Re-Engineering Australia Foundation

STEM 4.0 LIFE-LONG LEARNING

Re-Engineering Australia Foundation

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

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REPRODUCTION

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Executive Summary

This paper explores the historical development of education and the role industry has played in shaping it. It also delves into the reasons behind the creation of STEM as a catalyst to bring about a change in educational strategy. The concept of STEM 4.0 is introduced, and alternative education structures to support STEM are presented, along with the outcomes of deep engagement with STEM activities. The implementation of STEM requires a shift in institutional attitudes and education culture towards a more networked, cross-curricular environment that promotes linkages between schools and industry. The Re-Engineering Australia Foundation (REA) has been successfully implementing STEM programs based on the concept of Life-Long STEM Learning for over 25 years.

STEM 4.0 is the repositioning of the underlying fundamentals of STEM education to align with Industry 4.0, and this paper seeks to initiate discussion and debate on the necessary changes required in the current educational processes and provides validation of the positive impact of STEM and Life-Long Learning on education outcomes across all subject areas.

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.

STEM education is an interdisciplinary approach to learning that combines rigorous academic concepts with real-world lessons in science, technology, engineering, mathematics, and other subjects. This approach helps students develop problem-solving skills and build competencies that will assist them throughout their lives.

In the past, a university education was seen as the key to success. However, in today's competitive job market, simply having a degree may no longer be enough. To increase students' competitiveness, we must boost their skill levels in ways that many current institutions struggle to achieve.

That's where STEM comes in. It's an industry-driven concept that aims to change the focus of education. STEM breaks down the silos that have developed over the past three decades, replacing them with a cross-curricular approach to problem-solving. By teaching the "science of things" in this way, STEM aims to deliver learning outcomes that align 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

The current education environment is vastly different from what most teachers experienced. Students now have access to a wealth of knowledge without national boundaries. The competition for opportunities has also increased, with more highly educated individuals vying for the same positions. This new environment demands that teachers be better at their trade than ever before.

While reading, writing, and arithmetic remain essential for primary education, the skills required for success in a career go beyond the traditional 3Rs. Today's industry demands higher levels of competence in employability skills, such as communication, collaboration, teamwork, emotional intelligence, creative thinking, cognitive flexibility, and entrepreneurship.

STEM, or Science, Technology, Engineering, and Mathematics, is a platform meant to teach students how to solve problems by working at the boundary layer between humans and problems. It is a concept aimed at promoting analytical problem-solving and communication skills through real-world, in-context projects. Analytical problem-solving and communication should not be viewed as single skills, but rather as combinations of skills that form a platform upon which knowledge can facilitate the development of solutions.

Unfortunately, the focus on equity, achievement, and quality control in education has hindered STEM's progress, making it difficult for it to fit in with existing structures and bureaucratic culture. Integration of knowledge and skills across disciplines is rare, with a preference for adding more science or math or simply offering activities that meet predetermined criteria for achievement and equity.

True STEM activities should deliver results that help students compete in today's global environments. They should focus on the development of employability skills sought by industry and move away from low-level implementations designed to tick quality control or equity boxes. STEM should be about facilitating innovative experiences that help students learn, grow, and succeed in a rapidly changing world..

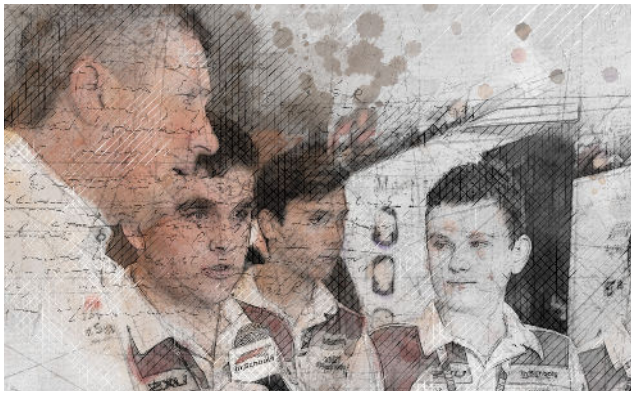
STEM is a platform to help teach students how to work at the boundary layer between humans and problems.

Origins of Education

To understand why STEM education was established, we must first look at the history of education. After World War II, there was a push to improve the education system and raise the standard of living for citizens. Manufacturing techniques were advancing quickly, and there was a need for more skilled workers who could keep up with the new technologies. However, there were not enough employees who had the necessary knowledge and skills.

