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.

AUTHORISED AGENT

Re-Engineering Australia Foundation Ltd.
PO Box 136
Castle Hill NSW 1765

P: 61 2 9620 9944

F: 61 2 8079 0622

E: contact@rea.org.au
W: www.rea.org.au

COPYRIGHT NOTICE

Author

Dr Michael Myers OAM
BE, MBA, DBA, HonFIEAust, FAICD, CPEng, EngExec.
Executive Chairman
Re-Engineering Australia Foundation Ltd

REPRODUCTION

Contents

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, presents alternative structures for the education system to support STEM, and examines students' outcomes resulting from deep engagement with STEM 4.0 activities.

To implement STEM effectively requires a change in the institutional attitudes and education culture to influence industry outcomes and create 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 linkages between schools and industry are promoted.

Re-Engineering Australia Foundation (REA) has been implementing STEM programs, built on the concept of Life-Long STEM Learning in schools for the past 23 years. To date, REA has engaged with over 1,000,000 students in Australia and achieved remarkable results in improving educational outcomes, 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 and Life-Long Learning can significantly impact education outcomes across all subject areas, not only Science, Technology, Engineering and Mathematics.

STEM 4.0 is the repositioning of the underlying fundamentals of STEM education to align with Industry 4.0. An alignment that has become waylaid in the last few years. This document intends to provide feedback on existing research into the application of STEM 4.0 and 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 deliver STEM-based education and technologies in the classroom. Technologies that facilitate students' development of the employability skills industry seek and aid in their transition to the world of work.

By its original definition, STEM education is an interdisciplinary approach to aid 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 for students to develop problem-solving skills and builds in students a range of competencies that will assist their transition through life.

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. To lift students' competitiveness in today's career market, we need to boost skill levels in ways current institutions struggle to achieve.

STEM is an industry-driven concept aimed at providing a platform for a change in the education system's focus, and conceived to break down the silos of learning that have developed over the past three decades, replacing them with a cross-curricular approach to problem-solving as the foundation upon which the science of things is taught. STEM aims 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

Todays Educational Environment

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

The skills industry is seeking today are a far cry from the 3R's of reading, writing and arithmetic once asked for by industry following the war years. While the 3R's are still critical drivers for primary education, to succeed in a career, students need higher levels of competence in what have been called employability skills. These skills include communication, collaboration, teamwork, emotional intelligence, creative thinking, cognitive flexibility and entrepreneurship.

STEM is a platform to help teach students how to work at the boundary layer 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 skills that 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 struggling with an audience who don't understand how and where it fits within 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 academic silo structure in ways that dilute the value and the intent of any original thought.

Within this bureaucratic environment, the implementation of STEM rarely facilitates the cross-curricular integration of knowledge and skills initially 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 of 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 of STEM designed to tick quality control or equity boxes and moved back to facilitating the development of the employability skills sought by the industry.

Origins of Education

To understand the industry drivers behind the establishment of STEM, we need to understand the origins of education the 30s and what it has become today.

Lifting the educational standards of society following the Second World War was a significant driver behind the design and development of the education system. 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 manufacturing technologies. The number of employees who had knowledge of applying or implementing new technologies or processes were few and far between.

Industry needed to create productive workers who understood democratic values and had the knowledge and skills to contribute to national productivity and the education system had to change to deliver more significant numbers of employees capable of filling manufacturing plants. Thus the drive by Governments was to altruistically lift the general education standards across the proularion. The 3R's of reading, writing and arithmetic became the mantra of the education system.

Industry was, to some extent, driving society to achieve the higher levels of expertise and competence 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 production system.

Based on the production principles created in the industry, there was a belief that these techniques would be the most modern innovations for developing 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:

- The School as Factory
- The Child as Product
- Standardised Testing as Quality Control

The child was a raw material shaped by the educational 'factory' into a quality 'product'. Teaching became viewed as a form of training, and schools operated 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 and it's a story told by John Taylor Gatto in his 2009 book Weapons of Mass Instruction, echoed by The New York Times's David Brooks.

