in Schools
Re-Engineering Australia Foundation Ltd

Re-Engineering Australia Foundation

STEM 4.0 LIFE-LONG LEARNING

21 Years
Re-Engineering Australia

Re-Engineering Australia Foundation

Re-Engineering Australia Foundation (REA) is a not-for-profit charity and Deductible Gift Recipient focusing on the implementation of a educational programs which take the concept of STEM education to another level. By focusing on the analytical problem-solving capacity, communication and collaboration skills of students, we help build resilience and character, preparing them for their future careers and the world of work. REA's programs promote career relevance, life-long learning and foster the transition of knowledge from primary school, through high school, University and directly into industry.

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Executive Summary

This paper examines the historical development of education; the role industry has played in that development and the reasons behind the creation of STEM as a catalyst to lead a change in educational strategy. It examines the definition of STEM 4.0 and presents alternative structures for the education system, which support STEM, and examines students outcomes resulting from deep engagement with STEM 4.0 activities.

Re-Engineering Australia Foundation (REA) has been implementing STEM 4.0 programs built on the concept of Life-Long STEM Learning in schools for the past 22 years. To date, REA has engaged with over 1,000,000 students in Australia and achieved remarkable results in terms of improving educational outcomes, which have been validated by the performance of Australian students on the world stage.

Longitudinal research undertaken by REA over 14 years supports the notion that the application of STEM 4.0 and Life-Long Learning can have a significant impact on education outcomes across all subject areas not only Science, Technology, Engineering & Mathematics.

STEM 4.0 is the repositioning of the underlying fundamentals of STEM education which have in the last few years become waylayed. It requires a change in the institutional attitudes and culture if it is to influence the outcomes that are being sought by industry and the creation of learning experiences that deliver those outcomes. It requires moving away from a siloed education to a networked, cross-curricular environment where knowledge is shared freely and where we promote linkages between schools and industry.

This document intends to provide feedback on existing research into the application of STEM 4.0 and to initiate discussion and debate on the changes required in the existing educational processes.

Introduction

At a time of rapid technological advancement, It is crucial to provide approaches to help the delivery of STEM-based education and technologies in the classroom. Technologies which facilitate the development in students of the employability skills industry seeks and that aid in their transition to the world of work.

STEM education by its original definition is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons to promote students applying science, technology, engineering, mathematics, and other subject skills as required. It provides a platform from students to develop problem-solving skills and aims to build in students a range of competencies which will assist their transition through life.

To be able to lift the competitiveness of students in today's career market, we needed to boost skill levels in ways current institutions struggle to achieve. Thirty years ago, the perception was that all you needed to excel in life was a University education. Today, a University education will no longer guarantee inclusion on an employment shortlist.

STEM, is an industry-driven concept, started as a well-thought-through strategy aimed at providing a platform for a change in the focus of the education system. Conceived to break down the silos of learning that have developed over the past three decades and replace them with a cross-curricular approach to problem-solving as a basis of learning. STEM was intended to deliver learning outcomes aligned with the skills needed in the modern work environment.

Team Triton : Primary Students from Prince Alfred College in Adelaide
SUBS in Schools National Champions 2016

Today's education environment is significantly different from the one that the majority of the current batch of teachers experienced. It is an environment filled with students who have access to vast amounts of knowledge, it has no national boundaries, and it contains more significant numbers of highly educated competitors all vying for the same opportunities. It requires teachers to be better at their trade than ever before.

The skills industry is seeking today are a far cry from the 3Rs of reading writing and arithmetic once asked for by industry following the war years. While the 3Rs are still critical drivers for primary education, to succeed, a student needs to leave high school with higher levels of competence in what have been called employability skills, enterprise skills or sometimes by industry: uncommon skills. These skills include communication, collaboration, teamwork, emotional intelligence, creative thinking, cognitive flexibility and entrepreneurship.

STEM is a platform that can help teach students and teachers work at the boundary layer that exists between humans and problems.

STEM is a concept meant to bring about an industry-driven change in the education system, based on promoting analytical problem solving and communication skills via real-world, in-context projects. The use of the terms analytical problem solving and communication should not be interpreted, as single words, but as combinations of a set of skills which together form a platform upon which knowledge facilitates developed solutions.

In a world that is changing daily, the ideas and concepts driving the development of STEM have unfortunately gone missing, particularly over the past 2-3 years: lost in an education bureaucracy more focused on the need to tick boxes of equity, achievement and quality control than on student outcomes.

STEM is being been misinterpreted and forced to fit within the existing silos, structures and fiefdoms that have grown up with education. An educational environment created 50 years ago but now choked by a bureaucracy seeking only to reverse engineer any new ideas to fit within the established educational silo structure in ways that dilute the value and the intent of any original thought. Within this bureaucratic environment, today the implementation of STEM rarely facilitates the cross-curricular integration of knowledge and skills that was intended. It rarely steps outside the existing silos structure, and its positioning today can usually be classified as one of the following:

1. The application of simply more science or more maths to placate the science and maths communities,
2. A set of activities or games which keep students occupied during the standard 40-minute period include an element of making, building or coding, sufficient to tick an achievement or equity box in one or more areas of science, technology, engineering or mathematics.
3. "Maker Spaces" designed to expose a generation students, more experienced at social media and computer games, to hands-on, innovative experiences once provided by fathers or grandfathers in the garage.

STEM activities should be learning experiences that deliver results that will help students compete in today's global environments. They should be focused away from low-level implementations designed to tick quality control or equity boxes and moved back to facilitating the development of the employability skills sought by industry.

Origins of Education

To understand the industry drivers behind the establishment of STEM, we need to understand the origins of the development of education since the 30s.

Lifting the educational standards of society following the second world war was a significant driver behind the design and development of the education system.

In the early years, employees with the knowledge of how to apply new technologies or processes were few and far between, and industry felt that the only way to fill the gap was by altruistically lifting general education standards. The 3R's of reading, writing & arithmetic became the mantra of the education system. After the war period, the education system had to change to be able to deliver more significant numbers of more employees capable of filling manufacturing plants.

The application of volume manufacturing techniques accelerated at a rapid pace building economic wealth as nations sought to lift the status of their citizens. With this rapid advancement came the need to increase the level of skills and competence across all of society to keep pace with the advancing application of manufacturing technologies. Industry needed to create productive workers who understood democratic values and who had the knowledge and skills to contribute to national productivity.

Industry was, to some extent, driving society to achieve the higher levels of expertise and competence that it needed to take full advantage of the advances it was making.

Educators in the early 20th century, represented notably by Ellwood Cubberley, were genuinely interested in creating schools that educated with the same efficiency that the industrial revolution had brought to the factory system of production.

Based on the production principles created in industry at the time, there was a belief that these techniques would be the most modern innovations for creating efficiency in education. According to Cubberley, schools were to be: "factories in which the raw materials (children) are to be shaped and fashioned into products to meet the various demands of life. The specifications for manufacturing come from the demands of twentieth-century civilisation, and it is the business of the school to build its pupils according to the specifications laid down."