As a result, the government began to focus on improving education standards across the population, with a particular emphasis on the 3Rs of reading, writing, and arithmetic. Educators, such as Ellwood Cubberley, saw the education system as a way to shape children into productive members of society. The idea was to use production principles from industry to make the education system more efficient.

Cubberley believed that schools were like factories, and children were raw materials that needed to be shaped and molded into products that met the demands of society. The child became a product, and teaching became a form of training. Schools operated like assembly lines, with children moving through



various stages of the curriculum.

Improving education was considered a social matter, leading the industry to entrust the government with the responsibility. Unfortunately, this resulted in the rise of bureaucracy, leading to the formation of power structures that were resistant to change and encouraged divisions. Consequently, there was a decline in competency, with departments such as Science, Maths, and English protecting their domains and opposing cross-disciplinary education.

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

Overall, the history of education shows that there was a need to improve standards and raise the level of expertise and competence to keep up with the advancing technologies in industry. However, the focus on efficiency and production principles from industry may have led to a bureaucracy that stifled innovation and creativity.

Disruption

Since the 1950s, we have made significant progress in improving the education standards of our children. Our society is now highly educated and adaptable to new technology. People from all walks of life are eager to innovate, and we have an economic system that provides access to the support and financing necessary to turn ideas into reality.

We have transitioned from a society where industry led development, to one where society drives industry growth. This shift is because a well-educated market now dictates the products, processes, and services it wants or requires from industry. This is an exciting time for bringing ideas to fruition, as there are more opportunities than ever before.

However, the traditional strategic advantages of the education system are no longer relevant in this new technological era. These advantages included owning knowledge of the "Science of Things," the ability to break down complex concepts into bite-sized pieces for equitable delivery, and providing equitable access to the distribution of information.

Although educational standards and delivery methods have improved, they have not kept pace with industry or society. The education system continues to produce "factory students" who learn in silos and are measured against universal standards. The system needs to reposition itself to avoid falling into a chasm.

Nowadays, anyone can access the "Science of Things" anytime, anywhere, which has disrupted the traditional role of the education system. However, this disruption provides an opportunity for the education system to identify strategic points of differentiation that cannot be replaced by technology.

Therefore, the need for change in the education system, particularly in high school, does not spell doom and gloom for schools, teachers, or the education system. Only the bureaucracy needs to change.

Changed Strategic Strengths of Education

In a world where information is easily accessible, it is not enough to just have knowledge. We must also learn how to apply it in context and interpret massive amounts of data to solve problems. This is especially important as we enter the era of Big Data. The education system needs to adapt to accommodate the opportunities presented by Big Data.

Rather than being a source of wisdom like "Yoda", education should focus on being a coach or administrator. In the same way that reading about Rugby rules and watching videos can only prepare you so much for playing the game, teachers cannot keep up with the vast amount of knowledge available to students. Instead, they need to focus on coaching students to interpret and apply data, bringing real-world relevance to problem-solving.

As educational coaches, teachers need to understand the relevance of knowledge and be able to move freely across different areas of expertise. They may need to work in teams to deliver specific experiences when required in the classroom, and possibly even have work experience outside of education to better understand how the industry works.

STEM education is about sourcing expertise and knowledge to solve problems. Teachers should focus on helping students apply knowledge, much like using Apps to provide part solutions to a larger problem-solving process. This may involve calling on teachers with specialisations in other subjects to provide specific understanding related to the projects students are working on.

Overall, the critical role left for teachers in a disrupted education system is to become coaches or conductors of expertise, helping students interpret data and apply knowledge to real-world problems..

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.

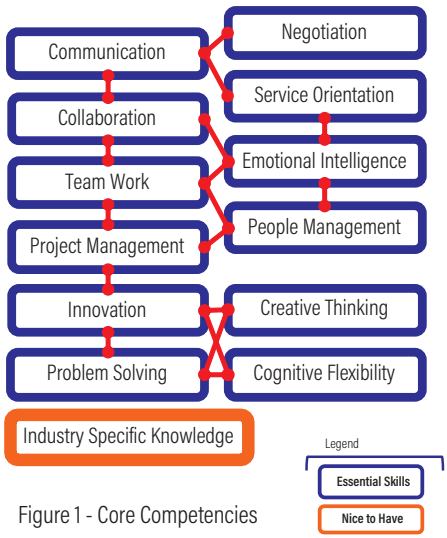


Figure 1 - Core Competencies

Industry's Perspective

The Australian industry has attempted to create a change point through acronyms and slogans, with the concept of STEM being an example. The goal was to refocus educational outcomes towards industry needs by connecting knowledge, skills, and industry. Although industry is the employer of the education system's output, it has played a significant role in shaping education since handing over responsibility to governments decades ago.