Improving educational standards was seen as a social issue, so to make this happen, the industry handed responsibility for the education process to Governments. An unfortunate outcome of the 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 and Paul Principles). The growth of fiefdoms to maintain control, cover up incompetence, resist change and ensure the status quo was inevitable. We can see this playing out even down at the level of teaching staff with the creation of departments of Science, Maths and English, Departments which 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 have come a long way in lifting the educational standard of our children since the 1950s. We now live in a highly educated society that appears to absorb technology easily. People at all levels are 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 industry's growth as a now well-educated market dictates the products, processes and services that it wants or requires from Industry.

We are in a golden age for the transition of ideas to reality.

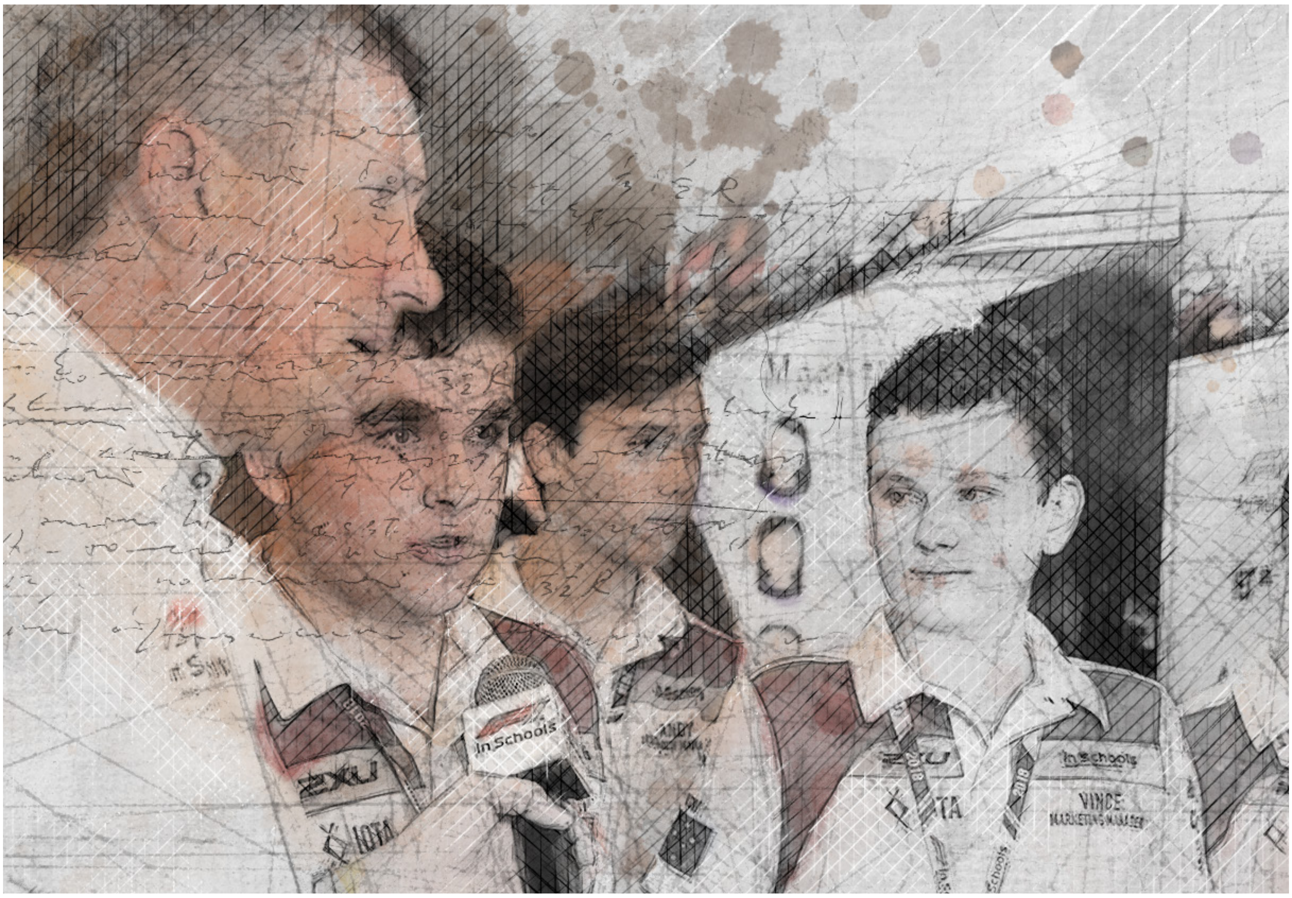
Technological disruption has taken the strategic advantages the education system once had:

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

While the current educational standards and delivery methods are a vast improvement over the '50s, they are no longer keeping up with industry or society. It is still running on the belief that its strategic adventages have not changed, producing factory students, delivering knowledge in silos and measuring students against universally standard testing regimes, driven by equity.

