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Growing the STEM: Encouraging Interest in STEM subjects among low socio-economic Australian secondary students

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Growing the STEM

Encouraging interest in STEM subjects among low socio-economic Australian secondary students

Policy Analysis Exercise, Harvard Kennedy School

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Client: Australian Business Community Network

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HKS Policy Analysis Exercise

Title:	Growing the STEM: Encouraging interest in Science, Technology, Engineering & Mathematics (STEM) subjects among low socio-economic Australian secondary students
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CONTENTS

EXECUTIVE SUMMARY

- **Section 1: Problem Identification**
  - The client for this paper, the **Australian Business Community Network**, was established to harness business resources to address educational inequities in Australia. The organization is a network of 30+ large Australian companies, which designs and runs business-to-school mentoring programs for students in 'high-need' schools.
  - Problematically, given Australia's deeply held desires for equity and intergenerational mobility,[1] socio-economic status (SES) is positively associated with the educational engagement and performance of Australian secondary students. The relationship is observable across all of the key subject areas in the OECD's Programme for International Student Assessment (PISA), rendering it possible to claim that "the higher the level of socioeconomic background, the higher the student performance."[2]
  - This paper focuses on the weak participation and poor performance of low SES students in science, technology, engineering and mathematics (STEM) related subjects. Like the general data, a disproportionately high number of low socio-economic students perform poorly in STEM subjects. Somewhat unsurprisingly given the weak performance of low SES students in junior-level subjects, a disproportionately low number undertake senior STEM subjects.
  - The **weak participation and poor performance** of low SES students in STEM secondary school education has both negative equity and economic implications.

- **Section 2: Objectives, Policy Options and Strategic Perspective**
  - The policy options for improving the participation and performance of low socio-economic students in STEM subjects are wide-ranging. The options necessarily involve a variety of actors, with different program options available or better suited to some actors. The types of policy options appropriate to industry/corporate actors include internships, direct funding, in-kind resources including volunteering, and mentoring.
  - Rather than undertaking a comprehensive analysis of the types of industry/corporate programs that could best promote low SES student interest in STEM, the paper scans the horizon of potential program options and undertakes a preliminary analysis of the main types of industry/corporate programs using Herman Leonard's framework for strategic public sector analysis, which focuses on public value, capacity, and support.
  - The main types of effective programs offered by industry or corporate partners to increase low SES student interest in STEM are:

i. Funding for **innovative curriculum options / add-ons**
ii. **Direct instruction** of students, including remedial instruction
iii. Funding / Support for **existing nonprofits**
iv. Support student participation in **existing STEM activities** e.g. competitions
v. Provide **professional development** for STEM teachers
vi. Out-of-school **mentoring**

- The assessment reveals that a number of the program options that are suitable for industry / corporate partners provide public value and are aligned with ABCN's mission. However, it is less clear that the operational capacity and / or stakeholder support is sufficient for program options outside the sphere of mentoring **in the short term**. ABCN's chosen and exclusive delivery mechanism is mentoring. Accordingly, the paper focuses on the design of a mentoring program that best encourages low SES student interest in STEM subjects.
- However, **in the medium term**, it is recommended that ABCN seriously explore the possibility of offering member companies with the opportunity to i) provide direct instruction, using the WestEd 'Math Pathways and Pitfalls' curriculum; and ii) support participation in existing STEM competitions, notably the FIRST Robotics and Lego Leagues.
- Using a modified subset of goals recommended by the US National Science Foundation as potential objectives for out-of-school science education efforts, the proposed program outcomes for the mentoring option could include:
    - Increased **engagement** of high need students in STEM concepts and processes, including excitement towards STEM concepts/processes and involvement.
    - Improved **positive attitude** towards STEM-related topics.
    - Improved **intentions to undertake further secondary and tertiary STEM** subject study.

- Section 3: **What works in STEM engagement and Mentoring Programs**
    - In order to inform the design of a program that maximizes the value created by the ABCN, the report looks at best practice in both STEM promotion and mentoring programs.
    - Research into exemplary or high performing STEM-promotion programs in the UK and US, as well as findings from large national surveys in those countries, indicate that effective STEM-promotion programs for school students involve: a consistent **mentor or role model** from a STEM-related occupation; **breadth or diversity** of subject matter content beyond traditional curriculum; a **hands-on** STEM-related project; **collaborative work** in a small group; **relevance** and linkages to real world contexts; and **career guidance** and knowledge about STEM-related occupations and work environments.

- Numerous robust evaluations of mentoring programs, including those targeted at high need students, revealed that programs are most effective when: based **outside a school setting**, such as within the community or workplace; mentors were caring adults who possess a background in a helping profession; the mentor-mentee relationship was **longer in duration and at least 6 months;** firm requirements and **expectations around frequency of contact** between the mentor and mentee were established; **ongoing training or support** was provided to the mentor during the relationship and mechanisms to **monitor the mentor** were established; **structured activities** for mentor-mentee sessions were provided; and **parental involvement** was encouraged.

- Section 4: **Recommended Program Design**
  - **Theory of Change:** A business-to-school mentoring program, which focuses on STEM-related activities, career reflection and discussion, has the potential to promote a number of the factors that are correlated with further STEM education and employment. Specifically, such a program could boost interest in STEM subject content, help build a network of STEM-involved peers, and promote understanding and knowledge of STEM careers.
  - The recommended **target audience** is junior high school students, up to and including Year 9, who are not interested in STEM and either proficient or not proficient.
  - **Key pedagogical methods** that should underpin the program include: a consistent **mentor or role model** from a STEM-related occupation; **breadth or diversity** of subject matter content beyond traditional curriculum, with a particular focus on engineering and technology; a **hands-on** STEM-related project; **inquiry-based** methods; **collaborative work** in a small group; **relevance** and linkages to real world contexts; and **career guidance** and knowledge about STEM-related occupations and work environments.
  - Other recommended **design features** include a group mentoring setting (with a mentor/mentee ratio of 1:2 or 2:4); conducted after school hours in an out-of-school setting (at the member company); firm expectations around frequency of contact and parental involvement.
  - Program delivery and structure includes 2 hour-long sessions per month for 6 to 8 months, with the first hour dedicated to a STEM-related activity; a 15 minute food break; and final 45 minutes for reflection and discussion.

- Section 5: **Measurement and Evaluation**
  - Measurement and evaluation processes can be undertaken for different purposes and these purposes can be reflected in different stages of the evaluation. The process should capture both measures of effort and effect. It is not recommended that the evaluation involve either a simple pre-program and post-program comparison or a simple treatment versus control estimator.

- Instead, a randomized controlled trial is recommended given that this method represents the highest quality mechanism for estimating the causal impact of a program and because the usual barriers of cost, logistical difficulties or ethical challenges are not overwhelming. If the ABCN or schools are not inclined to adopt this method, a difference-in-difference approach represents an alternative, albeit inferior, method.