Australia has experienced severe shortages of skilled people, particularly in engineering, project management, and supporting professions. The increase in defense and infrastructure projects, along with the desire to become more independent post-COVID-19, will only exacerbate these shortages. There is a universal acceptance by industry and government that more students need to take up STEM-based courses such as engineering to address these shortages.

Successive federal governments have aimed to develop a skilled nation by granting industry a leadership role. However, industry has shown little interest in engaging students or developing attractive critical professions such as engineering. Career intervention programs aimed at attracting students to appropriate occupations have been ad-hoc and ill-structured, with few based on fundamental social science research. The industry definition of necessary skills (employability skills) is ambiguous and imprecise, with responsibility for constructing learning environments to develop these skills landing in the lap of the VET systems.

Several studies have been conducted 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). However, few organisations involved in these studies have designed or developed intervention programs to meet the goals they have identified. Recent research has highlighted the need for a clear definition of the pathways and activities that lead students into careers such as engineering.

Underlying Social Competencies

The COVID-19 pandemic has highlighted the ever-changing nature of our world and our ability to handle risks and challenges. Our survival and success depend on our capacity to navigate these challenges effectively. The social hierarchies in which we live rely on the trust we have in our leaders' ability to solve problems and communicate solutions. COVID-19 has revealed both effective and ineffective leadership.

Although science and technology play crucial roles in problem-solving, effective leadership at the interface between people and problems is fundamental to achieving desired outcomes. Communication is critical in resolving issues, as it ensures that all parties involved understand the problem and how to navigate it. Without strong problem-solving and communication skills, we risk falling into chaos.

Society's ability to tackle the COVID-19 crisis draws on a range of competencies beyond science and technology. The solution requires integrating vast amounts of data from various areas, including medical and social sciences, technology, engineering, and mathematics. We can use this knowledge, similar to how we use apps, to help populate our analytical problem-solving capacity.

The COVID-19 crisis underscores the importance of STEM education, which provides the foundations for problem-solving skills. Applied knowledge helps provide solutions to the details of any problem.

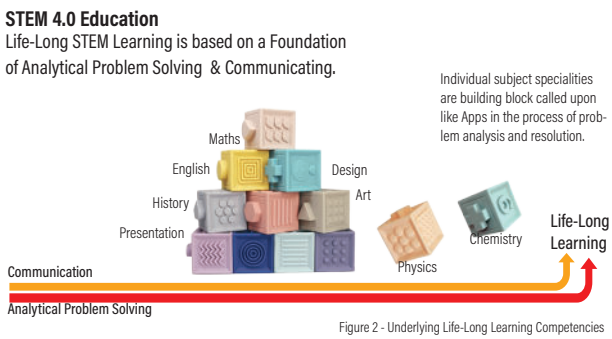


Figure 2 - Underlying Life-Long Learning Competencies

STEM Career Pathways

STEM is an acronym that should not be treated as a standalone subject or term, as every individual's career journey is unique and may encompass various technical and non-technical areas beyond the traditional confines of STEM or any specific field. For instance, an engineer's career path might involve a wide range of skills and competencies that extend beyond STEM. Even in my career as an engineer, spanning over 30 years, I have found myself engaging with non-STEM areas and relying heavily on my communication and problem-solving skills to succeed.

My educational background in math, science, and English paved the way for me to pursue engineering, but being in business required me to develop marketing, sales, and collaboration skills. In addition, businesses that work across geographical borders soon realise the importance of understanding the social constructs of each country. Success is achieved not just through technical knowledge but also through analytical problem-solving and effective communication, cultural awareness, and social skills.