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. There is, however, a clear opportunity within this turmoil for points of strategic differentiation for the school education system to follow, which are



not replaceable 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.

Changed Strategic Strengths of Education

What is not always readily available in a world of ubiquitous access to information is knowing how to interpret and apply knowledge in context and understand and decipher the massive amounts of data now public, 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.)

Education needs to fill the role of coach/administrator rather than being focused on being a Yoda - a source of wisdom.

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 we need in the classroom. Coaches can not keep up with the skill of the players nor can teachers keep up with the knowledge available to students.

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 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 by reading a book or watching a video, but you can win if you have a good coach.

Teachers as educational coaches will need to understand the relevance of knowledge and move freely across the areas of expertise. 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 themselves may also need work experience to gain an understanding of how industry works.

Teachers can focus on helping students apply knowledge similarly to the way they have learned to use Apps, each providing part solutions to a more extensive problem-solving process. Design and Technology teachers may call on teachers who have a specialisation in Science, Maths or English to their class to deliver a specific understanding of topics related to the projects the students are working on and vice 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 expertise.

Australian Industry Perspective

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

It is now become widely accepted across industry and politics that Australia has been through severe shortages of skilled people. While these shortages come and go it is only they are at the bottom the curve do they become politically sensitive. With the increase in Defence and infrastructure projects, and a drive to make Australia more independent as we rebuild after COVID-19 that will again drive the shortage of engineers, project management and supporting professions.

While these shortages can 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 developing 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 the underlying mind set, during the 1980s, an educational policy convergence between the major political parties toward economic rationalism had both sides of politics becoming 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 developing a skilled nation became waylaid by a big business focus on short term solutions and the reafermation as education as a production line.

Industry untill recently has shown little interest in engaging students or establishing the set of crucial skills that it wants from the education system. Nor has it helped teachers or administrators develop 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 have 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 results have impacted increasing awareness of STEM for those who participate, they have a minimal effect outside the participants' environment. 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 constructing 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 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, Initiative 2001, Government, 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) highlighted the need for a clear definition of the pathways and activities that lead students into careers such as Engineering.

As the populus have become more educated, STEM is the process of reconfiguring the education into a learning platform that will move and change with the needs and problems Industry seeks to resolve.

Industry Competencies

Industry's education system requirements have advanced significantly with the advancement of technology. It is now assumed that the high levels of competancy in the 3R's exist in the population at large.

Industry has no issue concentrating its internal training efforts on skills development specific and unique to its field of operation. They are happy to bring new entrants into line with their own culture and ways of doing things. The industry benchmark for the 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 readily visible in the general populous. These skills revolve around 12 core competencies listed in Figure 1. Industry agencies have proposed various forms of this set of competencies.