This approach, which was considered scientific and based on theories of social efficiency, was predicated on three main concepts of Ellwood Cubberly:

1. The School as Factory
2. The Child as Product
3. Standardised Testing as Quality Control

The child was considered as a piece of raw material to be shaped by the educational 'factory' into a quality 'product'. Teaching became viewed as a form of training and schools were expected to operate more like assembly lines, working on children as they passed through various stages of the curriculum. It's a story featured in one of Sir Ken Robinson's TED Talks. It's a story told by John Taylor Gatto in his 2009 book Weapons of Mass Instruction and a story echoed by The New York Times' David Brooks.

Improving educational standards was seen as a social issue, so to make this happen industry handed responsibility for the education process to Governments. An unfortunate outcome of industry stepping back from the process of education in Australia has been a growth of bureaucracy surrounding training crafted on the model of Cubberly and based on silos.

As with all vast bureaucracies, the levels of competence decreases in inverse proportion to the size of the administration (Peter & Paul Principles). The growth of fiefdoms designed to maintain control, cover up incompetence, resist change and ensure status quo was inevitable and can be seen playing out even down at the level of teaching staff with the creation of departments of Science, Maths & English, Departments who tend to protect their turf and oppose the promotion of cross-curricular education.

Team Hyperdrive : Trinity Grammar School Kew, 2017 F1 in Schools World Champions

Disruption

We now live in a highly educated society that appears to absorb technology easily. We have come a long way in lifting the educational standard of our children since the 1950s. We now have people at all levels willing to innovate, and we have an economic system in place which allows access to the support and the finance needed to bring ideas to fruition.

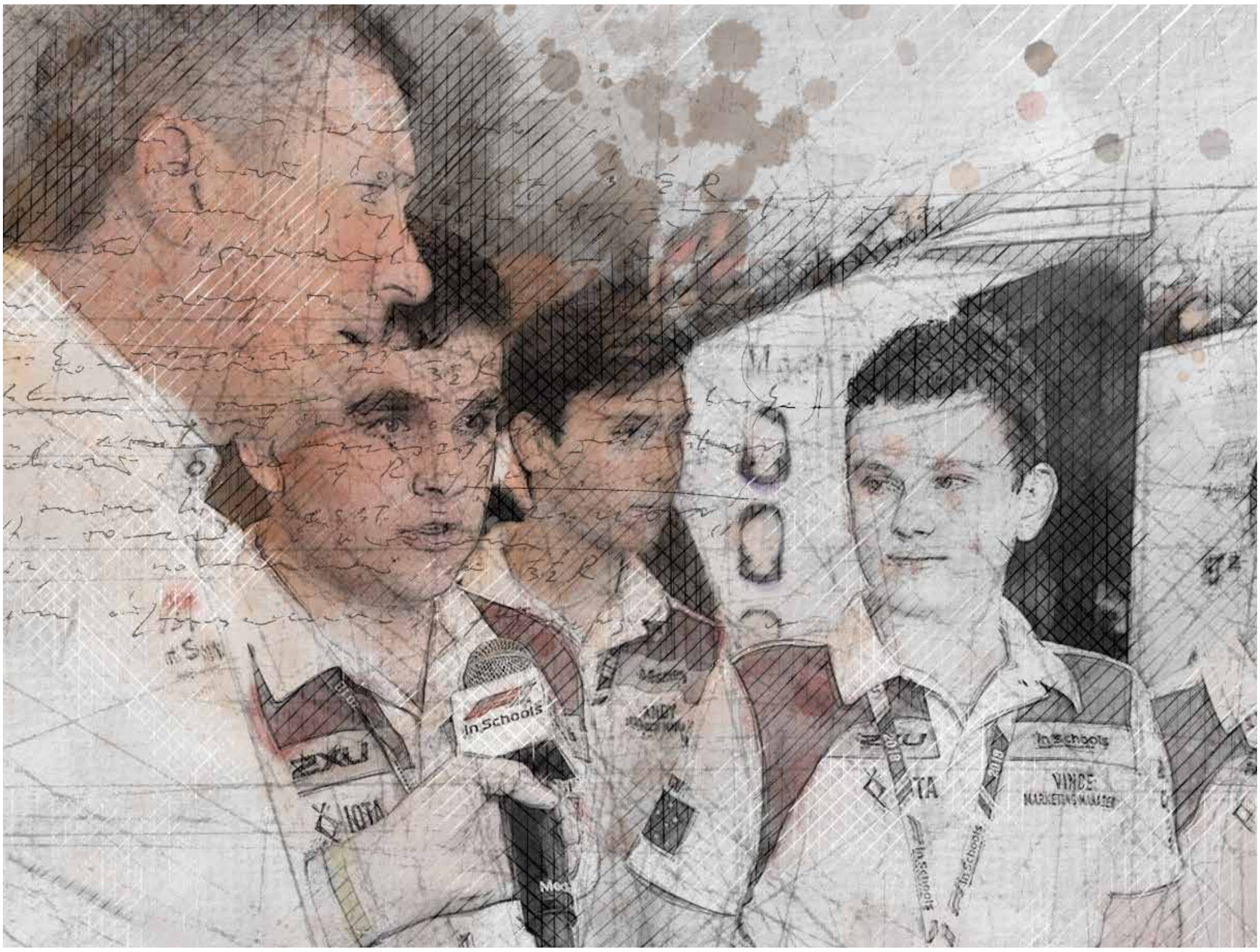
We have moved from industry driving the development of society, to society now driving the growth of industry as a now well-educated market dictates the products, processes and services that it wants or requires.

We are in a golden age for the transition of ideas to reality yet the education system is still running with a mentality of producing factory students, delivering knowledge in silos and measuring students against universally standard (quality control) testing regimes, driven by equity and by the need to create the child as a product. While the current educational standards and delivery methods are a vast improvement on the '50s, they are on longer keeping up with the rest of the world.

The strategic advantages of the education system were once:

1. Owning the knowledge of the "Science of Things",
2. The capacity to break down the "Science of Things" into bite-sized chunks ready for equitable deliver.
3. Owning the channel of distribution for the "Science of Things" and providing equity in the delivery process.

Disruption has taken all of these strategic advantages away. The earth between the feet of education is shaking and it now needs to reposition itself, or it will fall into a chasm. Today, the "Science of Things" is accessible by everyone, anywhere and anytime, and the strategic advantages the education system once had no



longer exist.

There is a clear opportunity within this turmoil, for points of strategic differentiation for the education system, which can not be replaced by technology. These strategic opportunities and the need for change, particularly in High School, do not need to spell doom and gloom for schools, teachers or the education system, only the bureaucracy.

What is not always readily available in a world of ubiquitous access to information, is the knowledge of how to interpret and apply information in context, and how to understand and decipher the massive amounts data now available which can help solve problems. We are entering the era of Big Data, and we need to learn how to accommodate the opportunities Big Data presents and how to fit these within the education system. Further discussion on the concepts surrounding Big Data appears later in the section on Industry 4.0.

To use a football analogy: you can read a great deal about the rules of rugby, and you can undoubtedly watch thousands of videos about the game, but the first time you walk onto the field, and into a scrummage, you soon learnt that google didn't adequately prepare you for what it would feel like in the scrummage - particularly the thump you received from the opposition when the referee wasn't looking. Interpretations of the rules, and what you can get away with, are the things a good coach would have highlighted and it is this level of coaching that is now required in the classroom.