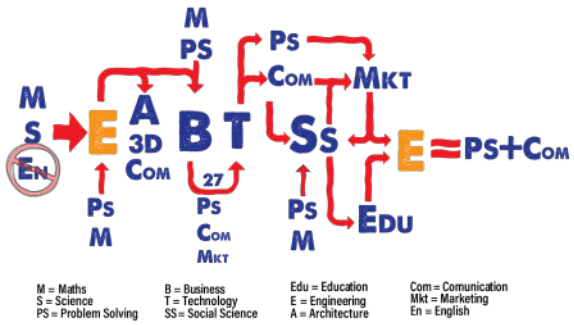


Figure 3 - Engineering Career Path Map

When REA was founded, there was a lack of research on social science issues that directly influenced children's career motivations regarding STEM engagement. To fill this gap, REA initiated a research project into the motivational drivers of children's career decision-making at the University of South Australia. Although this began as a Doctoral Research project, it has continued as a longitudinal study over the past 16 years, providing valuable insights not only into the career drivers of children but also aspects of human nature that can be applied to running any successful business.

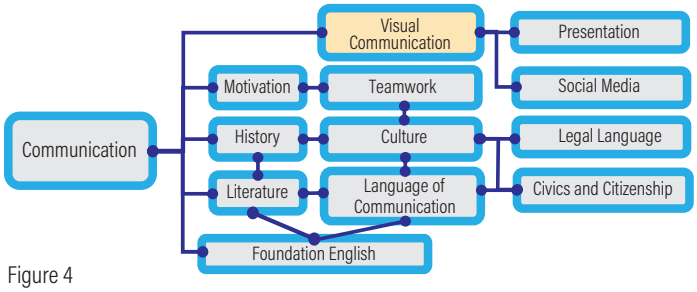
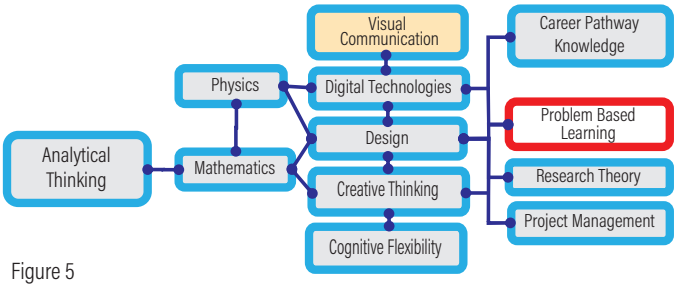


Figure 4



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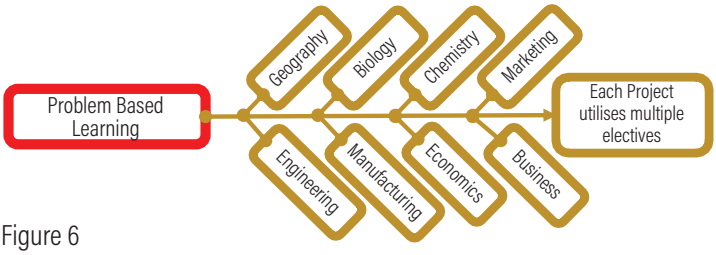


Figure 6

REA STEM PROGRAM LEARNING MAP

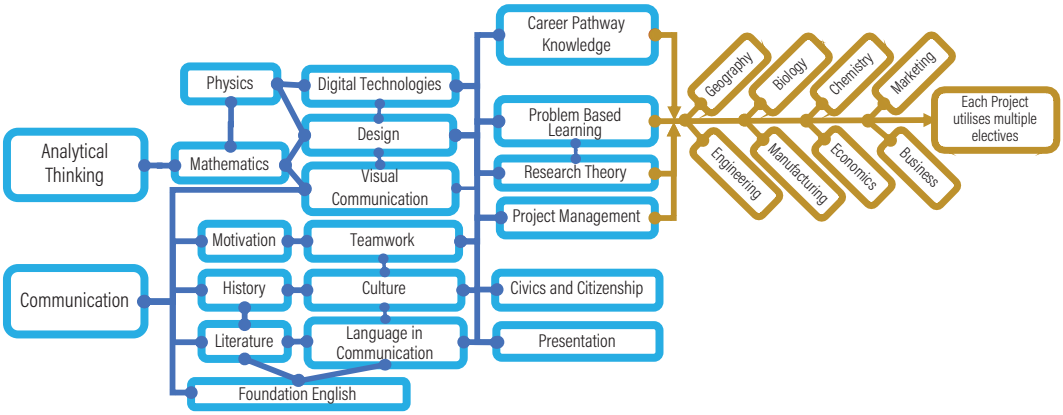


Figure 7

As the work environment our children will enter becomes increasingly diverse and complex, they will require empathy and seamless communication skills to navigate cultural differences and solve problems effectively. Therefore, the education system should prioritise problem-solving and communication skills, rather than passive outcomes that are not aligned with the varied demands of industry.