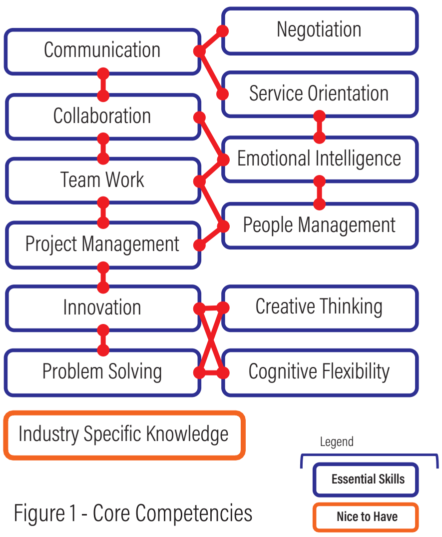


Figure 1 - Core Competencies

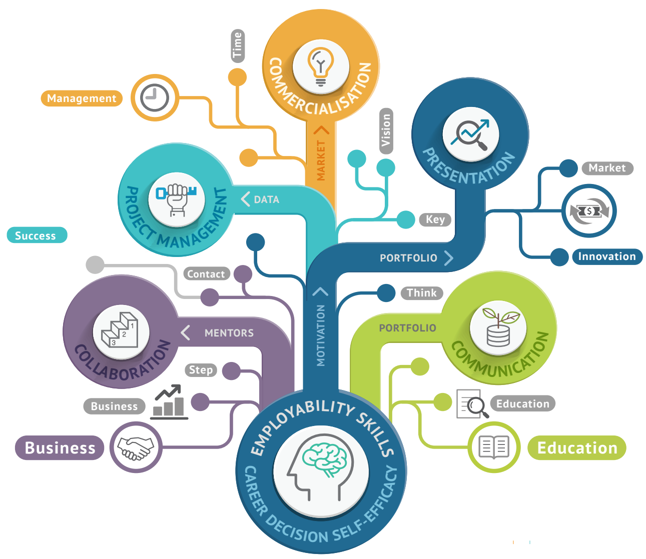
While most States and Territories have also produced documents defining Employability Skills Frameworks based on similar core competencies, the leap from proposition to delivering a change in the education system has not resulted.

Industry believes that these competencies are best learnt in a school environment rather than in the workplace. From Indutrie's perspective, these skills are now the equivalent of the 3R's of the 30's. If they could 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, the capacity to communicate well is most evident in a range of business functions, including our ability to negotiate, manage people, collaborate, be service orientated, have emotional intelligence and work in teams. 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 that directly focus on building these skills. The current Australian curriculum has room within which to structure activities which create these skills, they are not defined outcomes. It is left to teachers to build in activities that develop these unique skills, in many cases without guidance.

At present, Industry does not have the capabilities to measure new entrants' competencies in these 12 skill areas. The only measurements system that currently exists to aid selection on compitence choice between applicants is the 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 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 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 issues. COVID-19 has highlighted where our leadership has been effective and where it has not.

We live in a highly advanced world where advancements in science and technology allow us to resolve the most critical of situations. Still, its leadership at the interface between people and problems defines our capacity to deliver the outcomes we seek. Resolving problems requires a level of communication to ensure all involved clearly understand the issues involved and how to manage a way through those issues: the fundamental of Project Management. Without a capacity analytical solve problems and communicate solutions we can quickly fall into anarchy.

The competencies society has 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 that together will help us improve and implement solutions. In the 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.

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. On top of these base skills, we use applied knowledge to help provide solutions to the detail of any problem..

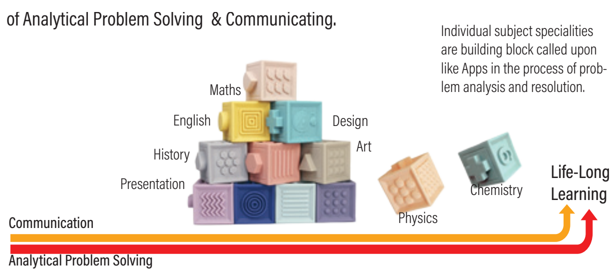


Figure 2 - Underlying Life-Long Learning Competencies

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 that continually engaged with skills and competencies way outside the traditional Engineering or STEM environment. The universal constant has been a continuing dependence and improvement of my capacity to communicate and solve problems.

While at school, the main subjects I studied were Maths, Science and English,

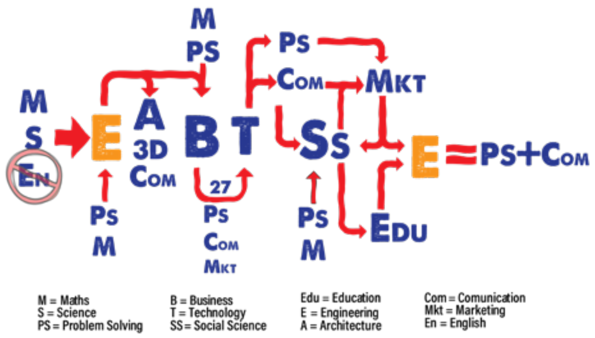


Figure 3 - Engineering Career Path Map

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 my starting a business focused on Computer-Aided Engineering 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 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 meet a new language, 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 would make these trips successful. It was the capability to understand and deal with the changing issues of history, culture, language, norms and bureaucracy in a context that allowed me to operate effectively and do business internationally against heavy competition from the UK and USA.

When I founded the Re-Engineering Australia Foundation in 1998, I 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 that was applicable to run any business successfully.