In a disrupted education system, the critical role left for teachers is to become the coaches able to help students interpret the vast amounts of data available to them and help them understand the problems they may face in interpreting that data. Coaches who can warn students about what might happen in a scrummage, and can bring real-world relevance to the process of problem-solving.

You can't win a rugby game out of a book, but you can win if you have a good coach.

Teachers as educational coaches will need to be able to understand the relevance of knowledge and be able to move freely across the areas of knowledge. They will need to have a high level of cross-curricular knowledge and possibly work in teams to deliver specific experiences when required in the classroom. Teachers should help students with the application of knowledge in a similar way to the use of Apps, each providing part solutions to a more extensive problem-solving process. As an example, a Design & Technology teachers may call on teachers who have a specialisation in Science, Maths or English to their class to deliver a specific understanding on topics that are related to the projects the students are working on and visa versa.

STEM is about the capacity to source expertise and knowledge to solve problems. At its core is the concept of teachers as coaches or conductors of knowledge.

Australian Industry Perspective

Acronyms and slogans can create a change point around which new ideas can abound, and the concept of STEM was industry's attempt to create an acronym and change point which would refocus educational outcomes back in line with its needs. The STEM acronym came about in the hope that educators would understand the value of providing a platform that makes the connections, not only between knowledge but also between industry, and the skills required in the world of work. Industry is ultimately the employers of the output of the education system but has played an insignificant role in Australia in shaping the development of education since it handed its responsibility for management of education to Governments decades ago.

It has, however, now become widely accepted across industry and politics that Australia has been through severe shortages of skilled people. While deficiencies are not currently perceived to be politically sensitive since the global economic downturn of 2009, and the slowdown in the mining industry, it is the increase in Defence projects such as the Future Submarine Project and the every increasing infrastructure projects that will again drive the shortage of engineers, project management and supporting professions.

While these shortages can, to some extent, be related to specific sectors of the economy, there has been a universal acceptance by industry and Government alike that there is a severe shortage of students completing Engineering and other STEM based courses at University (Heydt 2003). Consequentially a need exists for more students to take up prerequisite study at high schools which facilitate participation in Science, Technology, Engineering and Maths pathways such as Engineering.

The response by successive Federal Governments to the shortage of Engineers and Scientists has resulted in rhetoric focused on the development of a skilled nation. Within this rhetoric, the Government granted the industry a significant leadership role, yet it failed to understand its responsibility, nor take the opportunity to use its leadership position to attract students to professions critical for success.

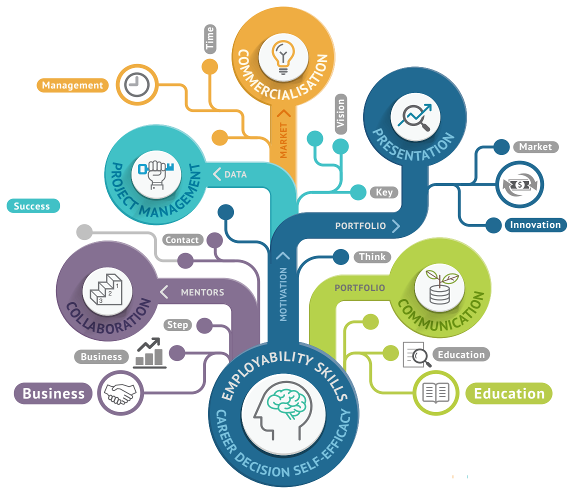
Adding further to this environment, during the 1980s, an educational policy convergence between the major political parties toward economic rationalism had both sides of politics becoming particularly responsive to industry spokespersons and financial analysts who advocated that education restructures according to market principles (Pusey, 1991, Marginson, 1993, Seddon, 1999). As a result of this economic rationalism, the ideological imperatives for the development of a skilled nation became way-laid by a big business focus on short term solutions that have shown little, if any, interest in engaging students, or establishing the set of crucial skills that industry wants from the education system. Nor has it helped teachers or administrators in developing the attractiveness of critical professions such as Engineering (AIG, 2006). As a result, "Over the past four decades, Engineering has suffered a poor profile leading to less interest from high school and university students" (Heydt, Jan/Feb 2003).

What little, by way of industry developed career intervention programs aimed at attracting students to appropriate occupations, that has taken place, in the vast majority of cases, has been ad-hoc and ill-structured in terms of their design, implementation or measurement of outcomes. In most cases, while the outcomes have had an impact on increasing awareness of STEM for those who participate, they are having a minimal effect outside the environment surrounding the participants. In addition, few if any of these programs have had their design or construction based on fundamental social science research which could add significant validity to the processes being called upon to achieve the required intervention outcomes.

Within the development of a skilled nation lies an ill-defined description of the skills required to achieve this national aim. The industry definition of necessary skills (employability skills) emphasises the role, definition and measurement of a range of soft skills which are somewhat ambiguous and imprecise. With industry lacking understanding of the education process the responsibility for the construction of learning environments to develop these employability skills landed in the lap of the VET systems (Billett, 2004), a system driven by people ill-prepared for the task at hand.

While there has been significant energy within the Australian context to attempt to understand the drivers and influencers impacting the attraction of students to key professions such as Engineering (Lewis and Vella, 1885, Australian Committee on Technical and Further Education, Kangan, 1974, Government, 2006, AIG, 2006, Raison, 2005, Initative 2001, Govenment, 2001, DEST, 2005, Engineers-Australia, 2004, Macquarie-University, 2005, Australian-Government, 2001, Australia, 2011b, Australia, 2011a) few of the organisations involved in these studies have had direct involvement in designing or developing intervention programs to meet the goals they have identified. More recent research (King et al., 2011, Watson and McIntyre, 2011, Wise et al., 2011) continued to highlight the need for a clear definition of the pathways and activities which lead students into careers such as Engineering.

As populations have become highly educated STEM is about starting the process of recombining education into a learning platform which will move and change with the problems it seeks to resolve.



Industry Competencies

Industry's requirements of the education system once revolved around boosting core skills of Reading, Writing & Arithmetic. In the past 30 years, however, industry's needs have advanced significantly with the advancement of technology. They now take for granted that the 3Rs exist in everyone.

When it comes to education, industry has no issue concentrating its internal training efforts on specific industry skills which are unique to that industry, and they are happy to bring new entrants into line with its own culture and ways of doing things. The industry benchmark for required skills in new entrants has changed. Industry is now looking for a set of what it calls employability skills. Skills that are not explicitly taught in school, and to no small extent, not-common in the general populous. The skills industry would like to see in new entrants revolve around 12 core competencies (Refer Figure 1). Various forms of this set of competencies have been proposed by the Australian Industry Group and many other industry agencies. Most States and Territories have also produced documents defining Employability Skills Frameworks based on similar core competencies, yet the leap from proposition to delivering a change in the education system has not been achieved.

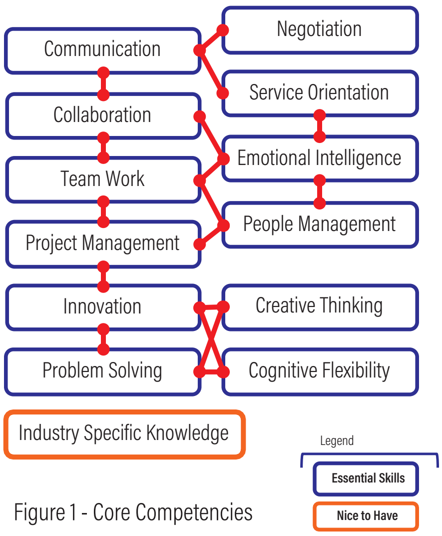


Figure 1 - Core Competencies

Industry believes that these competencies should be taught in schools and not in the workplace. From their perspective, these skills are now the equivalent of the 3Rs and if they were able to access new entrants with these 12 competencies, they would be a long way further down the path of bringing innovation, efficiency and profitability to fruition.