- **Appendices** include
  - Appendix A: Research methodology
  - Appendix B: Case for Investment in STEM
  - Appendix C: Map of Existing STEM-related External Supports for Australian schools
  - Appendix D: Program Tools and Further Resources

SECTION 1: PROBLEM IDENTIFICATION

1.1 Context and Definitions

The client for this paper, the Australian Business Community Network, was established to harness industry or corporate resources to address problems around educational inequity in Australia. The ABCN is a network of around thirty large Australian companies, which designs and runs business-to-school mentoring programs for students in 'high-need' schools. Companies pay an annual membership fee to the ABCN, which the ABCN uses to design programs and build relationships with schools. Member company employees then sign up as volunteers for different programs through the Network. The Network currently operates ten business-to-school mentoring programs, which are broadly focused on 'developing leaders', 'raising aspirations', and 'building critical skills'.[3] The ABCN does not currently offer a program that focuses on building interest in further STEM education or STEM-related employment.

The term STEM is shorthand for 'science, technology, engineering and mathematics' and is intended to capture a broad field of education and employment opportunities, beyond the more narrow fields of science and mathematics. The term is also designed to conceptually integrate the study of "science, technology, engineering and mathematics into a new transdisciplinary subject in schools."[4]

The ABCN works exclusively with Australian students from 'high need' schools. ABCN classifies 'high need' schools as those with ICSEA scores below 1000. ICSEA, or the 'Index of Community Socio-Educational Advantage', is an index designed to encompass the "key factors that correlate with educational outcomes"[5] so that schools could be more easily grouped into like categories, more meaningfully compared, and more effectively targeted for policy. The measure incorporates the socio-economic characteristics of the area in which the student lives, including "average income, level of education, and types of employment for the households of students enrolled in the school"; remoteness; and proportion of indigenous students.[6]

1.2 Socio-economic Status and Educational Performance

1.2(a) Poor test performance of low socio-economic students

Socio-economic status is positively associated with the educational performance of Australian secondary students (grades 7 to 12, typically aged 11 – 18). The relationship is observable across many of PISA's key subject areas, rendering it possible to claim that "the higher the level of socioeconomic background, the higher the student performance."[7] A large performance gap between high and low SES groups exists for all key subject areas, including reading, mathematical and scientific literacy.[8] For example, by the age of 15, the average student in the lowest socio-economic quartile (hereafter referred to as low socio-economic)[9] exhibits a reading literacy level that is nearly three school grades behind the average student in the highest socio-economic quartile.[10] The Program for International Student Assessment (PISA) attributes 13 percent of the explained variance in Australian student performance is the students' socioeconomic background.[11] Students attending schools with a higher average SES perform better than when they are enrolled in a school with a low average SES background.[12]

While this performance gap is compelling, the composition of the tail also speaks to very poor performance of a disproportionate number of low SES students. Schools with a high proportion of low SES students have significantly more students in the lowest performance bands than schools with a high proportion of high SES students. By way of example, 28 per cent and 22 per cent of low SES students did not achieve the minimum standard in mathematical and scientific literacy respectively, compared to 5 and 4 per cent of high SES students.[13]

The above picture of educational performance and equity in Australia is not dissimilar to the situation in many OECD countries. Results from 2009 PISA testing classified Australia as 'High Quality – Average Equity', that is, performing above the OECD average on overall test achievement and around the OECD average on the relationship between socio-economic background and test performance.[14] New South Wales (NSW), the Australian state of interest for this paper, is also classified as 'High Quality – Average Equity'.

Although positive associations between socio-economic status and education performance persist in most countries, the intensity of the relationship varies between countries and a number of countries achieve both strong educational and equity outcomes. In fact, five of the six countries that performed more strongly on PISA testing exhibited a higher level of equity than Australia's level, suggesting that there is not a trade off between higher performance and improved educational equity. Figure 1 provides a graphical representation of the education/equity performance of Australia and its states in reading literacy by comparison to select OECD countries. The figure shows Finland, Hong Kong, and Canada as 'High Quality-High Equity.'

Figure 1: PISA measures of educational performance and equity for select OECD countries

(Source ACER 2010 "Challenges for Australian Education: Results from PISA 2009" p19)

1.2(b) Poor performance on other non-test education indicators

In addition to test performance, low SES students perform poorly on non-test indicators such as school engagement and completion. Specifically, low SES students are "more likely to…have negative attitudes to school, to truant, to be suspended or expelled and to leave school early."[15] As a likely corollary to these attitudes and behaviors, 19 year-old low SES individuals exhibit a Year 12 completion rate some 26 percentage points lower than high SES students. Subsequent to school, low SES youth are more likely to struggle with the transition to work and are less likely to both enroll in and succeed in further education.[16]

1.2(c) Socio-economic status and STEM subject performance and interest

Like the general data, the socio-economic profile of performance, interest and completion of STEM subjects is not proportional to the socio-economic distribution of secondary school students. First, Australian secondary schools with a high proportion of low socio-economic status (SES) students have significantly more students in the lowest performance bands in mathematics and science than schools with a high proportion of high SES students. Specifically, in the OECD's worldwide student assessment processes (the PISA testing), 28 per cent and 22 per cent of low SES students did not achieve the minimum standard in mathematical and scientific literacy respectively, compared to 5 and 4 per cent of high SES students.[17]

Second, a disproportionately low percentage of students from low socio-economic backgrounds undertake senior STEM subjects, with Year 12 students from higher socio-economic backgrounds being more likely to pursue senior STEM study.[18] Research undertaken by the Committee for the Review of Teaching and

Teacher Education indicates that the participation rates in chemistry and physics for Year 12 students from the lowest socio-economic group are less than half the participation rates for students from the highest socio-economic group. Specifically, 12 per cent of low socio-economic Year 12 students undertake chemistry, compared with 26 percent of high socioeconomic students; and 11 percent of low socio-economic Year 12 students undertake physics, compared with 23 percent of high socio-economic students.[19]

There is likely a strong relationship between the weak performance in the junior years of high school and the disproportionately low percentage of low socio-economic students in senior STEM subjects. Singh and colleagues explain that "courses in mathematics and science are sequential, making performance in these subjects in middle school critical for later access to advanced courses and success in the full array of mathematics and science courses in high school and beyond."[20]

1.3 Problems with STEM Pedagogy

Some commentators have argued that student disengagement from STEM is partially a result of static STEM pedagogies that emphasize concepts over context and do not prioritize student-directed discovery. Tytler observes that "the broad shape of science education has remained relatively unchanged, at least in its official guise, for the last half-century at least."[21] Specifically, the dominant pedagogical methods for STEM subjects in Australian secondary schools are characterized as deductive, top-down transmission of compartmentalized disciplines with an "emphasis on conceptual knowledge" and where "context (is treated) as mainly subsidiary to concepts."[22] The Australian Council for Educational Research contends that, in part as a result of these outdated methods, there is "deep-seated disenchantment with aspects of the science curriculum and pedagogy in Australia.[23]

This so-called disenchantment is borne out in qualitative studies of student perceptions in Australia, mainland Europe and the UK. In Australia, a number of interview and survey-based studies of student attitudes towards science revealed that a dominant source of negative views towards science was the perceived irrelevance of science course content to students' lives.[24] Somewhat differently, European and US studies found that students disliked the minimal time for discussion and reflection in traditional STEM curricula. A Swedish longitudinal study of students, which ran from primary school through high school subject selection, found that "students resented the lack of opportunity for personal opinion and expression in science, caused by the narrow range of transmissive pedagogies used."[25] Likewise, a UK qualitative study found that students disliked the absence of time "to discuss or reflect or offer opinions" and concluded that the curriculum failed to provide students with the opportunity to "stand and stare, and absorb what it was that they had just learned."[26]

1.4 Does Poor Participation and Performance in STEM Education Matter?

The weak participation and poor performance of low SES students in STEM secondary school education has negative implications for both equity and productivity.

