energy drinks on school athletes and if horse manure be used to produce energy. It was obvious that both projects were successful as they were closely linked to the interests and lives of these students, and this is offered as a major engagement tool for the students of this rural school.

Coach Miller, is another 9th Grade Science teacher and school Basketball coach. He takes an individual inquiry-based approach to science lessons with this group. Students were working collaboratively to complete a range of reports from projects for end of term grading. Miller takes advantage of SAU STEM for professional learning and often borrows high-cost resources to bring more hands-on activities into his classrooms. Initially not interested, he credits the support and professional development from SAU STEM for changing his classroom approach. STEM is taught in silo classes here, not integrated across faculties.

These are clear examples that providing access to both teacher professional learning and quality resources can help provide successful STEM education to rural students. SAU STEM Centre provides equity for rural schools.

## Arkansas Department of Education, Education Renewal Zone – Magnolia, Arkansas

Arkansas is the only state to have a legislated program to support schools that are under performing, with a focus on not only raising student achievement but building teacher capacity and quality. Dr Roger Guevara, the Director of the local Education Renewal Zone for the Arkansas Department of Education sees one his main roles as leveraging for the funding to acquire resources and run teacher professional development for programs like South Central Educational Cooperative and SAU STEM.

A challenge for Dr Guevara is how can they quickly build teacher capacity that can help students learn how to think, rather than teaching to the standardised tests. He hopes Arkansas schools will move towards a more integrated approach and believes a key factor is the vision of leadership in a school and it ensuring the structures and support are in place to help teachers realise the vision.

## Southern Arkansas University STEM Centre – Magnolia, Arkansas

I met with Dr Scott White, Director of the SAU STEM Centre. Dr White showed me through the spaces where their Mathematics and Science specialists work with teachers for professional development and some of the resources that they loan to schools for STEM lessons. SAU STEM hosted a district Science Fair, with local schools sending students with projects that have been graded in the top three in their school class. This has helped promote inquiry-based learning within local rural schools.

I met with Susan and Stacey, who are Science and Math specialists. We spoke at length about how the SAU STEM Centre supports teachers from local district schools and was given examples of some of the project-based tasks they train teachers with to take back to their classrooms. Loan equipment plays an important role as these resources are not normally owned by schools, due to not having enough funding or not being able to prioritise spending money on a resource used only a few times each year.

As with SCEC, providing the professional development to staff in STEM education and providing the loan resources to schools had led to successful STEM education for rural schools. The STEM Science fair has great value in motivating students and staff, promoting STEM and providing clear university education links.

## 79th annual International, Technology and Engineering Educators Association – Dallas Texas, USA

I attended the 79th annual International Technology and Engineering Educators Association, as part of an international round table on technology education, presenting the Canobolas STEM program that was one of 75 international programs in the STEM showcase.

The first keynote was Jonathon Gerlach, a STEM Expert for Discovery Education. He spoke at length about in importance of the 4 C's of 21st century education preparing students for an uncertain future workforce. It was although he had borrowed my slides from my upcoming presentation about the Canobolas STEM program, this is the message we have been sharing with anyone who will listen for almost two years now. From my perspective, it is reassuring to see that a large, influential organisation like Discovery have come to the same conclusions as us.

The best experience for the conference was sharing the Canobolas STEM story as part of the STEM Showcase. I was continuously answering questions and explaining our STEM model to people from around the world for over an hour and a half. The fact that our model is in addition to Science, Technology and Mathematics class and is truly integrated gave us a great point of difference. Most of the STEM here are conducted in silo classes, as either one off activities or curriculum programs and reference other learning areas, rather than being truly integrated. This has further reinforced that we are heading in the right direction in our school and in wider New South Wales.

The next keynote speaker was Steve Culivan. who works for an organisation that provides the STEM education programs for NASA through the John C. Stennis Space Centre in Mississippi (<https://www.nasa.gov/audience/foreducators/stem-on-station/lessons>).

A big part of Culivan’s message was around careers in NASA, and that there is more to working for NASA than just STEM. While NASA places great importance on the development of students with STEM skills as future employees, the very wide range of opportunities for students was pointed out, and the one common thing with all the careers is teachers.

Culivan explained NASA's plans to get back to Mars, possibly with a manned mission somewhere between 2020-30. The Orion spacecraft is due to be tested in late 2018. The point was made to look past the initial cost of the mission and look back to the benefits from the Apollo moon mission program. We all benefited from so many technological advancements made during this program, including the development of cordless power tools. The income earned from this technology alone has paid for the Apollo 9 times over. What we will get from the Orion project?! With the current discussion around 65% of jobs that primary students will apply for do not yet exist, he pointed out that our Mars astronauts are most likely in primary school right now. STEM is critical in developing the people required for the success of this program.