Education Mirroring Industry

Throughout history, the concept of education mirroring industry has been observed. During Industry 1.0, the introduction of steam mechanised manual labor and led to the shift from rural to urban living. Industry 2.0, which involved the use of electricity and process development, resulted in the creation of assembly lines, greatly improving production efficiency. In Industry 3.0, computers and automation led to machines performing tasks previously done by humans, highlighting the need for a common communication platform. While Industry 4.0 represents the future of manufacturing, the education system is struggling to keep up.

The issue with education is that it has become compartmentalised, with separate silos of knowledge that lack a strategic vision to connect them. Unlike industry, which uses profitability to drive innovation, education is hindered by bureaucracy. To improve educational outcomes, it is necessary to break down these silos and allow all taught knowledge to link together like apps. This requires a shift towards STEM 4.0, which can elevate the performance of Australian students and meet the needs of a highly educated society.

The industrial revolution brought economic growth and employment opportunities, but it also created technology silos that impeded progress. Automation and technology have made it necessary to understand the essential information for systems to move towards automation. Thus, it is imperative to break down silos and reposition them as apps that can communicate with each other.

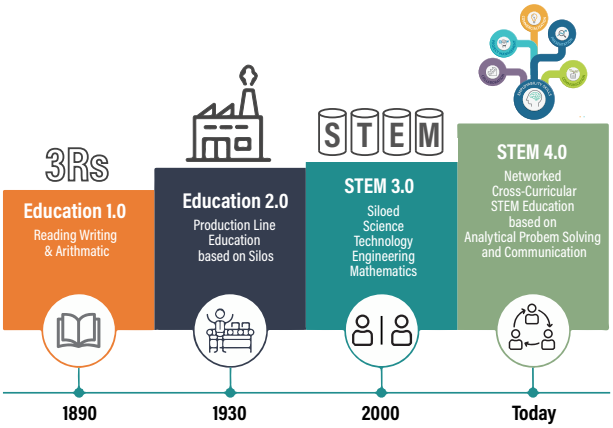
Currently, education operates with knowledge silos that lack a strategic vision to connect them, similar to industry. However, industry is driven by profitability to move towards Industry 4.0, while education is hindered by bureaucracy, leading to declining standards. All taught knowledge should be connected, allowing students to prepare for their future education pathways. To achieve this, it is necessary to break down divisions and take a top-down approach to enable transformation in education since it lacks the commercial incentives present in industry.

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".

About REA's Programs

The Re-Engineering Australia Foundation (REA) is a non-profit social enterprise established in 1998 with the aim of increasing students' understanding of STEM-based careers. It has become a recognised leader in designing and implementing STEM career intervention activities. Over the past two decades, REA's programs have directly impacted 1,300,000 students throughout Australia, from Thursday Island to Tasmania and Sydney to Perth. This extensive experience base contributes to the continuing success of their programs.

REA's programs focus on providing students with exciting challenges, world-class technology, and industry mentors to facilitate their thirst for knowledge.



Industry 4.0

Industry 4.0 is the fourth phase of industrial development, characterised by the implementation of Cyber-Physical Systems (CPS) that enable intelligent machines, storage systems, and production facilities to exchange information and control each other autonomously. This exchange of information occurs through the Industrial Internet of Things (IIOT), where thousands of sensors work in real-time and transfer data to a local or cloud server. By developing predictive models, organisations can anticipate irregularities in their processes or systems and take corrective action well in advance, thereby avoiding system failures.

The shift to CPS generates large volumes of data, referred to as "Big Data", which industries can analyse to improve their manufacturing processes, material usage, supply chain, and life cycle management. Industry 4.0 aims to use internal protocols to support the collection and analysis of Big Data, with the ultimate goal of enabling machines to solve problems independently.

However, the success of Industry 4.0 is contingent on the availability of pervasive networks and ubiquitous access to the internet, as well as an application development mindset to connect all the systems together. The potential benefits of Industry 4.0 are immense, but their realisation depends on the development of middleware that facilitates communication between all the different systems involved.

Figure 7 shows the learning map that underlies each of their programs. A critical aspect of the REA programs is that students are required to work directly with industry partners in their projects. This allows students to see the direct relevance between a classroom activity they enjoy and the world of work. REA also provides the latest technologies, which enables 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 industry's role in their future careers.