1.4(a) Education and future earnings

The mobility of individuals between socio-economic groups, particularly across generations, is considered a strongly desirable feature of many modern economies. In fact, in a survey conducted by Roy Morgan for the Australian Institute of Social Services, 91 per cent of Australians noted that the right to a fair go was a very important Australian value.[27] The relationship between education and employment outcomes is well established, with lower education levels typically associated with increased risk of unemployment, employment instability, and lower lifetime earnings.[28] For example, individuals in the US with tertiary qualifications earn more than twice the income of individuals without post-compulsory education.[29] This relationship between education and employment outcomes no doubt also holds true for STEM education. With specific regard to STEM, the failure to pursue senior level 'enabling sciences' such as chemistry and physics precludes a number of university degree paths that require these subjects. As areas of skill shortage, STEM fields also exhibit relatively high average weekly earnings.[30]

1.4(b) The economic importance of STEM

Like many OECD countries, Australian governments and think tanks emphasizes the economic importance of a strong STEM workforce and a robust pipeline of well-trained STEM graduates. (For a full discussion of the importance of STEM industries to economic growth, see Appendix B.) However, labor supply challenges in STEM-related industries, particularly engineering, continue to beset Australian industry. Given "declining participation in post-compulsory STEM subjects, particularly 'enabling science of physics, chemistry and higher mathematics,'"[31] ongoing constraints are forecast for the medium term. (For a full discussion of existing and forecast labour supply challenges related to STEM, see Appendix B. ABCN may find this background useful in making the case of a STEM-specific mentoring program to its member companies, in addition to the equity argument).

While a low level of interest and participation in STEM subjects is a problem across all socio-economic groups, the particularly low performance and take up rates among low socio-economic students also contributes to labor supply constraints. No doubt, Australia could mitigate some of the labor supply constraints through mechanisms that are unrelated to the involvement of low socio-economic students; for example, through skilled immigration programs. Further, the investment that ABCN companies make in a program that encourages low socio-economic student interest in STEM may not exhibit the same cost-benefit ratio as other efforts. Efforts to increase low socio-economic student interest in STEM are primarily based on equity arguments.

However, given the high correlation between interest and further study, efforts to increase interest are likely to also increase participation in further STEM study. The failure to pursue senior level ‘enabling sciences’, such as chemistry and physics, precludes many undergraduate degree options that require prior knowledge of these subjects. With participation rates in senior-level chemistry and physics hovering just above 10 percent, compared with around 25 percent for high socio-economic groups, there is potential to increase potential tertiary STEM candidates by bringing participation rates closer to higher socio-economic students.

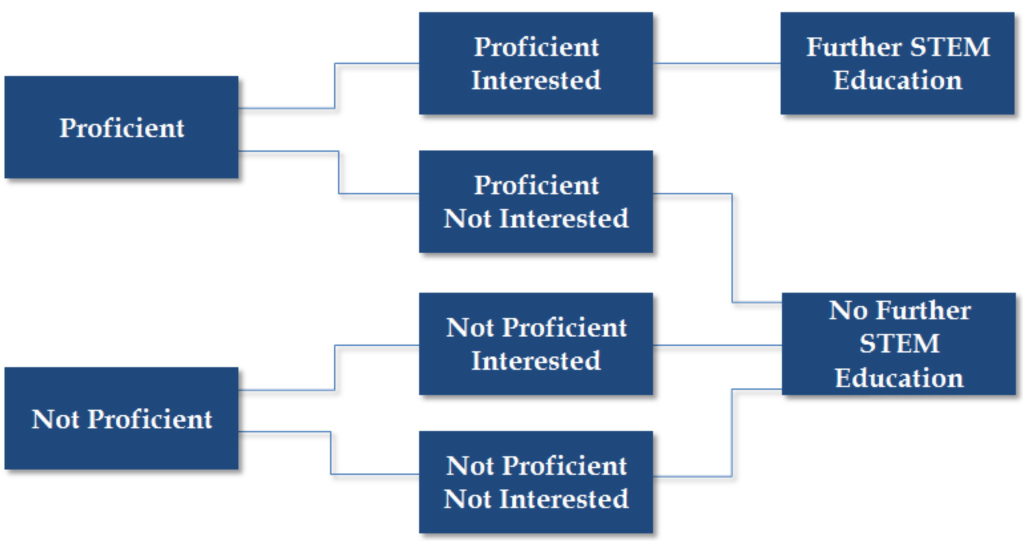
SECTION 2: OBJECTIVES, POLICY OPTIONS & STRATEGIC PERSPECTIVE

2.1 Objectives

The problem identified in this paper is the poor participation and performance of low socio-economic students in STEM subjects. Accordingly, the longer term objective is to increase the proportion of low socio-economic students who are interested in and trained for STEM-related occupations. Given that senior secondary STEM subjects are typically required to undertake tertiary-level study in STEM, a necessary pre-condition is a higher proportion of low socio-economic students who undertake senior secondary school STEM subjects.

The Raytheon Company, as commissioned by the US-based 'Business High Education Forum', developed a systems dynamics model of the American STEM education system that concluded that an increase in the number of students enrolling in undergraduate STEM subjects required that "students be both **proficient** and **interested** in STEM."[32] Figure 2 demonstrates that if students are not proficient and interested in STEM subjects, they will not undertake further STEM education.

Figure 2: Relationship between proficiency, interest and further STEM education



The concept of interest has proven to be particularly important in predicting both disengagement from mathematics and science and performance in mathematics and science. Specifically, research has found that "attitudinal and affective variables such as self-concept, confidence in learning mathematics and science, (and) mathematics/science interest and motivation" [33] both predict:

- academic achievement in mathematics and science; and
- "mathematics and science avoidance on the part of students, which affects long-term achievement and careers aspirations in the mathematics/science fields." [34]

Like the international research, a broad-ranging review commissioned by the Australian Government's Department of Education, Employment and Workplace Relations (DEEWR) found a number of similar key factors that are associated with student participation in STEM education and subsequent STEM-related employment.[35] Specifically, the review found that STEM participation is associated with:

- achievement in STEM subjects;
- strong interest in STEM subject content;
- STEM-involved peers; and
- understanding and knowledge of STEM careers.