Of these, our capacity to communicate is most evident in a range of business functions including our ability to negotiate, manage people, collaborate, be service orientated, have emotional intelligence, work in teams and manage projects. Project Management, innovation, creative thinking, problem-solving and cognitive flexibility all have links to our capacity to combine analytical based problem-solving with communication.

The current education system, however, has very few if any of these skill areas designated explicitly as educational outcomes nor are there subject areas which directly focus on building these skills. While there may exist a desire to promote competencies in these areas, the school system is not structured via curriculum to support them directly. While the current Australian curriculum has room within which to allow the creation of these skills, they are not defined outcomes. It is left to teachers to build in activities which develop these unique skills, and this is done, in most instances, without guidance.

At present, industry does not have the capabilities to measure the level of competences of new entrants, particularly in these 12 skill areas. All that currently exist to aid choice between applicants is an ATAR (Australian Tertiary Admission Ranking) which has little connection to any of the skills they are keen to measure. As a consequence, employee selection can, in most cases, be little more than a lottery.

Underlying Social Competencies

The social hierarchies we live in, survive because of the inherent trust we have in the capacity of our leaders to solve problems and to communicate our way through the process.

It is how well we can operate at the interface between people and problems that will define our capacity to manage the outcomes we seek. Without an ability to solve the problem and to communicate the solution effectively, we quickly fall into anarchy.

Even though we live in a highly educated world where advancements in science and technology allow us to resolve the most critical of situations, we are not invincible. Rarely can problems be solved by single-point, black & white solutions. Most require high levels of communication during the process to ensure we clearly understand all of the issues involved and can manage through those issues to resolution: a fundamental of Project Management.

The emergence of the threat from the COVID-19 has highlighted that we live in an ever-changing world and it will be our capacity to handle risks and challenges such as COVID-19 that will determine our ability to survive and thrive.

The competencies society is drawing upon to resolve the COVID-19 environment are not only based on science or technology alone. While these are essential competencies, our capacity to bring together large amounts of data from disparate areas to develop a solution to the problems we face, is much more complicated than just the science of the situation. We are drawing on medical science, social science, technology, engineering and mathematics to develop components of the solution to this problem. However, these will be plug-ins which together will help us improve and implement solutions. In modern speak, we will use knowledge from different sources like Apps and calling on them when needed to help populate our analytical problem-solving capacity.

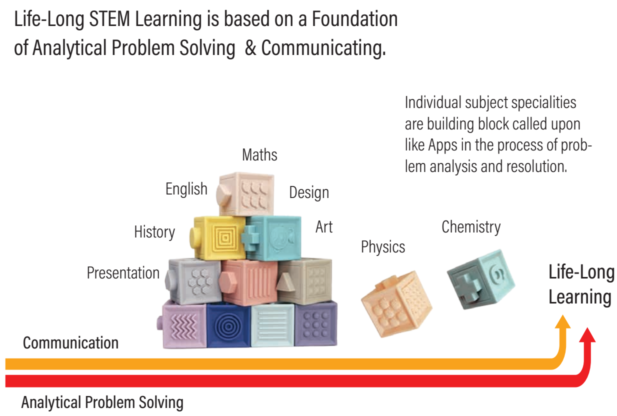


Figure 2 - Underlying Life-Long Learning Competencies

The methods being used to solve the real-world COVID-19 crisis, are based directly on the foundations of STEM learning. We work on developing these skills throughout our lives, and they should be at the core of our education system. It is on top of these base skills that we use applied knowledge to help provide solutions to the detail of any problem.

STEM Career Pathways

STEM is an acronym and not a word. There are no STEM career pathways as such, and there should not be a STEM subject.

If I were to examine the career path of an Engineer, while generally grounded in Science, Technology, Engineering and Mathematics, an engineering career rarely follows a STEM sequence nor is it stuck in the Engineering silo of STEM. Each engineer may travel a very different career journey which may touch on many areas, both technical and non-technical that may or may not relate to the simple definition of STEM or for that matter Engineering.

A map of my professional engineering career over the past 30+ years shows a convoluted path which continually engaged with skills and competencies way outside the traditional Engineering or STEM environment. Throughout, the universal constant has been a continuing dependence and improvement of my capacity to communicate and solve problems.

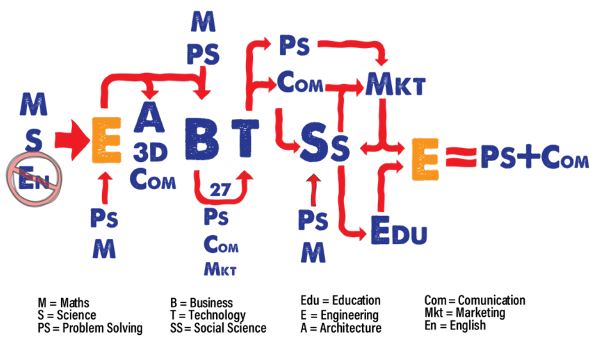


Figure 3 - Engineering Career Path Map

While at school, the main subjects I studied were Maths, Science & English, although I was never very good at English. I went on to study Engineering but was soon involved in art, architecture and the use of 3D design technology which facilitated me starting a business focused on Computer-Aided Engineering. This was at the very start of this technology becoming available. I was deep into business for 27 years, travelling the world learning how to communicate and operate in different environments.

Being in business dictates that you become at least reasonably competent at marketing, sales and collaboration, which lead to me undertaking an MBA to build on these skills.

While I was technically competent, the need to be able to deal and operate across national borders soon induced a realisation that I had to learn the social constructs that existed in each of the countries I worked. It also drove the reliance on combining analytical problem solving and communication as the foundation of all problem resolution.

It was not uncommon to travel from Sydney to Jakarta, step off the plane and immediately face a new language, new culture, new norms, new historical precedents and new bureaucracy. We would then fly to Tokyo and face the same issues of a new language, new culture and norms, unique history and a new administration. Next stop India before Thailand, Singapore and then back home. Each of these working environments is very different, and it was not a deep understanding of any specific STEM topic that was going to make these trips successful. It was the capability to understand and deal with all of the changing issues of history, culture, language, norms and bureaucracy in-context that allowed me to operate effectively and do business internationally against heavy competition from the UK & USA.

When we founded the Re-Engineering Australia Foundation in 1998, we lacked an understanding of social science issues underlying the career motivations of children. This lack of knowledge drove the Doctoral Social Science Research we undertook at the University of South Australia, into the Motivational Drivers of Children's' Career Decision Choices. While miles away from Engineering, an understanding of underlying human nature influencing career motivation and motivation, in general, was valuable knowledge which was aplicable to run any business successfully.