Aside from the measurable outcomes, REA's programs help students develop 12 industry employability skills to varying degrees. They work in teams, manage time and resources, and seek industry support and mentors towards a common goal.

REA's programs are longitudinal and can engage students over a 1 - 4 year period. They require students to collaborate and interact with industry and industry mentors to learn about technology and career path options. REA adopts a pull strategy, focusing students on possible career pathways rather than just handing career information to students to increase their engagement with industry career pathways.

To achieve desired educational outcomes, it is necessary to break down divisions and implement a top-down approach to enable transformation..

Supporting Research

REA began a longitudinal research project, in 2006 that examines the motivational drivers of children's career decision choices. The research has collected primary data from over 3,500 students and 600 teachers alone in the last three years. Some of the critical findings of the ongoing research include:

- 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 STEM.
- 55% of students have an interest in the manufacturing element of the program.
- 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.
- 71% of students indicated that they would recommend a career in specific STEM industries to their peers.

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

76% Met people during the project that inspired them.

89% Had a much clearer understanding of STEM as a career.

83% Are more interested in careers in STEM.

73% Reported that role models changed their perception of STEM careers.

50% Believe that companies helped change students perceptions of STEM.

90% Like using technology used by industry in the project.

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

94% Believe that STEM is interesting.

84% Believe that STEM is good for them.

83% Think STEM is fun.

88% Clearly understand what STEM brings to them.

86% Felt good when they were doing the project.

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

Attracting Boys & Girls to STEM

Students of both genders may need support to discover the excitement and engagement that STEM-based industries can offer. It's essential to have learning environments that promote a better understanding of the different professions within these industries, which can fit with the varying motivational drivers of Boys and Girls. This approach can significantly impact students' critical career decision-making processes.

For over two decades, attracting girls to STEM careers has been a challenge. Research has shown that Boys and Girls respond differently to messages about STEM careers. Boys require continuous human interaction, specifically with role models and mentors, to perform their best. On the other hand, Girls are drawn to managing complexity in environments, and emphasising the complexity and processes involved in STEM career pathways is key to attracting them.

At REA, we aim to engage with all students regardless of their background and use our understanding of their motivational drivers to attract their intrinsic interests. We've found that pushing Girls towards STEM careers can be counterproductive and lead to negative attitudes among Boys. Instead, exposing Girls to STEM career opportunities in a language that fits their motivational drivers is crucial.

The industry plays a crucial role in helping students make informed career decisions. Direct interaction with students and ongoing positive messaging about the industry is key. Poor STEM experiences can lead to a lack of enthusiasm, resulting in little measurable outcomes. To increase students' exposure to employment pathways in the industry, teachers' awareness and understanding of career pathways must be raised. Our research shows that our programs have positively impacted teachers' knowledge of the industry and its career pathways.

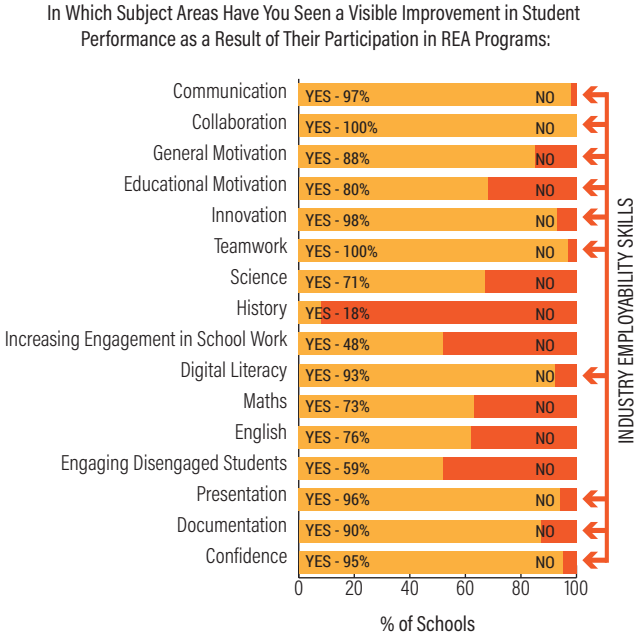


Figure 8 - Teacher Feedback on the Impact of REA programs on increase students performance across a broad range of subject areas.

Creating the Best STEM Students.