I was also able to chat with both Jared P. Bitting (ITEEA Director and former President) and Ed Reeve (ITEEA President Elect). Both agree that it's the technology and engineering activities that brings STEM education to life. It's the making of the projects in STEM that gives the opportunities for students to apply scientific and mathematical skills, and in turn develop deeper understanding.

## High Tech High- Point Loma San Diego, California

I spent two days at High Tech High, the independent public charter school made famous in the recent movie documentary 'Most Likely to Succeed'. This school was established after the San Diego business community identified the need to better prepare local students for high tech careers. Fortunately, I had a chance meeting with Larry Rosenstock as he had just returned from visiting Australia. He is the program and curriculum leader behind everything that has happened at the school. It started off with a guided tour of High Tech High and High Tech Middle with a very articulate senior student called Blake. As with all students, Blake gained a spot at one of the seven High Tech schools in the High Tech Village through a lottery system for San Diego locals.

Flexible learning is at the heart of everything that the High Tech schools do, and this is reflected in the purpose designed faculties. All bar one of the seven High Tech schools are housed in former Navy training buildings and have been fitted out to feature interconnecting classrooms and common learning spaces. There are a lot of windows into classrooms, allowing working students and teachers to be easily seen. When students are doing independent work, Blake explained how students like himself could work where ever they are comfortable, providing they are being productive. Students understand their teacher's expectations and realise the consequences for wasting time. Being the last week of the session before spring break, many students were completing work due from the term or participating in week long interest electives. This meant that there were more than the usual number of students in non-structured lessons. One thing that stuck with me in the senior school was the 100% student engagement, and 0% behaviour issues.

I was also free to spend an hour and a half walking the seven schools of High Tech Village and dropping into any class. I called in on 8th Grade Maker-Teacher Carrie Lawrence who was working with a class to complete the term's project. This project was on how the brain works and mental health. During their investigations students had to select a 'fact' about mental health and offer a 'tip' for managing it. Students then created a page for a class book with 52 weeks of facts and tips. This was then being scanned, printed and sold to parents – a great example of entrepreneurial learning.

I returned to the High Tech Village for a second day of discussion and exploration, with a tour of High Tech Elementary with a senior student, led by four well prepared 4th Grade students. These students took turns explaining how their school days work and how the purpose built school building works. Here the collaborative, project-based learning approach from the original High Tech High is being applied to Elementary students from Kinder to 5th Grade. As with the other High Tech Village locations, rooms have been designed so that they can be opened up for class collaboration with the students from the class next door. To support teaching and learning, there are shared specialist rooms for subjects like music and a makerspace. This makerspace looks like a timber / mixed materials technology room you would see in many New South Wales secondary schools.

More considerable time was spend wandering through the High Tech Village schools and classrooms . I revisited Carrie Lawrence’s 8th Grade class, this time working in the High Tech Middle makerspace on their mental health class book project. Here students have been creating stamps by hand to illustrate and number their individual book pages. This activity looked more like a Stage 4 Art class in a New South Wales secondary school. I asked her if any consideration had been made for utilising the advanced manufacturing tools like laser cutters and 3D printers, and the decision for this group came down to the incompatibility of the stamp material with the laser. Several students were so motivated to ensure that their book page was ready for scanning and publishing that they stayed behind during recess to keep working with her.

A feature of every High Tech Village building is the display of student work everywhere you go. It really gives a sense of student engagement and value in their work. With each display, there is a poster/s explaining the project and celebrating the successes of the students involved.

A small group of visitors including myself met with the current Director of High Tech High, Kaleb Rashad. The Q and A style discussion was around setting up a project-based curriculum, facilities and overcoming challenges. Kaleb shared his experiences in supporting teachers who plan, deliver and assess integrated project-based learning (PBL). An important factor is allowing teachers to follow their inspiration, as a motivated teacher will always get better results from students than one who is not. The visit ended with reflecting on thoughts with Ady Kayrouz, the Professional Development Coordinator for the High Tech High Graduate School of Education. We discussed integrated project-based learning in situations where not every teacher is a subscriber to an integrated project-based approach.

Based on this visit, integrated PBL is easy to implement when you have students nominating the be there, and staff given the freedom to follow what inspires them. They see how engaged with learning their teachers are, and most are willing to follow them on the journey. Reassuringly, students are still students and no one project engages everyone. Even the staff here acknowledge there is isn't a magic bullet for student engagement. Interestingly, you don't see STEM jumping out at you as you do in other places, as everything here is integrated. It’s all part of what happens here.

## Deeper Learning Conference – San Diego, California

I returned to High Tech High (HTH) for their fifth Deeper Learning Conference. This has grown from 250 five years ago, to 1100 attendees this year. It is held in the High Tech Village and the majority of the sessions are run by HTH staff, supported by many of the HTH student ambassadors.