As previously highlighted the common thread in the development of my career was a focus on improving my analytical problem-solving capacity and communications skills. While I started as an Engineer and will always be an Engineer, I did not follow a Science, Technology, Engineering and Mathematics pathway. These were just Apps of knowledge I called upon to populate the skills I needed to solve the problems along the journey.

Our children will face the need to be able to operate empathetically and to move between cultures seamlessly, to communicate and solve problems.

Given the differing requirements of industry, the education system needs restructuring with a focus on these skills at its core as primary drivers rather than passive outcomes.

Education Mirroring Industry

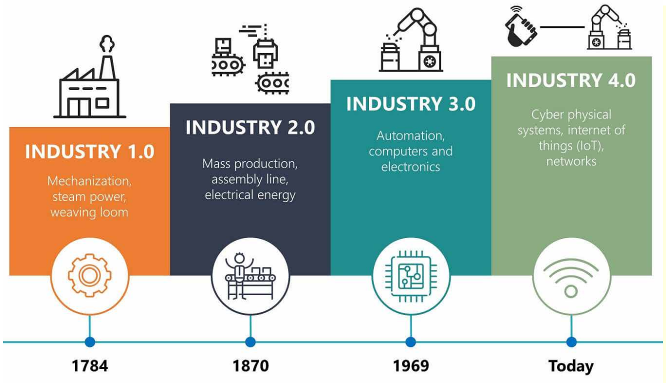
The industrial revolution, now called Industry 1.0, brought with it the mechanisation of work which our ancestors used to perform manually. The introduction of steam facilitated industrialisation and drove the transition from a rural to an urban lifestyle. It came with jobs and economic development.

The introduction of electricity and a focus on processes development facilitated assembly lines, and we entered the world of Industry 2.0. The first electric assembly line was constructed in 1870 but its was the influence of the world wars that provided the impetus for industry to apply the mentality of production line manufacturing to all manner of things, from planes to hamburgers and finally education.

With a need to rebuild nations, production line techniques provided a method to suppling the needs of large numbers of people with large quantities of high-quality components that were interchangeable and replaceable. It provided jobs and economic development for large numbers of people and facilitated the building of job competence in a population who at the time had little formal education. It provided a platform to build self-worth and self-efficacy and a structure around which people could build the stability missing for the many long war years.

The advent of the computer and automation drove the industrial scene and the transition to the era of Industry 3.0. It was during this period of transformation that we stepped into the age of the programmable logic controller (PLC) and the robot. Robots began performing repetitive tasks once performed by humans and machines started on the road to becoming intelligent. This was, unfortunately, implemented in silos with devices isolated from each other, much like the silos in education.

With the advent of Ethernet, the industry was able to start to connect machines, at least physically. Computers began the march down to the shop floor, and you could finally access data anywhere in the plant as the drive toward the paperless office continued. In most instances, however, the equipment still stood alone on



Industry 4.0

The fourth generation of industry development, often called Industry 4.0, is the era of Cyber-Physical Systems (CPS). CPS comprises of smart machines, storage systems and production facilities capable of autonomously exchanging information, triggering actions and control each other independently. This exchange of information via by an Industrial Internet of things (IIOT) in which thousands of sensors work real-time and transfer the data to a local server or a cloud server. Here the analysis of the data is carried out by developing predictive models which help the organisation to anticipate some irregularities in the processes or systems so that action can be taken well in advance, as opposed to taking action when a process or system fails.

A change to CPS will produce data in enormous volumes, often termed as Big Data. Analysis of this Big Data will help the industries to improve manufacturing processes, material usage, supply chain and life cycle management of the product. Industry 4.0 is about attempting to use internal protocols as a platform to support the collection of big data and its analysis: the end game if for machines to solve problems unaided.

In theory, it sounds terrific. It will be facilitated by the availability of pervasive networks, ubiquitous access to the internet, and build around an AP (Application Development) mentality to form the glue. The opportunities are potentially endless, but they are dependant on the development of sets of middleware upon which everything can communicate.

the shop floor like silent sentinels: silos of automation. The advent of networked PLC's started to provide a glimmer of hope as significant manufacturers like Siemens push their solutions for factory floor automation. The missing link to bringing everything together was a lack of a common platform on which different equipment could co-exist and communicate. Most equipment manufacturers had built their technology on propriety operating systems and code. The vision of a solution, software that could allow equipment and office systems to talk together seamlessly, came in the form of middleware: software code sitting on a proprietary Ethernet backbone able to connect disparate technologies and allow at least some level of backward and forward communication.

Given the millions of pieces of equipment on the market, each with a different language, the nirvana of a standard industrial communications language, as was the goal of "Esperanto" (the global language), was proving to be tough to achieve. The electronic factory did not progress much beyond point solutions. What industry came to realise was the importance of the understanding of the necessary information any system would need to move the vision of an automated factory forward. It needed to break down the silos of technology and reposition them as Apps that plugged together and communicated. Fundamental capabilities upon which industry would build if it were to advance and innovate.

Industry 4.0, the most recent incarnation of the development of industry, is little more than a vision for what is possible, but it is a vision and direction that industry can follow and innovate toward as it leads its destiny based on a set of fundamental principles. It will be the tool that will bring manufacturing back onshore, create careers for very high skills people and meet the needs of society to drive the development and application of technology for the betterment of society.

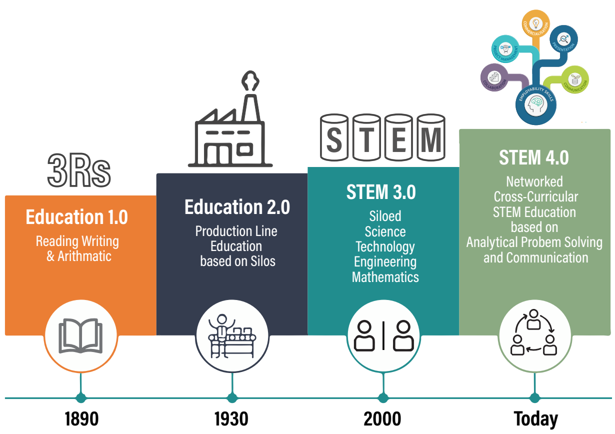
This position is very similar to where the education system finds itself in today. It has created silos of knowledge, each of which may pass muster under the gaze of a magnifying glass, but each has grown without an underlying strategic vision which would tie the different components of Education together to produce the best students in the world, and the students' industry is seeking.

Knowledge has made massive advances based on the application of technology. While industry is using the motivation of profitability as a powerful influencer to bringing about innovation and advancement toward Industry 4.0, Education has applied the brakes of bureaucracy, and educational standards in Australia are going backwards compared against an internationally competitive market.

Within a world of highly educated customers (students, parents & industry), Education must realise the fundamental underlying principles upon which its success lies if it is to achieve the outcomes required of it. It should allow all taught knowledge to link together, like Apps, to use current day speak, so all students can learn in a way that fits with the education pathway they will need to follow as they migrate through life. Education needs to be using the leap to STEM 4.0 as a change point upon which it can again universally lift the performance of Australia students.

Within Industry, the economic driver of profit lies behind the development of Industry 4.0. Within the education environments and bureaucracy, there is no similar commercial driver. There is only a propensity to maintain the status quo. Achieving improved educational outcomes will need to be top-down and will require the dismantling of many fiefdoms that exist to allow transformation to take place.