The goal of REA, which was founded in 1998, is to develop employability skills in students and enhance the nation's capacity. Initially, they focused on the engineering field due to their industrial background and observed that the education system wasn't producing enough skilled engineering students. REA's research has demonstrated that the application of STEM 4.0 methods can significantly improve the performance of students in the classroom.

In 2006, REA produced their first set of STEM World Champions in the F1 in Schools program and realized that they were creating some of the best STEM students

in the world. They have since produced eight world championship teams in the world's most extensive and complicated STEM competition, using STEM 4.0 methodology. Their focus is on cultivating successful entrepreneurs while emphasising the application of STEM 4.0 fundamentals and the development of resilience through both success and failure.

REA's programs place a significant emphasis on industry engagement, as industry needs to be more appealing to students. The existing education system can adopt REA's successful approach.

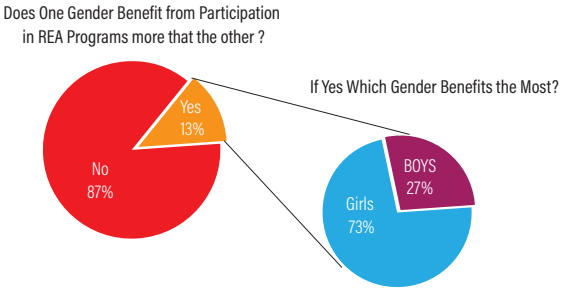


Figure 9 - Impact of STEM 4.0 on participation by gender as described by participating teachers

Figure 10 is a proposed roadmap for restructuring high school learning environments based on REA's learning map and a more comprehensive education landscape. It is presented as a conceptual roadmap and vision to foster discussion. However, bureaucratic agendas must not dominate the conversation, and industry must validate the skills they want to see from the education sector. Australia inherently produces excellent problem solvers, and it has the potential to provide the industry with the required quantity and quality of students in the future..

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.

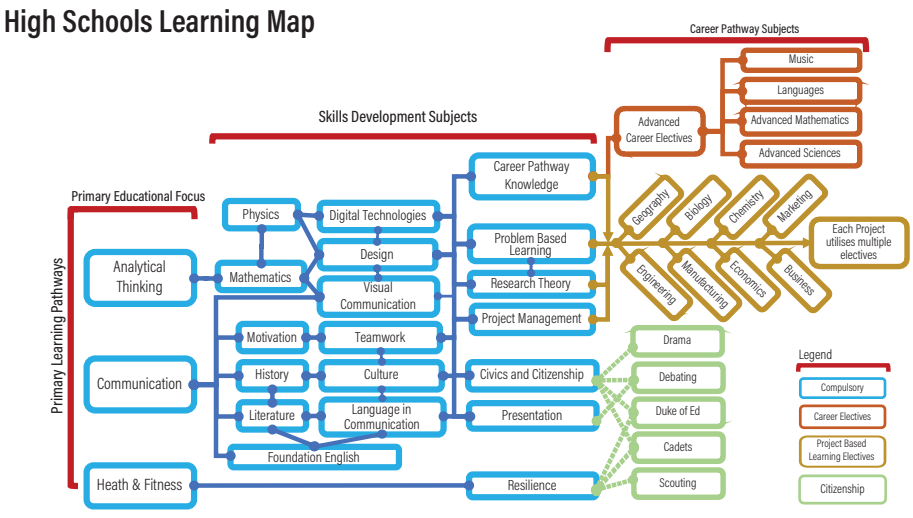
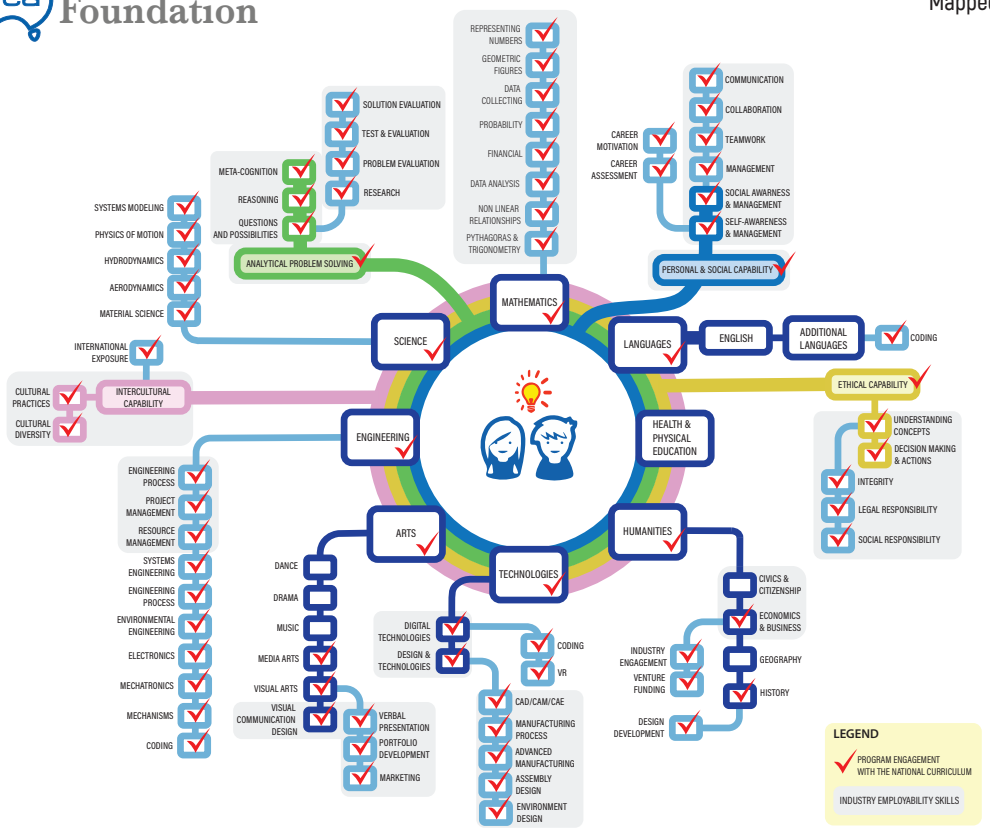