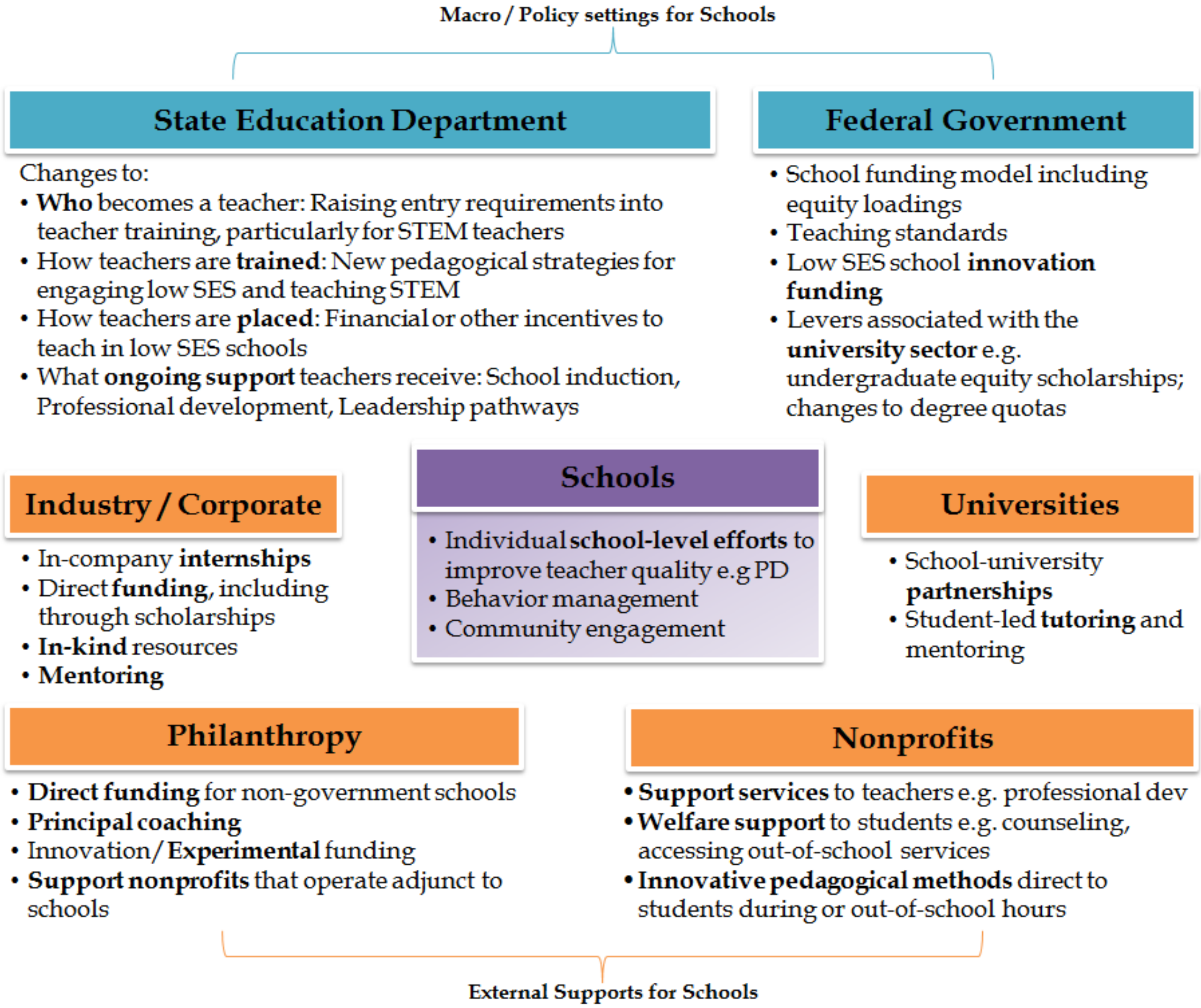
Accordingly, the objective of a higher proportion of low socio-economic students in senior secondary school STEM subjects can be targeted by either increasing proficiency/achievement or student interest in STEM subjects. In order to leverage a number of the factors associated with further education, any program recommendation should also build in peer networks and career guidance. More specific or granular outcomes, under either proficiency or interest, will depend on the type of program that is recommended (See Section 4.2 for suggested program outcomes).

2.2 Relevant Actors and Policy Options

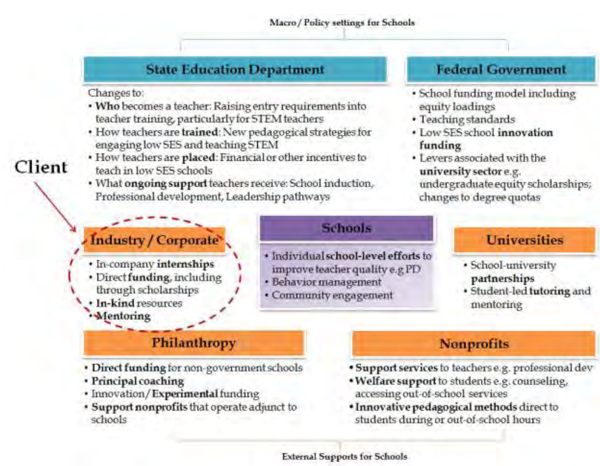
The policy options for improving the proficiency or interest of low socio-economic students in STEM subjects are wide-ranging. Policy options can target different points on the spectrum of STEM education opportunities or capitalize on different levers, including teaching standards and pedagogy; teacher education/professional development; school-to-industry relationships including through internships; and scholarships or other financial incentives for students to pursue further STEM education.

These policy options necessarily involve a variety of actors and different program options are suited to different actors. A map of the key actors in the schools sector who could impact the participation and performance of low socio-economic students in STEM subjects and the types of policy/program options available to each actor is provided at Figure 3. Namely, the key actors controlling the macro, policy and funding settings for schools are the Federal Government and the State Education Department (blue boxes). Schools obviously sit at the center of the sector and are capable of individual school-level efforts to improve participation and performance. There are also a number of types of organizations that exist external to schools but often serve in different support functions for schools, including industry/corporate, nonprofit, university and philanthropic actors (orange boxes).

Figure 3: Map of Key Actors in Schools Sector and Potential Policy Responses



As the client of this 'Policy Analysis Exercise', the paper adopts the perspective of the Australian Business Community Network. The ABCN sits in the industry/corporate section of the Actor Map (see opposite). The types of policy options appropriate to actors under this category include in-company internships, direct funding including scholarships, in-kind resources including employee volunteering, and mentoring.