As has been highlighted, STEM education was a vision intended to dramatically improve the capabilities of the students in a way that would significantly enhance their career prospects. It is unfortunate that in most instances STEM is currently being reverse engineered to fit with the existing standard silos, structures, people and fiefdoms, and pushed back to what could be called STEM 3.0: silos of components of STEM. Its has become a series of separated point solutions back on the production line, and subject to a time and motion study to determine value.



STEM 4.0 Life-Long Learning

Throughout our lives, from our first day at school until long after we retire, the two fundamental skills that we continue to work on improving are our problem-solving capacity and our capacity to communicate.

The focus on these skills should start in primary schools and be built on through the education process. We should begin teaching students in kindergarten skills that they can rely on throughout their life journey and which will directly aid their transition to the world of work.

If schools are to focus on a continuum of improvement of skills that will assist students throughout their lives rather than having them concentrate on little more than gaining an ATAR score, they need to change the learning model. While the education system in primary schools has a high focus on the fundamental development skills (3Rs) and socialisation which are essential in the formative years, as soon as students reach high school there is a dramatic transition to production line learning made up of siloed knowledge based on 40 minute periods of learning.

The core competencies of reading, writing and arithmetic, first put forward as the fundamentals of education in the 1920s, have been surpassed by the need to focus on higher-order skills of analytical problem solving and communication which in most instances will not fit within a time-constrained teaching environment.

English, the subject taught at school for so long as a foundation has now become just a subset of a more critical requirement to have our children become good communicators. Our capacity to read and write, skills taught as essential components of English, will not get you very far. To be able to communicate in a much more literate world effectively requires competence in many of higher-order skills, the interplay between those skills and their use in a problem-solving environment.

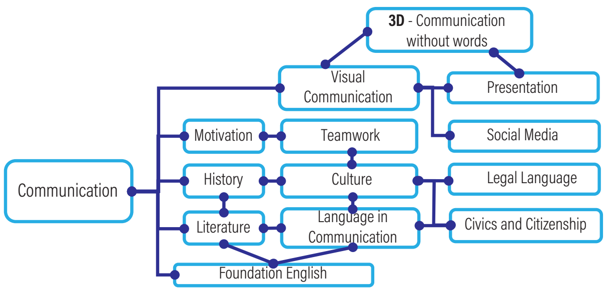


Figure 4

It may be time for "English" as a core subject to take a back seat to "Communication" of which English, History, Languages, teamwork, collaboration, presentation, motivation, literature and psychology are subsets.

To suggest that English be replaced as a core subject at High Schools by Communication, will undoubtedly put a cat amongst the pigeons. Within the existing educational bureaucracy, the emotional walls that surround subjects and departments of English, Science & Mathematics have been build on years of status and position in the hierarchy.

Having the people within these hierarchies realise the disruption which has come to education and their need to reposition themselves will be the most challenging component of the change process. Unlike UBER, which was a direct affront to the taxi industry it challenged, tools such as Google, YouTube and Podcasts (which is having a significant impact on the role of books in society) are applying subliminal pressure which is systemically changing education in a ways that we can never undo.

The banking system went through a similar transformation in the '90s with the advent of electronic transactions. Although intended to increase efficiency and not intentionally change the way banks operated, the disruption caused by technology result in 70% of bank employees became redundant in a short space of time. Bureaucracies build up around the concept and importance of a "Bank Manager" both within the bank and within society, found the change difficult and took years to accept.

Research undertaken by Macquarie University in the early 90s examined the effort required by banks to train bank managers. Historically becoming a bank manager was the pinnacle of your life-long career in the bank, and it carried with it a high level of status. One would work their whole life in the bank toward gaining that status. The research found that, via technology, it was possible to take a university graduate and train them to the level of a bank manager in only three (3) weeks. The status of a Bank Manager disappeared over night.

The bureaucracy of education is facing a similar fate and will also struggle to understand how it will make the changes it needs to make.

Education silos are the equivalent of the golden cloak on the Emperor who has no clothes. Who will be the first to shout this out?

If we genuinely seek to improve the competence of our children in a way that will have them able to compete on a competitive world stage, then the walls must come down. We can only hope that it does not take many years to realign the existing structures.

In a similar vein to English, Mathematics and Science, commonly sold as separate silos and core foundation subjects, could be replaced with a focus on analytical problem solving of which maths, science, technology, project management, teamwork, collaboration and a range of other subjects are subsets and elective add-ons to the underlying core focus on building critical thinking.

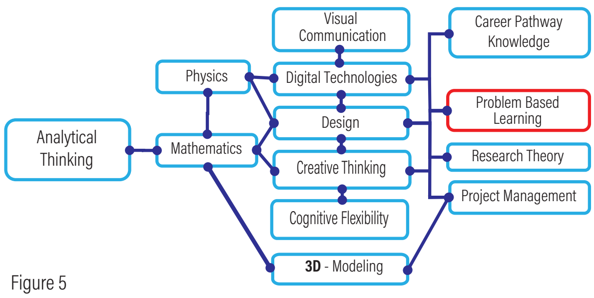


Figure 5

STEM 4.0 is a shift back to understanding the fundamentals for which the concept of STEM education evolved to influence the outcomes that are being sought by industry. It should consist of learning experiences that deliver results in-context with the skills we all need to survive a changing environment. It requires a focus on a networked cross-curricular environment where knowledge can pass freely and without the constraint of silos or bureaucracy.

If we are to build in student skills that will benefit them through high school and into the world of work, they should be grounded in problem-based learning where they learn to bring together the "Apps" of knowledge they need to solve a problem.

Students, in many instances, struggle with the question of why should they

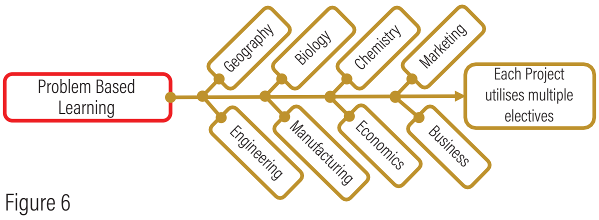


Figure 6

be learning maths, science, geography, history etc. Providing a context for learning via problem based learning leads to a developed understanding of the learning process. Within problem based learning environments, failure is a crucial catalyst for learning and innovating, and the process of failure, or at least an understanding of what it feels like to fail, should be promoted. At the moment, the focus at schools is that students must pass and with the highest mark possible to protect the schools' status!!

STEM education is not about "what you learn" ... it's not about "more maths", "more science", "more coding" or "more whatever". STEM is about "what you do with what you learn". ... it's about moving away with a siloed education system and aligning educational outcomes with the requirements of industry.

Supporting Research

Re-Engineering Australia Foundation (REA), established in 1998 as a not-for-profit social enterprise, has the primary objective of increasing students' understanding of Science, Technology, Engineering and Maths (STEM) based careers. We started by following the fundamental goals of STEM and are now a leader in the design and implementation of STEM 4.0 career intervention activities, recognised around the world.

Over the past two decades, REA's programs have had a direct impact on 1,000,000 students in Australia from Thursday Island to Tasmania and from Sydney to Perth. An extensive experience base from which we draw to populate our operating model: a contributor to the continuing success of our programs.