The common thread in my career development 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 a similar need to operate empathetically and move between cultures seamlessly to communicate and solve problems.

Given the differing requirements of industry, the education system needs restructuring with a focus on problem solving and communication skills as primary drivers rather than passive outcomes.

Education Mirroring Industry

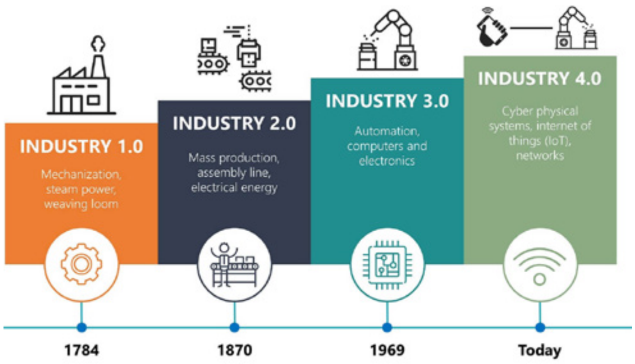
The industrial revolution, now called Industry 1.0, brought with it the mechanisation of work which our ancestors used to perform manually. The introduction of steam facilitated industrialisation and drove the transition from a rural to an urban lifestyle. It came with jobs and economic development.

The introduction of electricity and a focus on processes development facilitated assembly lines, and we entered the world of Industry 2.0. The construction of the first electric assembly line in 1870 resulted from 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 supply 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 job competence in a population that had little formal education. It offered a platform to build self-worth and self-efficacy and a structure around which people could make 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. During this period of transformation, 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. These technologies were implemented in silos with devices isolated from each other, much like the silos in education.

With the advent of Ethernet, Industry started 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. However, in most instances, the equipment still stood alone on 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 lacked 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 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), proving tough to achieve. The electronic factory did not progress much beyond point solutions. What Industry came to realise was the importance of understanding 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 Industry development, is little more than a vision for what is possible. Still, 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 skilled 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 today. It has created silos of knowledge, each of which may pass muster under the gaze of a magnifying glass. Still, each has grown without an underlying strategic vision that would tie the different education components together to produce the best students globally, and the students' Industry is seeking.

Knowledge has made massive advances based on the application of technology. While Industry is using profitability as a powerful influencer to bring 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 and Industry), education must realise the fundamental underlying principles upon which its success lies to achieve the outcomes required of it. It should allow all taught knowledge to link together, like Apps 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 Australian students.

Industry 4.0

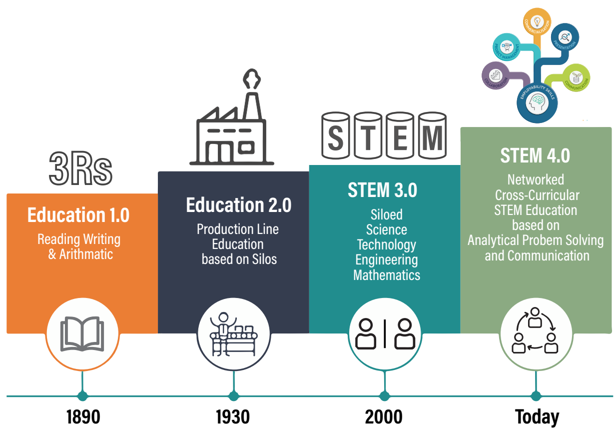
The fourth generation of industry development, often called Industry 4.0, is the era of Cyber-Physical Systems (CPS). CPS comprises intelligent machines, storage systems, and production facilities capable of autonomously exchanging information, triggering actions, and controlling each other independently. This exchange of information via 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 data analysis is by developing predictive models that help the organisation anticipate some irregularities in the processes or systems so that action can be taken well in advance instead of taking action when a process or system fails.

A change to CPS will produce data in enormous volumes, often termed Big Data. Analysis of this Big Data will help the industries improve manufacturing processes, material usage, supply chain, and life cycle management. Industry 4.0 is about attempting to use internal protocols to support the collection of big data and its analysis: the end game 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 economic driver to introcuce STEM 4.0 is profit. Within education environments, there is no similar commercial driver. There is only a propensity to maintain the status quo so achieving improved educational outcomes will need to be top-down and require the dismantling of many fiefdoms to allow transformation to occur.