The keynote speaker Becky Kanis Margiotta, – Co-Founder of The Social Change Agency and the Billions Institute, shared a story about a program she started that helped house every homeless person living rough in Times Square, New York. This program was so successful it was adopted in many cities around the USA. What made this a relevant presentation to begin the conference was that it was a tale of taking ideas to scale. This is a theme for the conference. Ideas in education usually play out in one of three ways, like:

* kindling – fast to light and equally burns out as quick.
* campfire – burns big but only once.
* candle – a steady, prolonged flame.

The theme for Deeper Learning is to begin discussions that burn like candles and not kindling when we all return to our schools.

I attended "The Lab: Creativity in Practice" presented by Michael Ha, eLearning coordinator from Newington College in Sydney. He shared a program that his school has implemented using deeper learning philosophies and took us through some typical creative activities that are used with students and suggested <http://www.gamestorming.com> as a resource for similar activities.

I attended a session led by Dr Don Mackay a Year 11 Engineering teacher at High Tech High International (HTHI) It focussed on the way virtual reality had been used for project-based leaning at HTH. His digital portfolio can be found here: <http://energineering.weebly.com/>

Mackay showed us how VR has been used in a term one project, and we were able to break into three groups to make our own Google Cardboard VR viewer (to use with a smartphone), create 3D video using a 360 camera and also try dedicated VR equipment including Occulus Rift. There were many HTHI students on hand to help us out with the activities and share their experiences during what was obviously a very engaging project. Students would pitch ideas for a VR project to parents, and the best 12 ideas were chosen. The successful 12 students became producers and had to hire (and fire...) classmates based on their skills, experience and productivity to get the project done on time. If you have access to VR gear like a Google Cardboard, examples of student work can be viewed from links on Don's digital portfolio.

He also talked us through how his class were able to participate in the Presidio project, that is a historic site in San Diego that has been buried for 150 years. Don's class has been working with a local business to create a virtual reality model and tour of this site. Other than the use of laser cutters in projects, this was the first real emerging technology I found in the High Tech schools. Evidence that while emerging technologies can enhance STEM learning, it is not a necessity.

The focus of day two was different from the previous day, a day for "Deep Dives". It featured full-day sessions to allow participants enough time to really get into things. The session I chose was building catapults, facilitated by HT Middle Media Arts teacher Law Ortiguerra (Science and Maths). Essentially today was a whole term project condensed into one day.

Once introduced to the concept of the project and where it fits in the school year, we were given some examples of desktop siege machines and a range of makerspace resources. Individually we constructed our own catapults and tested them for distance and accuracy by firing jellybeans. We then paired off and compared notes about our designs. Then our pairs split, one exhibiting both designs and the other checking out the class's designs. We had to know our partner’s design well enough to share their evaluation. Following this each partner traded places and repeated the exhibition process. It was a great example of effective STEM learning without emerging technologies.

After a break, we took returned to our Deep Dive session, this time working in groups to design and build a much larger scale catapult using what we had learned during the small-scale tests and exhibition. Once completed, we had to exhibit our work as the HTH students would and had the opportunity to wander around the High Tech Village and see the other exhibitions from other sessions.

## Mathematics, Engineering Science Achievement (MESA), San Diego State University San Diego California

I visited San Diego State University to meet Luis, program manager for the Mathematics Engineering Science Achievement (MESA) program at SDSU during their southern regional Senior MESA day. MESA supports students from low socio-economic backgrounds to experience STEM careers and enter further education through mentoring, industry experiences and role modelling. SDSU chapter has been operating since 1982, and MESA since 1970.

High School student teams prepared for a range of challenges prior to this day. They were checked against the competition rules and then faced off against each other. Challenges included mouse trap racers, balsa gliders, egg drop, arduino programming, bridge structures and most impressive was the robotic prosthetic arm! This was a real mix of the successful use of high and low technology resources for effective STEM learning.

This turned out to be a most valuable experience, as it is exactly what I have been doing with the same clientele but taken to a much greater scale. It was a great way to finish the tour where it started, back with High School STEM projects linked closely to and supported by a university. Part of the success of MESA is the lesson materials they provide for high school teachers and mentors. Visit [https://mesa.ucop.edu/ for more information](https://mesa.ucop.edu/%20for%20more%20information).

# Conclusion

The teacher is key to the success of a STEM program. Effective professional development gives teachers the confidence to deliver engaging STEM activities and program. This is critical when emerging technology like robotics or virtual reality is involved. However, low-tech STEM programs can be equally successful with students.

Links to careers and further education, as with SCEC, SAU STEM and MESA, give STEM the authenticity and relevance for students which is important to student engagement.

A STEM Centre model like that at Southern Arkansas University, would be an effective model to take the NSW DoE STEM Action School program to greater scale. It should be based at a regional university like Charles Sturt University and use an existing DoE structure like the environment education centres. Like SAU STEM it would support rural and remote schools with staff professional learning, loan equipment and workshops for students either on site or at the supported schools.