Regional Development Australia – Hunter (RDA Hunter) has designed and implemented an innovative school based program to improve career pathways for young people in science, technology, engineering, and mathematics (STEM). Funding for the project was provided by the Defence Materiel Organisation (DMO) to address future skill shortages in Australia. The Hunter’s “ME Program” is one of three DMO projects nationally with a total budget of $12 million over 5 years. The Hunter based ME Program involved contextualising the Year 9 to 12 curriculum with real world experiences and an emphasis on advanced manufacturing technologies. The program evolved into an embedded cross disciplinary school based curriculum known as iSTEM. It integrates the traditionally separated STEM subjects in an environment that utilises higher order problem solving strategies and employs emerging technologies such as robotics and additive manufacturing. Problem based learning strategies and industry collaboration are integral to the success of the “ME Program”. Student enrolment data was collected throughout the program to assess changing patterns on STEM subject choice. Schools involved in the program have seen significant increases in enrolments in STEM based subjects.

Introduction
In 2012, the Chief Scientist of Australia, Professor Ian Chubb produced a report that highlighted the importance of science, technology, engineering and mathematics (STEM) education in Australia and indicated that a failure to act on many issues raised in the report “...would put us at a growing disadvantage in maintaining our national wealth and security.” (Chubb & Kusa, 2012). Another key body, the Australian Industry Group (AI Group) has stated that a future workforce skilled in STEM is fundamental to Australia’s productivity and competitiveness. “...Australia’s productivity and competitiveness is under immense pressure. A key way to meet the emerging challenge of developing an economy for the 21st century is to grow our national skills base - particularly the Science, Technology, Engineering and Mathematics (STEM) skills of our school leavers. Our relative decline of STEM skills is holding back our national economy and causing real frustration for employers” (Willox, 2012).

Analysis of Australia’s Programme for International Assessment (PISA) results over the past decade is a source of major concern. In 2000, Australia was ranked third overall and in less than a decade we have slipped to 19th in mathematical literacy on the PISA scale, which is some three years of schooling behind Shanghai-China (1st). In science literacy Australia (16th) is some two years behind Shanghai-China (Thomson, De Bortoli, & Buckley, 2012).

Internationally there are concerns that there are an inadequate number of STEM skilled workers to support economic growth. In developed countries there is an observed decline in interest for students to study STEM. In Australia the proportion of students studying mathematics and science in Year 12 has decreased and continues to decline slowly (Chubb & Kusa, 2012). Between 1992 and 2009, the proportion of Year 12 students taking physics fell by 31% and chemistry 23% (Lyons, 2012) cited in (Chubb & Kusa, 2012). Over the past 15 years, there has been an overall decline in the proportion of students studying mathematics, however more concerning has been the historical shift from the advanced to the more
elementary mathematics courses (Barrington, 2011). At the university level, enrolments in STEM courses as a percentage of all enrolments fell in the 1990’s and were flat between 2002 and 2008. In recent years there has been a slight increase in numbers, but not at the levels required for sustained economic growth (DEEWR, 2013). There is also now universal acceptance by industry and government that there is a severe shortage of students completing Engineering at University (Myers, 2012).

It has been estimated that at least 75% of the fastest growing occupations require STEM based skills and knowledge. However, according to the AI Group, young people in schools and universities are not acquiring the STEM skills we need for our future prosperity (Willox, 2012). In the “Science, Technology, Engineering and Mathematics in the National Interest” position paper, from the Office of the Chief Scientist, the authors suggest that in order to reverse the declining trends in STEM participation, school curriculum and syllabi should provide a strong focus on the practice of STEM; should be delivered in ways that encourage curiosity and reflection and that Inquiry Based Learning should be emphasised (Chubb, 2013).

Advanced manufacturing school pathways program
The downturn in the total number and performance of students in STEM based subjects threatens to disrupt Australia’s performance amongst all industries and sectors but perhaps none more so than Australia’s Defence Industry. The Defence Materiel Organisation (DMO), which is part of the Department of Defence, exists to meet the Australian Defence Force’s military equipment and supply requirements. In response to the continued decline in STEM, the DMO set up the Advanced Manufacturing Industry Schools Pathway Program in 2010, with a budget of $12 million over five years. There are three DMO funded Advanced Manufacturing Industry School Pathways Programs strategically set up in areas around Australia with Defence manufacturing capability. All three programs are focused around increasing the number of students studying STEM and aim to increase the pool of young people ready to move from school into tertiary education, apprenticeships, cadetships, scholarships and part-time work/study combinations. The three programs include:

1. **Advanced Technology School Pathways Program – South Australia** administered by the South Australian Department of Education and Community Services.
2. **Marine Industry School Pathways Program – Western Australia** administered by the Western Australian Department of Education.