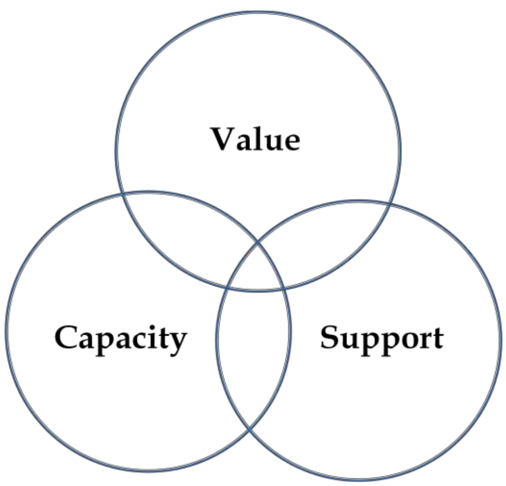
Given their potential role as providers of out-of-school, inspirational activities, this sector could also prove particularly useful in helping to fulfill the recommendation made by the US President's Council of Advisors on Science and Technology around students needing "opportunities to establish deeper engagement with and to learn science and mathematics in non-standard, personal, and team-oriented ways that extend beyond the curriculum and the classroom."[36]

2.2 Strategic Perspective

This paper uses a framework for public sector strategic analysis developed by Herman Leonard, which Leonard argues can "be applied to the analysis of…any contemplated or ongoing action, program, initiative or venture."[37] Given that this paper contemplates the creation of a new program to encourage interest in STEM subjects among high-need Australian secondary school students, Leonard's three questions for defining the strategic environment of a new program help to guide the analysis in this paper. Specifically,[38]

1. Would the operation of the program create **public value**?
2. Does the organization have the **capacity** to develop and deliver the program?
3. Does the program enjoy the **support** of the necessary people, organizations or other constituencies?

Figure 4: Leonard's 'Value, Capacity, and Support' Model



The potential policy options are appropriately constrained by ABCN's mission, delivery capacity and stakeholder interests. Rather than undertaking a comprehensive analysis of the types of industry/corporate programs that could best promote low SES student interest in STEM, the paper scans the horizon of potential program options and undertakes a preliminary analysis of the main types of industry/corporate programs against Leonard's framework of public value, capacity, and support. The main types of effective programs offered by industry or corporate partners to increase low SES student interest in STEM are:

i. Funding for innovative curriculum options
ii. Direct instruction of students, including remedial instruction
iii. Funding / Support for existing nonprofits
iv. Support student participation in existing STEM activities e.g. competitions
v. Provide professional development for STEM teachers
vi. Out-of-school mentoring

The following section provides a brief outline of the type of program, examples of effective programs under each category, and the direction and/or magnitude of results. Obviously, there is a wide range of effect sizes for programs under each category that are in operation, ranging from ineffective to effective, but only programs with moderate to large effect sizes or medium to high public value have been included below.
For reference, an effect size is a measure of the strength of a program's impact and is designed to "place an easily interpretable value on the direction and magnitude of an effect of a treatment."[39] For example, an effect size of 0.7 means that the average person in the program is 0.7 standard deviations above the average person in the control group, or scores above 69% of the control group.[40]

<u>i. Funding for innovative curriculum add-ons</u>

Some industry and corporate partners are funding the development and/or distribution of curriculum innovations. These curricula are typically developed by research-based institutions and delivered by regular classroom teachers or nonprofits in out-of-school hours.

- Example – WestEd's 'Math Pathways & Pitfalls' is a supplementary K-8 curriculum for US students, focusing on common pitfalls in mathematics, with optional professional development support for teachers. The program is designed to serve as a "model for teaching and learning mathematical concepts that can be applied to mathematics lessons in any adopted curriculum." WestEd makes the materials available at a very low cost.
- Example – 'Engineering is Elementary' is comprised of lesson plans and materials developed by the Boston Museum of Science, which aim to integrate engineering and technology concepts into elementary school science classes. The curriculum is comprised of storybooks and hands-on activities, supported by teacher professional development materials.
- Magnitude of results:
  - A randomized trial of WestEd's curriculum for 15 hours per year for two years produced effect sizes of 0.4 in standardized mathematics test scores and 0.53 for mathematical language development.
  - Evaluations of 'Engineering is Elementary' have found increased student interest in engineering and comfort with engineering-related skills.[41]

ii. Direct instruction of students, including remedial instruction

Some industry and corporate partners facilitate their employees to provide volunteer direct instruction to students, including remedial instruction, during regular school hours or out of school hours. This form of direct instruction is often supported by a nonprofit or university partner, who trains the volunteer employees.

- Example – Project SEED, which trains professional mathematicians, scientists and engineers to use inquiry-based and learning-by-discovery methods to teach low socio-economic elementary students abstract mathematics. The regular classroom teacher can observe the practice of the instructional specialist and attend workshops conducted by the trained specialists.
- Direction of results: Students receiving Project SEED instruction outperformed non-participants for four years; undertook higher level mathematics classes in later school years.[42]

iii. Funding / In-kind resources to existing nonprofits

Industry and corporate partners often provide either direct funding or in-kind support to nonprofits that pursue their own programs to increase student engagement or performance in STEM.

- Example: 'Gateway' is an outreach program by State University of New York designed to prepare NYC high school students for further tertiary study in STEM. Students attend classes with other Gateway students; undertake 4 year program of university preparation and advanced mathematics and science classes; and participate in internships.[43]
- Direction of results: Participants enjoyed higher graduation rates, higher enrolment in high school mathematics and science subjects, and a 75 percent enrolment rate in college.

iv. Support student participation in existing STEM activities e.g. competitions

A widespread and currently popular form of industry-school partnership is the support of student participation in existing STEM competitions. Employees within industry and corporate partners might provide support and mentorship for a team or individual to participate in a STEM competition. The company might also 'sponsor' the student's participation in the competition by funding the purchase of materials.

- Example: An extremely popular, well-established, and evidence-based set of competitions are conducted by FIRST, 'For Inspiration and Recognition of Science and Technology'. The most renowned program is the FIRST Robotics Competition, for students in grades 9 to 12. Teams participating in FIRST are typically supported by a volunteer mentor, who is often an engineer from a corporate partner, and a sponsoring organization.[44]

- Magnitude of results: When compared with students from similar backgrounds and similar levels of achievement in high school mathematics and science, minority and low socio-economic students that participated in FIRST were substantially more likely to attend college and twice as likely to major in science and engineering.[45]

v. Provide professional development for STEM teachers

In an attempt to build the capacity of the existing education sector to effect improved student engagement and performance in STEM, a number of programs and nonprofits target teachers rather than students. In particular, professional development programs tend to focus on deepening teacher's STEM subject matter knowledge and genuine understanding.