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



STEM 4.0 Life-Long Learning

As has been highlighted, throughout our lives, from our first days 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 (3R's), essential in the formative years, as students reach high school, a dramatic transition to production line learning based on siloed knowledge and learning period of 40 minute takes over.

The core competencies of reading, writing, and arithmetic, first put forward as the fundamentals of education in the 1930s, have been surpassed by the need to focus on higher-order analytical problem solving and communication skills. This skills development process does not easily 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 English components, will not get you very far. To communicate in a much more literate world effectively requires competence in many higher-order skills, the interplay between those skills and their use in a problem-solving environment.

It may be time for "English" to take a back seat to Communication as a core subject with english, history, languages, teamwork, collaboration, presentation, motivation, literature and psychology as subsets of communication.

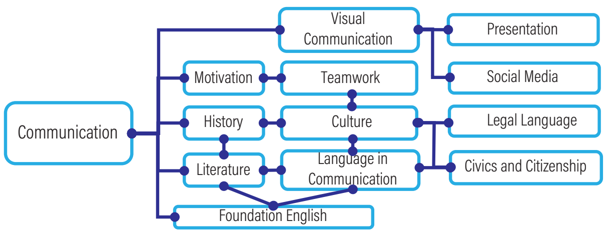


Figure 4

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 surrounding subjects and departments of English, Science and Mathematics have come from years of status and position in the hierarchy.

Having teachers accept the disruption which has come to education and the requirements for them to reposition themselves will be the most challenging component of the change process. Unlike UBER, which was a direct affront to the taxi industry, tools such as Google, YouTube etc (which have had a significant impact on the role of books in society) are applying pressure, systemically changing education in 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.

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 overnight. 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.

The bureaucracy of education faces 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 world stage, then the walls must come down. We can only hope that it does not take years to realign the existing structures.

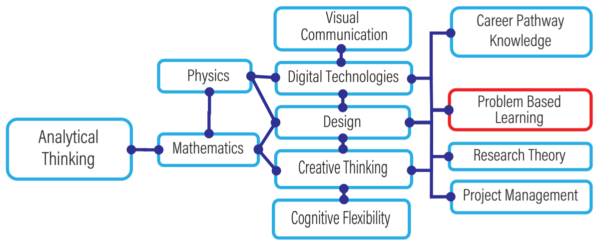


Figure 5

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.

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

Within problem-based learning environments, failure is a crucial catalyst for learning and innovating. The process of failure, or at least an understanding of what it feels like to fail, should be promoted. Currently, 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".

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 worldwide.

Over the past two decades, REA's programs have directly impacted 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.

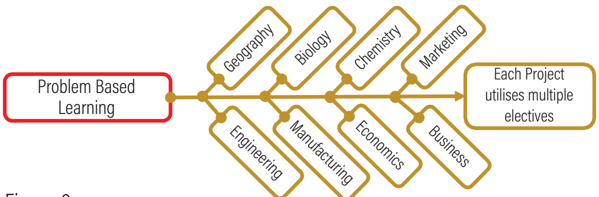


Figure 6

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. Figure 7 highlights the learning map which underlies each of REA's program.

A critical differentiator within the REA programs has been the requirement for students to work directly with industry partners in 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 take on complex project management tasks 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. They work in a team towards a common goal, managing time and resources and seeking 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 current marketplace has many programs parading as solutions to STEM education unable to deliver long-term or lasting STEM educational outcomes. Only when you can confirm that you have changed 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, REA has adopted a pull strategy to focus students on possible career pathways rather than handing career information to students. Each of our programs has students seeking out information about industry career pathways that align with their skills and motivations. A portion of the assessment regime has students within their project presentations and project portfolios highlighting their career research. Consequently, students show a much clearer understanding of the career paths that fit with their motivations.

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

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 student attitudes toward careers is collected. It looks at the capacity of these programs to influence change in career motivation. Our research has collected primary data from over 3,500 students and 600 teachers in the last three years alone.