These programs require participants to confront exciting challenges, be equipped with world-class technology and connected to industry mentors to facilitate the development of their thirst for knowledge. The learning map which underlies each of REA's program is shown in Figure 7.

A critical differentiator within the REA programs has been the requirement for students to work directly with industry partners in the context of their projects resulting in students seeing a direct relevance between a classroom activity they enjoy and the world of work. Another point of difference is the provision of the latest technologies which enable teachers, students and Industry to collaborate efficiently. With all of REA's programs students are required to take on complex project management tasks where they come to appreciate and acknowledge the role industry plays in their future career.

In addition to the more historically measurable outcomes, students develop the 12 industry employability skills to varying degrees as they work in a teams towards a common goal, managing time and resources and seeking out industry support and mentors.

Bringing about the long term and sustainable career change in students is difficult in itself and requires a concerted effort over an extended trajectory. The marketplace is littered with activities parading as solutions to STEM education which are unable to deliver any long-term and lasting STEM educational outcomes. Only when you can confirm that you have made a change a student's long-term perception of a career direction can you claim success and this is rarely displayed. All of REA's programs are longitudinal and can engage students over a 1 - 4 year period.

All REA programs require students to collaborate and interact with industry and industry mentors to learn about technology and career path options. To increase student engagement with Industry career pathways, rather than handing career information to students, REA has adopted a pull-strategy to focus students on possible career pathways. Each of our programs has students seeking out information about career pathways in Industry which aligns with their skills and motivations. The assessment regime we employed has students dedicating a portion of both their project presentations and project portfolio to highlighting career research they have undertaken. As a direct consequence, students have been shown to have a much clearer understanding of the career-paths that fit with their motivations.

Currently students of both genders can require support to discover just how exciting and engaging the activities of Industry can be, particularly in areas of STEM. Learning environments which facilitate an increased understanding of the professions involved, in a way which fits with the different motivational drivers of Boys and Girls, goes a long way to promoting students' critical career decision processes.

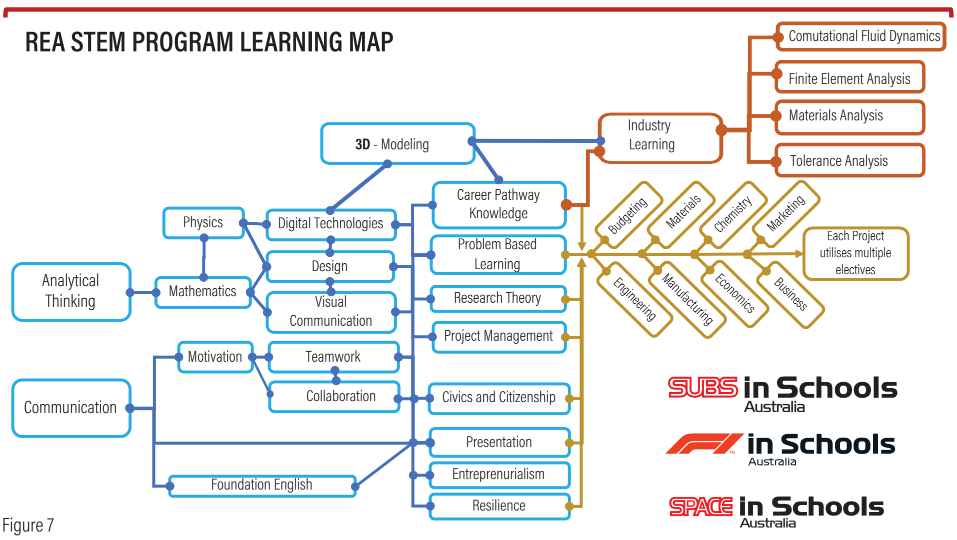


Figure 7

In 2006 REA started a longitudinal research project, which is continuing past 2020, that examines the motivational drivers of children's career decision choices. Data on a wide range of topics pertaining to student career attitudes are collected from students involvement in REA programs. It examines the capacity of these programs to influence change in career motivation. In the last three years, our research has collected primary data from over 3,500 students and 600 teachers.

A summary of some of the key findings of the ongoing research include the following:

- Students were showing an increased ability to understand the importance of the subjects they are studying at school and how they relate to large-scale problem-solving and real careers.
- 73% of the students who participated changed their motivation to follow a STEM based career as a result of their participation in the program.
- 55% of students have an interest in the manufacturing element of the program. Given that the manufacturing industry is currently considered in decline in Australia, making up less than 13% of our GDP, to have students with high levels of interest in manufacturing goes well for attracting students to the manufacturing careers.
- Teachers highlight the capacity of STEM to impact the complete education process. Teacher perception is that as a consequence of their participation in these programs, students show a marked improvement in interest and performance across a majority of subject areas. They highlight a capacity for these programs to bridge the educational silos and deliver improved performance in all subjects. Of note is the increase in students performance in the areas which could be directly liked to industry defined employability skills. (Refer also to Figure 8).

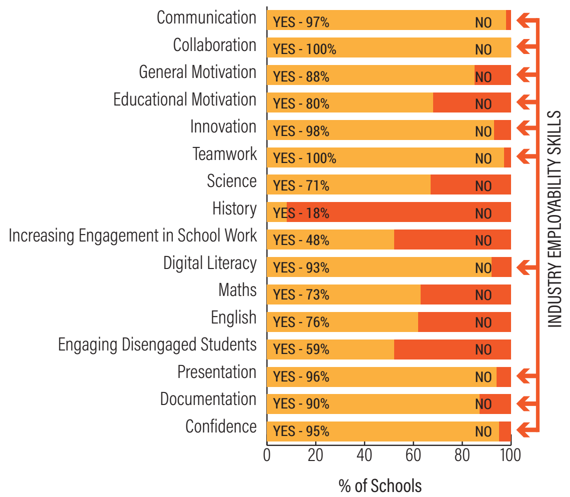


Figure 8 - Teacher Feedback on the Impact of REA programs on increase students performance across a broad range of subject areas.

- The only subject that did not show a significant improvement was History, where only 18% of teachers recorded an increase in students performance.
- 71% of students indicating that they would recommend a career in specific STEM industries to their peers. A clear indication that students have no blockages to the sector or jobs in STEM based industries.

Attracting girls into STEM careers has been problematic over the past 20 years. As part of our research, we examine the impact of gender on attraction to STEM in general, and to industries which classify as being STEM-based. Our research has highlighted that the story about STEM needs to be told in a different way to Boys than it is to Girls. Boys need continuous human interaction, particularly with role models and mentors to perform at their peak. Boys learn by apprenticeship and respond to the influence of role models. They need to touch jobs before making an emotional decision about career engagement. Movement of Boys into careers will increase when we can facilitate an increasing interaction between students and adults in industry roles. The underlying message is that during their career journey, there will always be people around them who will help them to learn and grow. For Boys, careers should be a continual learning environment.

Other key findings from the research (as reported by students) include:

76% Of students met people during the project that inspired them.

89% Of students had a much clearer understanding of STEM as a career.

83% Of students are more interested in careers in STEM.

73% Of students reported that role models changed their perception of STEM careers.

50% Companies helped change students perceptions of STEM.

90% Of students like using technology used by industry in the project.

92% Through the project was "cool".

71% Met people that inspired them to take up a career in STEM.

62% Believe they learned a great deal about Defence industries.