- Example – The Merck Institute for Science Education runs a 3 year professional development program, 'The Academy for Leadership in Science Instruction', for teachers, principals, and administrators to deepen understanding of science instruction and instructional leadership. The Institute also runs workshops to equip teacher leaders to facilitate peer teacher workshops designed to promote inquiry-based science instruction.[46]
- Example – K-8 Math Progressions is an 80-hour course in professional development for mathematics teachers, co-facilitated by practicing mathematician and mathematics educator. The course is primarily comprised of mathematics content knowledge in an attempt to "bridge the gap between insufficient mathematics training of elementary school teachers and the demands of the contemporary classroom."[47]
- Direction of results:
    - Evaluation of the Merck Institute for Science Education's 'Academy for Leadership in Science Instruction' found statistically significant increases in student science test performance in grade 5 but not grade 7.[48]
    - K-8 Math Progressions reported increased teacher confidence, computational skills, and conceptual understanding. The impact on student performance has not been evaluated.

vi. Out-of-school mentoring

There is a huge variety of industry-student mentoring programs, including in the STEM field. Examples of the most effective types of programs for lifting student engagement and performance in STEM combine mentoring with elements of other effective STEM promotion programs, such as hands on activities.[49]

- Example – The US-based 'Science Club for Girls' seeks to increase the STEM self confidence and literacy of young low income or minority females through hands-on activities and mentoring by professional scientists. The scientists "model and foster leadership, affirm college as an expectation, and promote careers in science and technology as goals and options."[50]

- Magnitude of Results: In a meta-analysis of mentoring programs that employed a majority of effective mentoring practices, effect sizes were around 0.2 across a range of domains, such as student performance and behavioral change. Mentoring programs that are combined with other elements of effective STEM promotion programs e.g. hands-on activities, exhibit higher effectiveness.

ABCN's Mission, Capacity and Support

In order to assess the strategic viability of the aforementioned options, it is necessary to first provide a brief outline of ABCN's mission, capacity and support.

- Mission: The mission of the Network is to "share resources available to businesses, including volunteer, expertise and services, with 'high needs' schools and students with the goal of improving opportunities for fulfilling employment, raising aspirations and setting and achieving their goals."[51] This mission is broad and could encompass a wide range of potential policy options.
- Capacity: However, in order to achieve the mission, ABCN has selected mentoring programs as their key delivery mechanism. As a result, the organization has developed core expertise in partnering volunteer mentors from their member companies with students from low socio-economic schools. ABCN's current funding model is to obtain relatively low annual membership fees from its member companies, which support the salaries of the core program staff and the minimal costs of program operation. The key resource input to their ten mentoring programs is volunteered employee time.
- Support: ABCN's key stakeholders are its Board, member company coordinators and volunteer employees, state and federal education departments, schools, and student mentees. As the providers, facilitators and recipients of the program, the key stakeholders are the member company employees and the schools. While member companies appear to be comfortable with and supportive of the key delivery mechanism of mentoring, member companies have also piloted and organized other programs through ABCN and its school relationships, which suggests there may be appetite for other types of programs.

Having provided a brief outline of the types of programs that can be offered by industry / corporate to encourage low socio-economic student interest in STEM and ABCN's mission, capacity and support, Figure 5 assesses the strategic alignment of the program options by examining each option against ABCN's mission, capacity and support.

Figure 5: Strategic Alignment Matrix

Type of Program	Public Value, including Alignment with Mission	Operational Capacity	Support from Stakeholders
i. Funding for innovative curriculum options	**Medium** • Potential public value of some curriculum options is high. • However, alignment with mission is low/ medium because does not utilize the volunteer, expertise or services of businesses and would instead require direct funding outlay.	**Low** • Resourcing model is currently to utilize in-kind volunteer resources from member companies, rather than seek cash donations.	**Low** • Value proposition for member companies is to engage employees, not merely provide funding • Not clear whether schools would be capable of integrating or receptive to curriculum add-ons
ii. Direct instruction of students, inc. remedial	**High** • Effect sizes are high. • Strong alignment with mission because involves the volunteer resources and expertise of member companies.	**High** • Maintains current resourcing model to utilize in-kind volunteer resources from member companies, with employees providing direct instruction. • Utilizes existing relationships with schools. • Member company employees would require significant training.	**Medium** • Outside current model of mentoring so would likely require Board approval. • Not clear whether schools would be receptive to direct instruction of students by non-teachers.
iii. Funding/ support for existing nonprofits	**Medium** • Impact of some very resource intensive interventions is high. • However, alignment with mission is low/medium because does not utilize the volunteer, expertise or services of businesses and would instead require direct funding outlay.	**Low** • Relationships are currently held with schools, not with nonprofits. • Few existing nonprofits in Australia with whom to partner. Effective programs in the US are very resource intensive. • Resourcing model is currently to utilize in-kind volunteer resources from member companies, rather than seek cash donations.	**Low** • Value proposition for member companies is to engage employees, not merely provide funding. • Discontinues existing relationships with schools.

Type of Program	Public Value, including Alignment with Mission	Operational Capacity	Support from Stakeholders
iv. Support student participation in existing STEM activities e.g. competitions	**High** • Public value is high. • Strong alignment with mission because involves the volunteer resources and expertise of member companies.	**Medium** • Leverages existing competitions, rather than creating new program. • Relationships are held with schools, not with the university and nonprofit bodies that run the competitions. New relationships would need to be built or encourage student participation. through existing school relationships. • ABCN would need to develop core competencies to support member company employees.	**Medium** • Existing relationships with schools may be disrupted where those schools are not interested / not able to participate in competitions • Not clear whether member company employees would be able to make the necessary time commitment
v. Provide professional development for STEM teachers	**Medium** • Less clear evidence on public value (student test performance), although anecdotal and qualitative evidence suggests medium public value through increased teacher confidence and pedagogical tools.	**Low** • Neither ABCN nor member company employees currently equipped to provide professional development for teachers.	**Medium** • Not clear whether schools would be receptive to teacher professional development, rather than student focus • Not clear whether member company employees would be as interested in supporting teachers as students
vi. Out-of-school mentoring	**Medium / High** • Public value of mentoring programs that incorporate key elements of effectiveness is medium; combined with some elements of effective STEM promotion programs is likely to create medium/high public value • Strong alignment with mission, given mentoring is currently baked into the mission	**High** • ABCN currently delivers 10 mentoring programs and has developed core competency in this area.	**High** • ABCN has a solid reputation for successfully managing business-to-school partnerships, particularly in mentoring. In recognition of their expertise, ABCN is regularly engaged by the federal government in business-to-school partnership efforts.

2.3 Strategic Alignment Assessment

2.3.1 Short-Term Option

The matrix reveals that a number of program options are suitable for industry / corporate partners, deliver public value, and are aligned with ABCN's mission. However, it is less clear that the operational capacity and / or stakeholder support is sufficient for program options outside the sphere of mentoring in the short term. Acknowledging that the key elements for developing a new program strategy include Leonard's categories of public value, capacity and support, this paper focuses on the optimal design of an employee-school mentoring program that encourages interest in further STEM education among low socio-economic students. In order to maximize effectiveness, the mentoring program can be structured to incorporate some of the most important features of STEM promotion programs (See Sections 3 and 4).

However, it is recommended that ABCN explore two alternative options that offer high public value and appear both operationally and politically feasible in the medium term (See Section 2.3.2). The matrix in Figure 5 and the brief outline of potential programs under Section 2.2 reveals that there may be non-mentoring program options with higher social impact, which are aligned to ABCN's mission, likely to enjoy stakeholder support and would require only minor to moderate changes to operational capacity.