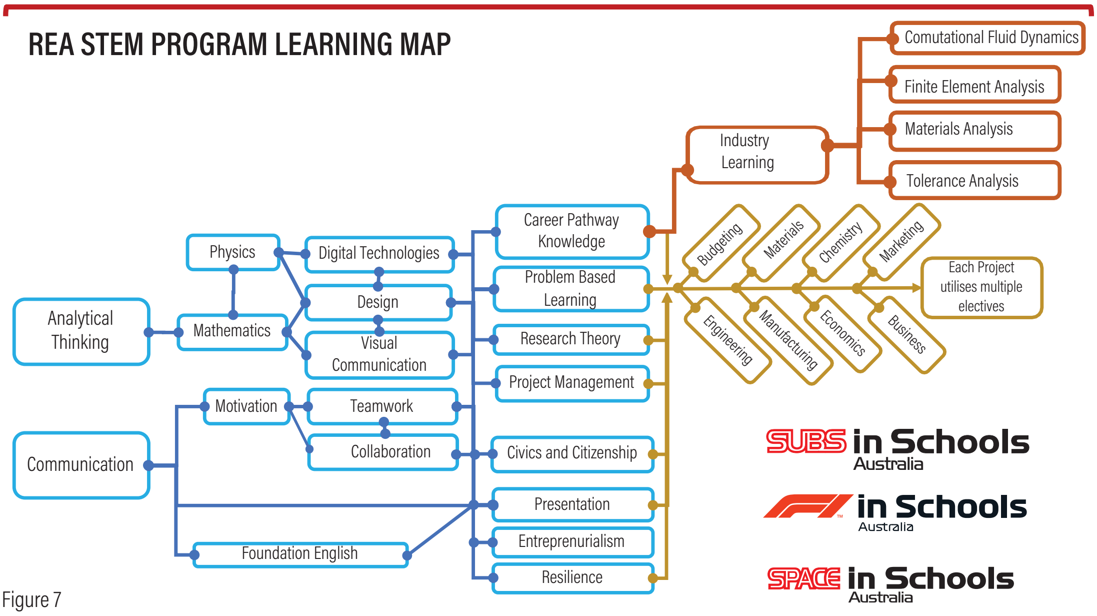


Figure 7

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

- Students show 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 participate changed their motivation to follow a STEM.
- 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, having students with high levels of interest in manufacturing goes well to attract students to the manufacturing careers.
- Teachers highlight the capacity of STEM to impact the complete education process. Teacher perception is that students show a marked improvement in interest and performance across a majority of subject areas due to their participation in these programs. They highlight a capacity for these programs to bridge the educational silos and improve all subjects' performance. Of note is the increase in students performance in the areas which link directly to industry-defined employability skills. (Refer also to Figure 8).
- 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.

In Which Subject Areas Have You Seen a Visible Improvement in Student Performance as a Result of Their Participation in REA Programs:

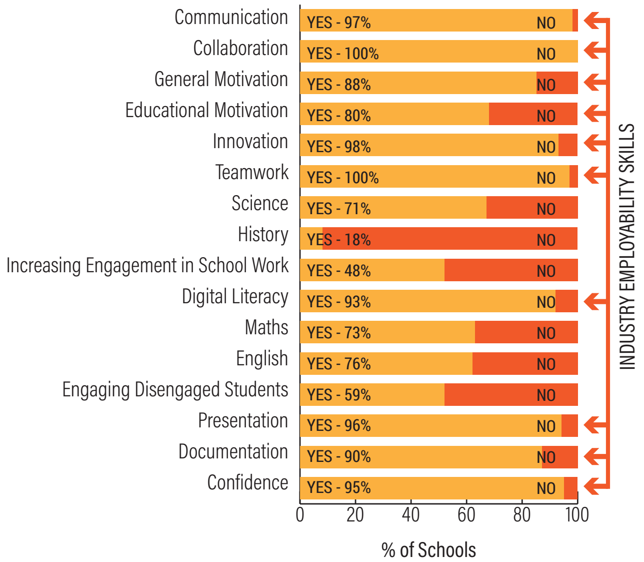


Figure 8 - Teacher Feedback on the Impact of REA programs on increase students performance across a broad range of subject areas.

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.

Attracting Girls to STEM

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 industries classified as STEM-based. Our research has highlighted that the story about STEM needs to be told differently 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. The 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 there will always be people around them who will help them learn and grow during their career journey. For Boys, careers should be a continual learning environment.

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 choosing that direction. Correctly targeted interventions can bring about a dramatic change in the number of girls interested in specific STEM career pathways.

The key to REA's strategy is to engage with students without creating a separation level based on 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 students' intrinsic interest no matter their gender or background.