**Regional development Australia Hunter (RDA Hunter)**
RDA Hunter, formed in 2009 works in partnership with federal, state, territory and local governments to develop and strengthen regional communities of Australia. It has a pivotal role in ensuring the long-term sustainability of Australia’s regions. RDA Hunter was awarded the contract to deliver the ME Program in 2009 under a $2.9 million funding agreement with the DMO.

The purpose of this study is to review the Advanced Manufacturing School Pathways Program from the Hunter Region of New South Wales, Australia to determine if the ME Program has met its original objective of increasing the number of students studying in STEM and if the program could be expanded to form the basis of a broader STEM initiative.
Advanced manufacturing school pathways program - The “ME Program”
The Manufacturing success through Education (ME) Program provides high school students from Years 9 - 12 with educational pathways and vital work experience required to assist them to build careers in engineering and in advanced manufacturing. In 2010, a pilot of the ME Program began with the main objectives of:

1. Increasing the pool of students studying STEM based subjects.
2. Contextualising Board of Studies, Teaching and Educational Standards curriculum.
3. Updating teacher’s awareness and understanding of advanced manufacturing.

After the successful pilot in 2010 the ME Program expanded each year and by 2014 the majority of government, independent and catholic high schools in the Lower Hunter had involvement in the program. Schools were provided with funds and support in order for them to facilitate STEM based enrichment activities tailored to the individual needs of their school. Much of the success of the ME Program is related to the flexibility the funding provided, which was also utilised to purchase leading edge equipment, such as 3D printers, CAD/CAM systems, CNC routers, wind/smoke tunnels, robotic systems, quadcopter drones and Information and Communication Technologies. Students were provided with the tools required for 21st century problem based learning.

The ME Program evolved each year based on feedback gained from industry, schools and other key stakeholders. The program facilitated problem based learning activities and provided opportunities for schools to participate in STEM based enrichment programs, such as: FlinSchools Innovation Challenge, administered by Re-engineering Australia (REA) Foundation; RoboCUP Junior; MECO2 Dragsters Science and Engineering Challenge; Honeywell Engineering Summer School; numerous engineering roadshows; Electric Vehicle Festival and the Internet of Things. Teacher and student involvement in these STEM based enrichment/intervention activities has been fundamental to the success of the program. They have enabled students to develop key competencies and capabilities which mimic those required by the manufacturing and engineering workforce.

Local manufacturing industries in the Hunter Valley have enthusiastically embraced the ME Program with over a dozen companies partnering with local high schools. Such partnerships have provided opportunities for teachers and students to develop an understanding of what skills are required by industry. Strong partnerships have also been built through links to Universities, TAFE, and other educational providers in the Hunter region.

Through industry partnerships students in the ME Program have been immersed in a broad range of activities targeted at career based education. This has been designed to support the development of the Hunter’s manufacturing and engineering industry. Students have improved their understanding of manufacturing processes by visiting local industries, work experience programs and being provided with hands-on learning experiences in advanced manufacturing and engineering education.

Contextualisation of the Board of Studies, Teaching and Educational Standards (BOSTES) curriculum has been a major ME Program objective. An interactive web based system known as the “Living Toolbox” was developed to assist teachers to contextualise curriculum content with industry relevant examples. The Living Toolbox resources are broken into four key areas; science, technology, engineering and mathematics and attempts to provided teachers from each faculty area with a rich source of industry relevant content. A large array of STEM based resources have been developed by the ME Program and delivered through its Living Toolbox. The ME Program has utilised the enterprise social networking service, ‘yammer’ to
share contextualised curriculum content and provide a platform for ME Program teachers to share ideas and to seek advice.

Perhaps one of the most innovative aspects of the ME Program has been the development of the integrated science, technology, engineering and mathematics program known as iSTEM. An initiative of the ME Program, Maitland Grossmann High School and industry, iSTEM is a Stage 5 (Year 9 & 10) school developed, BOSTES endorsed course (SDBEC) which aims to contextualise curriculum content using problem based learning activities. It is unique in the fact that it was developed in consultation with local manufacturing industries and integrates the often separately taught components of STEM. The curriculum was first endorsed by BOSTES in 2014 and was delivered by seven local schools. The number of schools delivering iSTEM in the Hunter will increase in 2015 and is likely to expand into the Illawarra through a partnership with the ME Program, Maitland Grossmann High School and the University of Wollongong.