2.3.2 Other Medium-Term Options

Accordingly, in the medium term, it is recommended that ABCN seriously explore the possibility of offering member companies with the opportunity to:

i. Provide direct instruction, using the WestEd 'Math Pathways and Pitfalls' curriculum
ii. Support participation in existing STEM competitions, notably the FIRST Robotics and Lego Leagues

i. Direct instruction

First, ABCN should consider offering member companies the opportunity to provide direct instruction to students using the WestEd 'Math Pathways and Pitfalls' curriculum. The effect size is high, particularly for such low material cost and volunteer time. The addition of this program to the suite of options offered to member companies is likely to be both operationally and politically feasible because it largely retains the resource model of using employee volunteer time and the value proposition to companies of actively engaging employees. The volunteer time commitment need not be excessive, with WestEd's evaluation indicating that results can be observed after a 15 hour intervention per year for two years. The option is recommended as medium term, rather than short term, because ABCN would need to develop competence in training volunteers in the curriculum. The materials are very low cost, at less than $200 for lessons and teaching manuals for two school years, and are available for order at:

http://www.wested.org/cs/mpp/print/docs/mpp/order.html.

ii. Supporting participation in existing STEM competitions

Second, ABCN should consider offering member company employees the opportunity to support the participation of a team of students in a STEM competition. The FIRST Robotics (grades 9 – 12), FIRST Technology Challenge (grades 7 – 12) and FIRST Lego Leagues (grades 4 to 8) are models proven to increase student engagement and participation in STEM subjects, including for low socio-economic students. In a survey of ABCN's partner schools and STEM teachers conducted for this research, a number of respondents noted the success of student involvement in competitions, including the FIRST Lego League, in increasing student engagement with STEM.

The competitions operate in Australia and teams typically require the support of a mentor and a sponsoring company. Given ABCN's existing relationships with schools and the resourcing model of ABCN (using employee volunteer time), the operational and political feasibility are reasonably high. The initiative is recommended in the medium term, rather than the short term, because ABCN would need to understand the competitions, including understanding resource requirements and developing relationships with competition organizers, and scope the interest of schools. It is likely that the FIRST Technology Challenge and Lego Leagues will be more appropriate to the target schools than the Robotics Challenge because of the high levels of resourcing required to participate in the Robotics Challenge. In a survey of both the Technology and Robotics Challenge team leaders, leaders in the Technology Challenge were much more likely to view their program as affordable to their relevant community.[52]

Recruitment methods would need to be carefully devised to ensure that the program is not comprised exclusively of students with high levels of pre-existing interest in STEM. US-based surveys of participants FIRST programs indicate that approximately 70% of participants in FIRST Robotics and Technology Challenges reported being 'interested' or 'very interested' in STEM prior to the program.

SECTION 3: WHAT WORKS IN STEM ENGAGEMENT & MENTORING?

In order to inform the design of a STEM mentoring program that maximizes the value created by the ABCN, the report looks at evidence of what is effective in both mentoring and STEM promotion programs. More specifically, the report attempts to answer two research sub-questions in order to design the most effective program for ABCN that encourages interest in further STEM education among high need Australian secondary students:

- What are the key characteristics of effective **adult-student mentoring programs**, particularly mentoring for high need or low socio-economic secondary school students?
- How is **motivation and interest in further STEM education** best encouraged among high-need or low socio-economic secondary school students?

Subsequent proposed elements of program design will incorporate the key criteria or components of exemplary mentoring and STEM promotion programs.

3.1 Programs Designed to Increase STEM Interest, Further Education and Employment

Research into exemplary or high performing STEM-promotion programs in the UK and US, as well as findings from large national surveys in those countries, indicate that effective STEM-promotion programs for school students involve: a **hands-on** STEM-related project; a consistent **mentor or role model** from a STEM-related occupation; **breadth or diversity** of subject matter content beyond traditional curriculum; **collaborative work** in a small group; **relevance** and linkages to real world contexts; and **career guidance** and knowledge about STEM-related occupations and work environments.

Hands-on / Project-based

Surveys of school students in both the US and Australia have revealed strong student preferences for hands-on STEM project work. Haury and Rillero have defined hands-on learning as educational experiences that "involve people manipulating objects to gain understanding or knowledge."[53] A survey of around 300,000 students in the US revealed strong student interest in using professional tools, with around 40 percent of students indicating that their interest in STEM careers could by improved through access to "advanced technology, laboratory devices, or professional tools."[54] Similarly, in a 2012 survey of around 1200 Australian students undertaking senior-level science subjects, the most common suggestion for improvements of science classes "was to make classes more interactive by including more investigations, excursions, practical lessons or class discussions."[55]

Mentoring / Role modeling

An ongoing relationship with STEM-engaged adults has been found to serve a variety functions in the 'theory of change' of effective STEM promotion programs. First, the relationship enables students to positively identify with STEM content. US-based research[56] concluded that "emotionally satisfying relationships centred on science, math and engineering (SME) activities and discussions positively shape students' likelihood of thinking of themselves in SME terms and engaging in SME activities."[57] Second, representatives of exemplary US programs believed that the mentoring component allowed STEM industries to be represented in positive ways and negative stereotypes to be broken down.[58]

Breadth / Content Diversity

In order to encourage student interest and better reflect the discipline, STEM pedagogical experts have recommended that STEM content be construed more broadly and offered in a more integrated fashion. Hoachlander and Yanofsky have commented on the limited and fragmented nature of the school curriculum, arguing that "in too many schools, STEM is still mostly science and mathematics, taught separately with little or no attention to technology and engineering."[59]

Real-world relevance

Evaluations of effective and ineffective STEM promotion programs and STEM pedagogical methods consistently demonstrate the importance of content that is clearly linked and relevant to the 'real world.' Deakin University has characterized or defined real-world relevance as "topics and activities…are meaningful to students; their lives outside school, and their needs and hopes for their various futures."[60]

In the US, a study by the Puget Sound Center for Teaching, Learning and Technology of informal activities to promote STEM interest among girls found that projects with a real-life context and relevance exhibit promising results, and particularly those that emphasize the contribution or 'difference' that STEM employees can make in a real-world context.[61] This finding is supported by self-reported student desires. In a survey of 300,000 US school students, middle and high school students reported that their most interesting STEM learning experiences involved "engaging in activities with real-world relevance."[62]

Likewise, in Australia, a number of qualitative studies of student attitudes towards science revealed that a strong source of students' negative view towards science resulted from perceptions around the irrelevance of science course content to their lives.[63] Such findings have led Universities Australia to advise that a key avenue for increasing STEM participation is "to make mathematics and science more relevant to daily life, present it on a personal level."[64] Specifically, UA recommends demonstrating the importance of science and mathematics to the lives of students by, for example, focusing the "discussion on more real and personally relevant issues such as chemical processes in human digestion or an environmental analysis of a local stream."[65] Further, in a survey of ABCN partner principals and STEM teachers conducted for this project, the majority of respondents considered the real-world relevance of a project to be a 'very effective' design element of a STEM mentoring program (See Appendix A for research methodology).