Our research highlights that biasing girls to take up STEM careers is counter-intuitive and shows an adverse outcome in boys' attitudes to jobs they would typically like to take up. Exposing girls to STEM career opportunities in a language that fits with their motivational drivers has been the key driver that impacts their

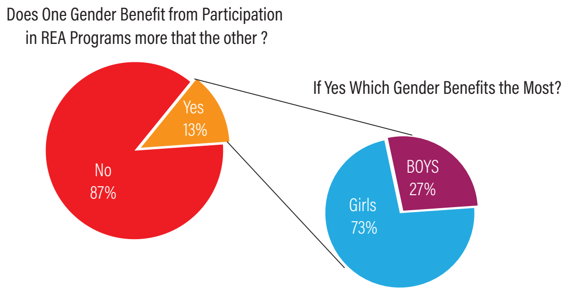


Figure 9 - Impact of STEM 4.0 on participation by gender as described by participating teachers

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 students, boys and girls, can relate too.

Industry plays a crucial role in assisting students in making the final career decision choice. This is achieved via direct interaction with students and ongoing positive messaging about the Industry.

Unfortunately, poor STEM experiences lead to insufficient 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 students' exposure to employment pathways in the 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 impacted 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 nation's capacity. 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 a dramatic impact on improving outcomes that students in the classroom can achieve. 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, based on STEM 4.0, the methodology we use has gone from strength to strength. Since 2006 we have produced 7 World Championship teams in the World's largest and most complex STEM competition.

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 existing education system can apply the outcomes achieved by REA. Figure 10. is a proposal for restructuring the learning environments at High Schools based on using the learning map utilised within REA's programs and expanding 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

Team Horizon - F1 in Schools World Champions 2018

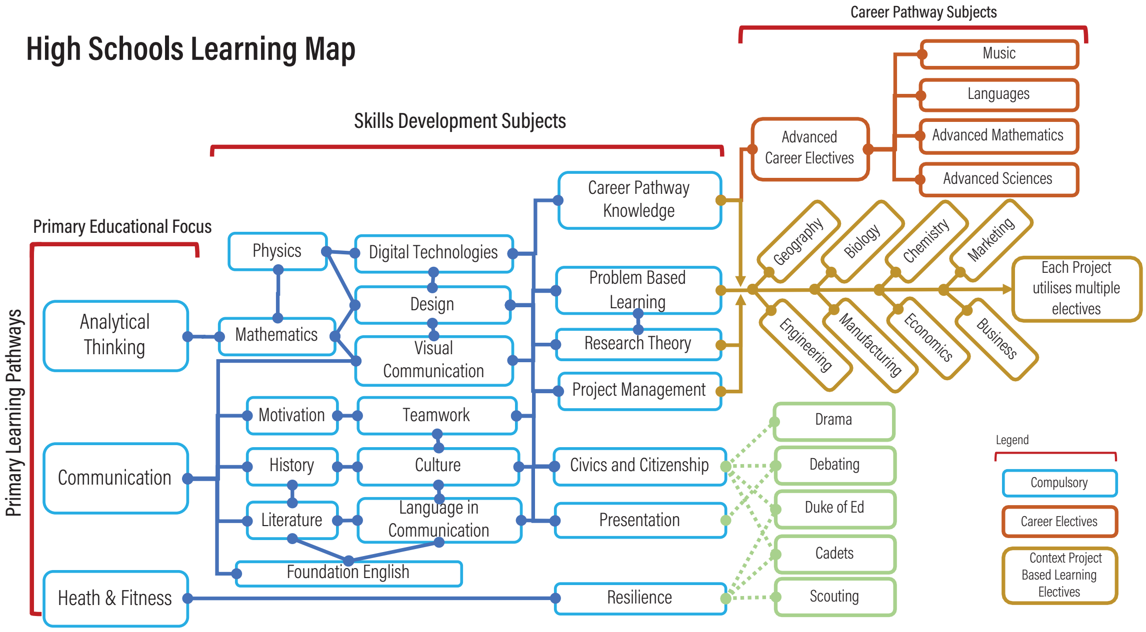


Figure 10 - Proposal for learning pathways map based on STEM 4.0 with Analytical Problem solving and Communication as core fundamentals

the bureaucratic agendas that exist within the current education system. That industry plays a part in validating the skills they want to see coming from the education sector.

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