The ME Program identified teacher awareness and understanding of advanced manufacturing skills as an area of opportunity. Through local industry partnerships teachers were given opportunities to spend time in the workplace of various advanced manufacturing and engineering companies. Resources were developed and delivered to teachers through the Living Toolbox and via teacher professional learning activities. The ME Program organised high quality teacher professional learning opportunities through a series of breakfast lectures, full day training courses in areas such as robotics and LEAN manufacturing and presentations from leading experts such as well-known demographer Bernard Salt.

Methods

A key indicator of the success of the ME Program was identified as increasing the number of students electing STEM based subjects in Year 11 & 12. In order to determine if the ME program was successful, an in depth analysis of enrolment patterns from 2011 to 2014 of ME students in physics, engineering studies and mathematics extension 1 was undertaken.

From a total of twenty-six schools, twelve were sampled for Years 11 & 12 subject choice data from 2011 to 2014. Schools were selected from Government, Catholic and Independent sectors. Subject selection data was taken after the previous year’s selection process was completed, which usually occurred between August-September. Data was collected from a larger number of schools, however some provided incomplete data sets. Missing cohort numbers or missing subject numbers in any year excluded that school from the analysis. All junior schools (7-10) were also excluded, as Years 11 and 12 subjects are not offered at these schools, leaving twelve schools in the data set. The total Year 11 and 12 cohort numbers from these twelve schools are shown in tables 1 and 2.

<table>
<thead>
<tr>
<th>Year</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 11 cohort size</td>
<td>1872</td>
<td>1759</td>
<td>1892</td>
<td>1950</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 12 cohort size</td>
<td>1543</td>
<td>1453</td>
<td>1530</td>
</tr>
</tbody>
</table>

The number of Year 10 students electing physics, engineering studies and mathematics extension 1 as a percentage of the entire school cohort in Year 11, was recorded from 2011 to 2014. The average of these percentages was taken over the twelve schools. These averages are shown in Figures 1, 3 & 5. They also compare the percentage enrolments for Year 11 across NSW. Year 12 subject enrolments were also taken as percentages across the twelve selected schools and compared with all NSW schools from the 2011 to 2013 Year 12 cohort.
This enabled comparison of subject retention rates for the STEM subjects of interest: physics (Phys), engineering studies (ES), and mathematics extension 1 (MExt1).

**Results and discussion**

**Physics**

Figure 1 shows that in 2011, just prior to the ME programs implementation, the percentage of students electing physics in Year 11 (13.9%) was less than the NSW state average (15.0%). By 2014, after the ME program had been established for a short number of years, the percentage of total enrolments had increased to 18.5% compared to the state average of 15.0%. The positive exponential trend line for ME schools shown in figure 1 demonstrates a positive correlation between the activities undertaken in the program and students enrolment patterns and attitudes towards physics.

This increase in students electing physics in Year 11 has also resulted in above average number of students matriculating into Year 12 physics. By 2013, 15.9% of the ME program students were studying physics in Year 12 compared to 12.9% for NSW (Fig. 2). The positive ME trend line against the static or declining NSW trend is a strong indication of the change in student perceptions of the subject and the ability of the ME program to establish relevance to the cohort.

Data prior to 2011, indicated that students in Hunter Region schools historically had below NSW state average enrolment in Year 11 and 12 physics (BOSTES 2014). In the context of a region with high employment in engineering and manufacturing, this below trend enrolment data has the potential to be a limiting factor in maintaining viable growth in local industries.

According to Chubb (2012) the proportion of Year 12 students in Australia completing physics at high school fell by 31% between 1992 and 2009. The ME Program has shown that it has the ability to increase student enrolment numbers in physics and without intervention the continued decline in student enrolment numbers is likely to continue. If the ME program results were replicated nationally it would go a long way to meeting the key objectives set out in the Australian Government’s position paper “Science, Technology, Engineering and Mathematics in the National Interest: A Strategic Approach” (Chubb & Kusa, 2012).

![Figure 1: Physics Year 11 enrolment, as a percentage of total cohort, 2011 – 2014. ME Schools vs NSW state average.](image1)

![Figure 2: Physics Year 12 enrolment, as a percentage of total cohort, 2011 – 2013. ME Schools vs NSW state average.](image2)
**Engineering studies**

Enrolment data collected in 2011 indicates that the percentage of ME Program students electing engineering studies in Year 11 (4.7%) was greater than the NSW state average (4.0%). The healthy enrolment numbers compared to NSW averages could be explained by the fact that the Hunter Region employs large numbers of engineers across many industries. Encouragingly by 2014, the percentage of total enrolments in engineering studies of ME students had increased to 7.5% compared to the NSW average of 4.0%. The strong uptrend demonstrated in total enrolment numbers in Year 11 strongly contrasts that of the flat enrolment numbers of NSW.