94% Believe that STEM is interesting.

80% Chose to participate for their own good.

84% Believe that STEM is good for them.

83% Think STEM is Fun.

88% Clearly understand what STEM brings to them.

86% Feel good when they were doing the project.

89% Believe being involved in STEM is important for them.

Girls, on the other hand, respond to managing complexity in environments. Highlighting the processes and complexity involved in career pathways will attract them to professions in those industries. Girls react positively to the project management aspects of careers and need to understand the processes involved in a career pathway before they will choose that direction. Correctly targeted interventions can bring about a dramatic change in the number of girls who have an interest in specific STEM career pathways.

Key to REA's strategy is to engage with students without creating a level of separation based on issues of ethnicity, gender, diversity, age or religion. We treat all students the same and see no reasons to highlight blockages to career path selection. We are focused on using our understanding of the motivational drivers of children's career decision choices to attract the intrinsic interest of students no matter their gender or background.

Our research highlights that biasing girls to take up STEM careers is counter-intuitive and is showing a negative outcome in the attitudes of boys to jobs that they would typically like to take up. Exposing girls to STEM career opportunities in a language that fits with their motivational drivers, has shown to be the key driver which impacts their career aspiration.

While there still exists a perception that boys dominate STEM activities, we can engage with girls just as successfully as we do boys. We do this by utilising the appropriate language which brings the programs within motivation that the

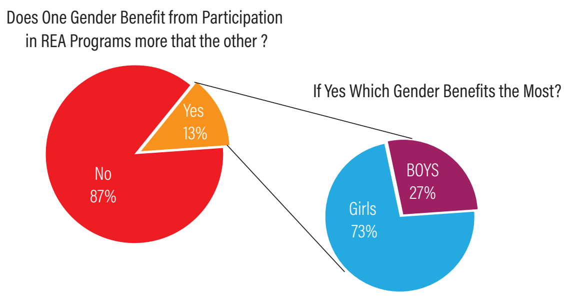


Figure 9 - Impact of STEM 4.0 on participation by gender as described by participating teachers

students, boys and girls, can relate too.

Industry plays a key role in assisting students make the final career decision choice and this is most effectively done via direct interaction with students and through the provision of ongoing positive messaging about the Industry.

Unfortunately, poor STEM experiences lead to the development of poor enthusiasm for STEM in the students, in the teachers and the school and little measurable outcome. Poor STEM experiences will not produce the pipeline of capable students that industry is demanding.

Critical to increasing exposure of students to employment pathways in industry is the need to raise the awareness and understanding of teachers to career pathways. As part of the research, we sought to determine the understanding teachers have of Industry and Industry career pathways, and if the programs were having an impact on teacher knowledge, which has been the case.

Creating the Best STEM Students.

REA started in 1998, focusing on building employability skills in students and building the capacity of the nation. We started with an Engineering focus because we were from industry and we knew that the education system wasn't delivering enough students with the appropriate skills to become Engineers.

Our research has shown that the application of STEM 4.0 techniques has dramatic impact on the potential to improve outcomes that can be achieved by students in the classroom. We began out of a passion for making a difference and in 2006 we produced our first set of STEM World Champions in the F1 in Schools program and suddenly realised that we were creating the best STEM students in the World. Since then, the methodology we use, based on STEM 4.0, has gone from strength to strength. Since 2006 we have produced 7 World Championship teams in the largest and most complex STEM competition in the World.

Australia intrinsically produces great problem solvers and can provide the quantity and quality of students that industry will need into the future. Within each of the programs, a great deal of focus is on applying STEM 4.0 fundamentals and helping students become successful entrepreneurs. Students learn through both success and failure, along the way, developing high levels of resilience.

REA's programs place high importance on engagement with industry. What is required by industry to support STEM activities is a focus on improving their attractiveness in the eyes of the students.

The outcomes achieved by REA can be directly applied to the existing education system. Figure 10. is a proposal for restructuring the learning environments at

Team Horizon - F1 in Schools World Champions 2018

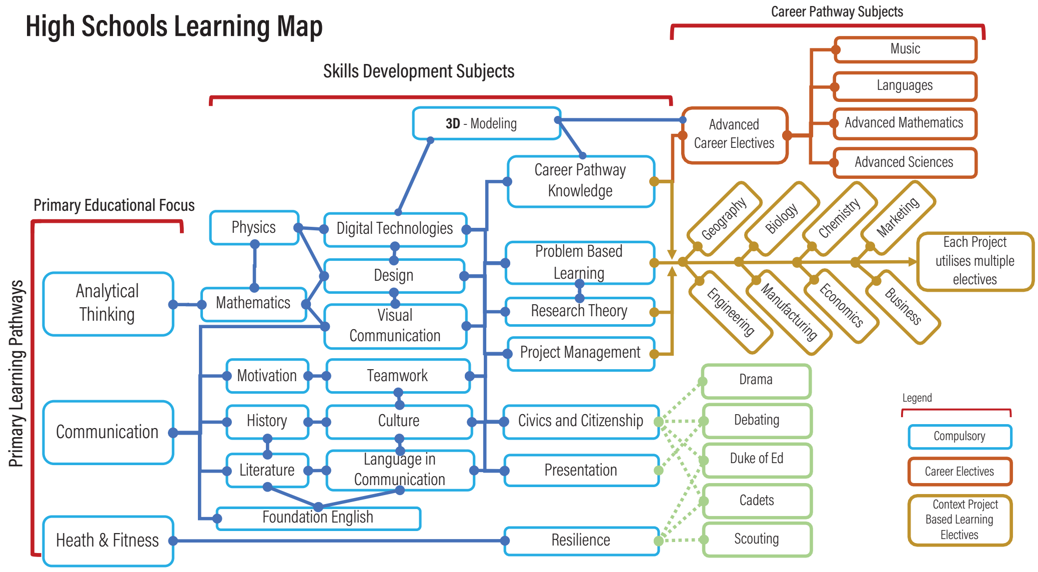


Figure 10 - Proposal for learning pathways map based on STEM 4.0 with Analytical Problem solving and Communication as core fundamentals

High Schools based on the application of the learning map utilised withing REA's programs and expanded to consider a much broader education landscape. It is presented as a conceptual road map and vision to promote discussion. We can only hope that the discussion and debate surrounding the information is not dominated by the bureaucratic agendas that exist within the current education system and that industry play a part in validating the skills that they want to see coming from the education sector.

STEM 4.0 is about "what you do with what you learn". ... it's about moving away from a siloed education system and aligning educational outcomes with the requirements of industry. It is about basing the education process on a foundation of Life-Long Learning, Analytical Problem Solving and Communication.

The outcome of implementing a STEM 4.0 strategy will be an unleashing of the innovative capabilities of our students in ways that will cement their career futures and create a platform upon which we can re-build the nation.

STEM 4.0 LIFE-LONG LEARNING

STEM education is not about "what you learn"... it's not about "more maths", "more science", "more coding" or "more anything".

STEM is about "what you do with what you learn"... it's about moving away with a siloed education system and aligning educational outcomes with the requirements of industry based on a foundation of Life-Long Learning, Analytical Problem Solving and Communication. It's about a networked cross-curricular collaborative learning environment.

AN INITIATIVE OF

RE-ENGINEERING AUSTRALIA

FOUNDATION