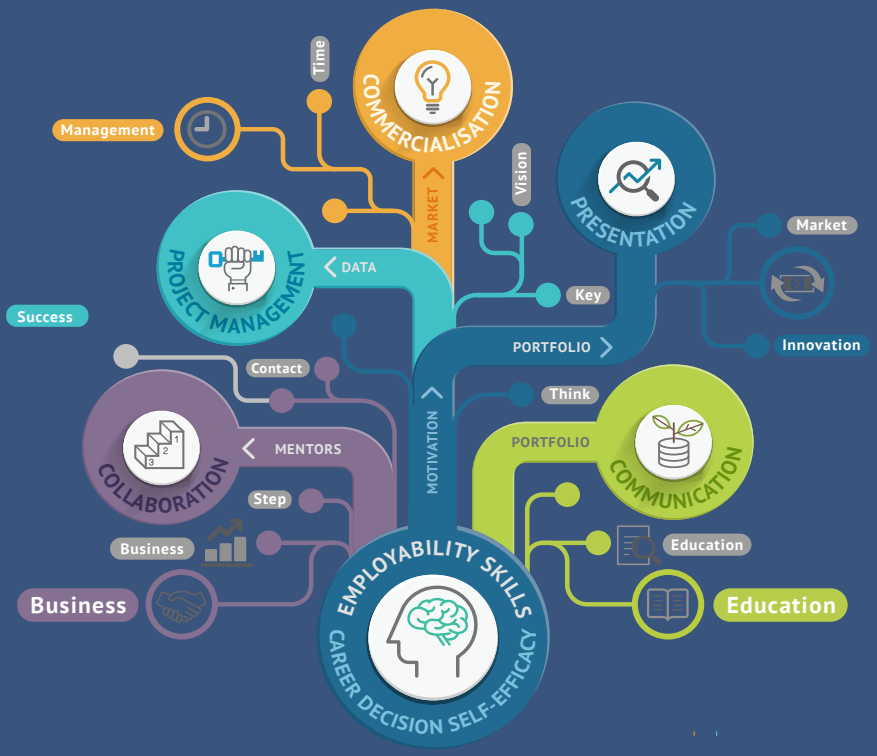
Figure 10 - Proposal for learning pathways map based on STEM 4.0 with Analytical Problem solving and Communication as core fundamentals

Re-Engineering Australia Foundation

Educational Outcomes
Mapped Against K-12 Curriculum

F1 in Schools
SUBS in Schools
SPACE in Schools





STEM 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 based on a foundation of Analytical Problem Solving and Communication. ... a networked cross-curricular collaborative learning environment where students transition from listening to taking ownership ... from ownership comes focus, motivation, innovation and leadership.

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