Further analysis of the engineering studies data reveals that once students in the ME Program had elected engineering studies they were more likely to continue on in the subject in Year 12. In 2013, the dropout rate from engineering studies between Year 11 and 12 in NSW was approximately 30% whilst the ME Program schools was around 13%.

Based on the three year data set shown in Figure 4, HSC enrolment numbers increased to a larger degree compared to the relatively flat NSW average each year the ME Program was in operation. This is a strong indication that the program has the potential to achieve even better results if allowed to continue beyond its current five year time line.

Engineering studies enrolment data has shown dramatic improvements since the implementation of the ME Program in the Hunter Region as evidenced by very positive trend lines shown in the enrolment data (Figures 3 & 4). This success can be somewhat explained by the fact that many of the teachers who have facilitated the ME program within schools have been engineering studies teachers. These teachers have been able to easily adapt their teaching strategies to implement science and mathematics concepts through an inquiry based learning approach. The nature of the engineering studies syllabus has meant that these teachers already have the ability to easily contextualise STEM content.

![Figure 3](image-url)

**Figure 3:** Engineering Studies Year 11 enrolment, as a percentage of total cohort, 2011 – 2014. ME Schools vs NSW state average with ME trend line.

![Figure 4](image-url)

**Figure 4:** Engineering Studies Year 12 enrolment, as a percentage of total cohort, 2011 – 2014. ME Schools vs NSW state average with ME trend line.
**Mathematics extension 1**

Despite the strong up trend for physics and engineering studies, mathematics extension 1 has not enjoyed a similar level of success. Figure 5, shows that mathematics extension 1 enrolment numbers in Year 11 have only slightly increased for ME Program schools and only in 2013 did the enrolment percentage exceed that of NSW. ME Program schools also show a larger drop from Year 11 to Year 12 enrolments than do NSW state schools. It would appear that the schools included in this study have much greater difficulty retaining mathematics extension 1 students than the NSW average. Encouragingly, there is a slight up trend in the Year 12 ME enrolment numbers compared to the slight down trend in NSW state numbers (Figure 6).

The lack of similar success in the mathematics extension 1 could be explained by the seeming lack of enthusiasm by mathematics teachers for the ME program when compared to other faculty areas. According to John Phillips from Engineers Australia that the success of many STEM programs “all depend upon dedicated champions...” (Phillips, 2014). School based champions of the ME program have chiefly come from technology and science faculties and the ME program merits have generally not been as enthusiastically embraced by mathematics teachers.

This data would suggest that much more work needs to done to ensure that students in the Hunter Region increase their participation in advanced mathematics. The lower than NSW average enrolment rates in mathematics extension 1 would suggest that intervention programs like those proposed by the ME Program are essential. This may require more emphasis being placed on programs to assist mathematics teachers to contextualise their curriculum in ways that encourage greater student participation and engagement.

![Figure 5](image1.png) ![Figure 6](image2.png)

**Figure 5:** Mathematics Extension 1, Year 11 enrolment, as a percentage of total cohort, 2011 – 2014. ME Schools vs NSW state average with ME trend line.

**Figure 6:** Mathematics Extension 1, Year 12 enrolment, as a percentage of total cohort, 2011 – 2014. ME Schools vs NSW state average with ME trend line.
Conclusions
ME Program schools have seen significant increases in the total percentage of student enrolments in physics and engineering in Years 11 & 12 and significant improvements in retention rates of students in these subjects from Year 11 to 12. These subjects now also compare favourably to NSW averages as a result of their participation in the program.

Small gains have also been demonstrated in extension mathematics 1, however it has not experienced the same high level of improvement demonstrated by physics and engineering studies. Mathematics extension 1 average enrolment percentages in the Hunter are stubbornly below that of the NSW norms. A future ME Program will need to place further emphasis on teacher education programs and initiatives to engage mathematics teachers and students.

Analysis of the data suggests that the ME Program has been very successful in increasing overall enrolment numbers in its targeted areas. Data also suggests that the program should continue to produce increasingly favourable results if it is to be extended beyond its current five year life span. It is clear from the research that STEM education, as the Chief Scientist of Australia has suggested, is a national imperative. The ME Program has demonstrated a capacity to deliver a number of the outcomes required in a National STEM initiative and therefore educational bureaucracies nationwide should consider adopting this program to help secure Australia’s future productivity and competitiveness.

Acknowledgements
I would like to acknowledge Mr Ashley Cox the program director of the ME Program from RDA Hunter for his support in the development of this paper. RDA Hunter provided the school based enrolment data used in the analysis of this program. Mr Peter Wall from Envisage Learning also made substantial contributions to the collection and analysis of the data used in this paper whilst under contract to RDA Hunter.

References
BOSTES. (2014). NSW subject enrolment data accessed through Board of Studies.