Inquiry-based learning

Inquiry-based science education has recently been promoted as a more effective pedagogical method than traditional, deductive or 'top-down transmission' methods. The European Commission has noted that inquiry-based science education "has proved its efficacy at both primary and secondary levels in increasing…students' interest and attainment levels."[66] Most promisingly, inquiry-based methods have proven to have "even stronger impacts on the students with lower levels of self-confidence and those from disadvantaged backgrounds"[67] and are methods that are "compatible with the ambition of excellence."[68] The US-based Center for Inquiry-based Learning at Duke University has identified a number of effective inquiry-based methods to promote student engagement in STEM subjects, including encouraging students to "take the initiative to observe and question phenomena; pose explanations of what they see; devise and conduct tests to support or contradict their theories; analyze data; draw conclusions from experimental data; design and build models; or any combination of these."[69]

Group/Collaborative work

Working with others and in small groups has been identified as a key feature of exemplary programs in the US that promote interest in STEM subjects. An evaluation by the Massachusetts Department of Education of around twenty programs targeting student interest in STEM subjects found collaboration and small group work to be a key component of effective programs.[70] Likewise, a study by the US-based Puget Sound Center for Teaching, Learning and Technology of informal activities to promote STEM interest among girls found that collaboration to be particularly important. The findings of these evaluations of are supported by students' self-reported desires. In a survey of 300,000 US school students, middle and high school students noted that "working with other students on projects" was the second most important self-reported strategy for increasing their interest in STEM subjects.[71]

Career Information and Guidance

A recent UK report into students' perceptions of science careers found that "students have a narrow and limited view of 'science careers', and the career routes available to people with interest or aptitude in science."[72] Promisingly however, nationwide surveys in both the US and UK confirm students' interest in direct contact with STEM employees. The UK report found that approximately 3/4s of students highly value contact and information from people who work in STEM fields. The report concluded that "for students, people, their lives and the work they do are the richest and most respected resource for learning about careers."[73] Similarly, a US survey found that high school students ranked "conversational interactions with professionals" and "visits to STEM companies" as among the top five most likely strategies for increasing their interest in STEM education and employment.[74]

3.2 Mentoring Programs Targeted at High-Need Students

Formal adult-school student mentoring programs are widespread among many OECD countries and, taking all manner of forms, vary in effectiveness. The effectiveness of mentoring programs "depends on the quality of the mentoring relationship"[75] and the quality of this relationship is associated with a number of key program characteristics. Numerous robust evaluations of mentoring programs, including those targeted at high need students, illuminate the program characteristics and criteria that underpin mentoring programs with strong positive impacts for the mentee. Specifically, programs are more effective when:

- Based **outside a school setting**, such as within the community or workplace.[76] In a survey of ABCN partner principals and STEM teachers conducted for this research, most respondents noted the importance of a program setting outside the school, in order to expand horizons and encourage professionalism (See Appendix A for research methodology and survey examples).
- Mentors were caring adults who possess a background in a helping profession.[77]
- The mentor-mentee relationship was **longer in duration**. In a robust study on effects of match duration, Grossman and Rhodes found a positive correlation between the relationship length and positive mentee outcomes. In particular, the study found that positive outcomes were the most significant when relationships exceeded 12 months in duration. Their research also found that positive outcomes were not observed for relationships of less than three months in duration. Specifically, negative effects on mentee self-worth and perceived scholastic competence were observed for relationships less than three months in length. [78]
- Firm requirements and **expectations around frequency of contact** between the mentor and mentee. In order to mitigate potentially harmful or less positive effects of shorter mentor-mentee relationships, subsequent research by Rhodes and DuBois found that meeting mentees' expectations of relationship length was very important.
- **Ongoing training or support** was provided to the mentor during the relationship and mechanisms to **monitor the mentor** were established.[79]
- **Structured activities** for mentor-mentee sessions were provided.
- **Parental involvement** was encouraged.[80]

Larger effect sizes were also observed when mentoring programs implemented at least a majority of these best practices.[81]

It is also worth noting some of the main reasons for relationship termination, in order to attempt to build in protections against these risks into the program design. Specifically, Spencer identifies six themes that contribute to relationship failure:

- "mentor or mentee abandonment;
- perceived lack of mentee motivation;
- unfulfilled expectations;
- deficiencies in mentor relational skills including the ability to bridge cultural divides;
- family interference; and
- inadequate agency support."[82]

SECTION 4: RECOMMENDED PROGRAM DESIGN

4.1 Theory of Change

A business-to-school mentoring program, which focuses on STEM-related activities and STEM-related career reflection and discussion, has the potential to promote a number of the factors that are correlated with further STEM education and employment (See Section 2.1). Specifically, such a program could boost interest in STEM subject content, help build a network of STEM-involved peers for a student, and promote understanding and knowledge of STEM careers.

The value of a STEM-focused business-to-school mentoring program may be reduced if the space was heavily crowded in Australia. However, mapping existing programs to promote STEM interest and further STEM education reveals that most efforts are currently conducted by universities and focus on offering school students university STEM experiences or university student-to-high school student mentoring / shadowing. See Appendix B for a brief summary of existing programs to support STEM interest among Australian school students.

4.2 Program-Specific Outcomes

Mentoring programs often focus on changing attitudes and building self-efficacy, which are positively linked to higher student proficiency, but where the improvements in proficiency operate via increased interest. Given the importance of interest in boosting both participation and performance, and the suitability of mentoring programs to increasing interest, it is recommended that the program outcomes focus on increased "interest" in STEM subjects among low socio-economic Australian secondary students.

An extensive and recent literature on student engagement with STEM subjects can inform the potential definitions of 'interest'. The National Science Foundation developed a framework for measuring impacts of informal science education and outreach programs that includes:[83]

- "Awareness, knowledge or understanding of STEM concepts, processes or careers."
  - Knowledge, awareness or understanding during, immediately after or long after the experience.
- "Engagement or interest in STEM concepts, processes, or careers."
  - Excitement and involvement. "This impact is often a focus of projects that aim to engage historically under-represented participants in STEM."[84]
- "Attitude towards STEM-related topics or capabilities" including long-term perspectives.
- "Behavior related to STEM concepts, processes or careers."
- "Skills based on STEM concepts, processes or careers" such as scientific inquiry or equipment skills.

Of these potential impact areas, the categories most easily measured for a change in observed or self-reported behavior are engagement / interest and attitude towards STEM topics and careers. Accordingly, program outcomes could include:

- Increased **engagement** of high need students in **STEM concepts and processes**, including excitement towards STEM concepts/processes and involvement.
- Improved **positive attitude towards STEM-related topics**.
- Improved **intentions to undertake further STEM subject study**, including at senior high school and tertiary levels.

4.3 Logic Model

Figure 6 illustrates a logic model, which includes the key inputs, activities, outputs, outcomes and objectives that comprise the program recommendation outlined in this section. A logic model provides "stakeholders with a road map describing the sequence of related events connecting the need for the planned program with the program's desired results."[85] A logic model is comprised of planned work and intended results.

The **planned work** is comprised of:

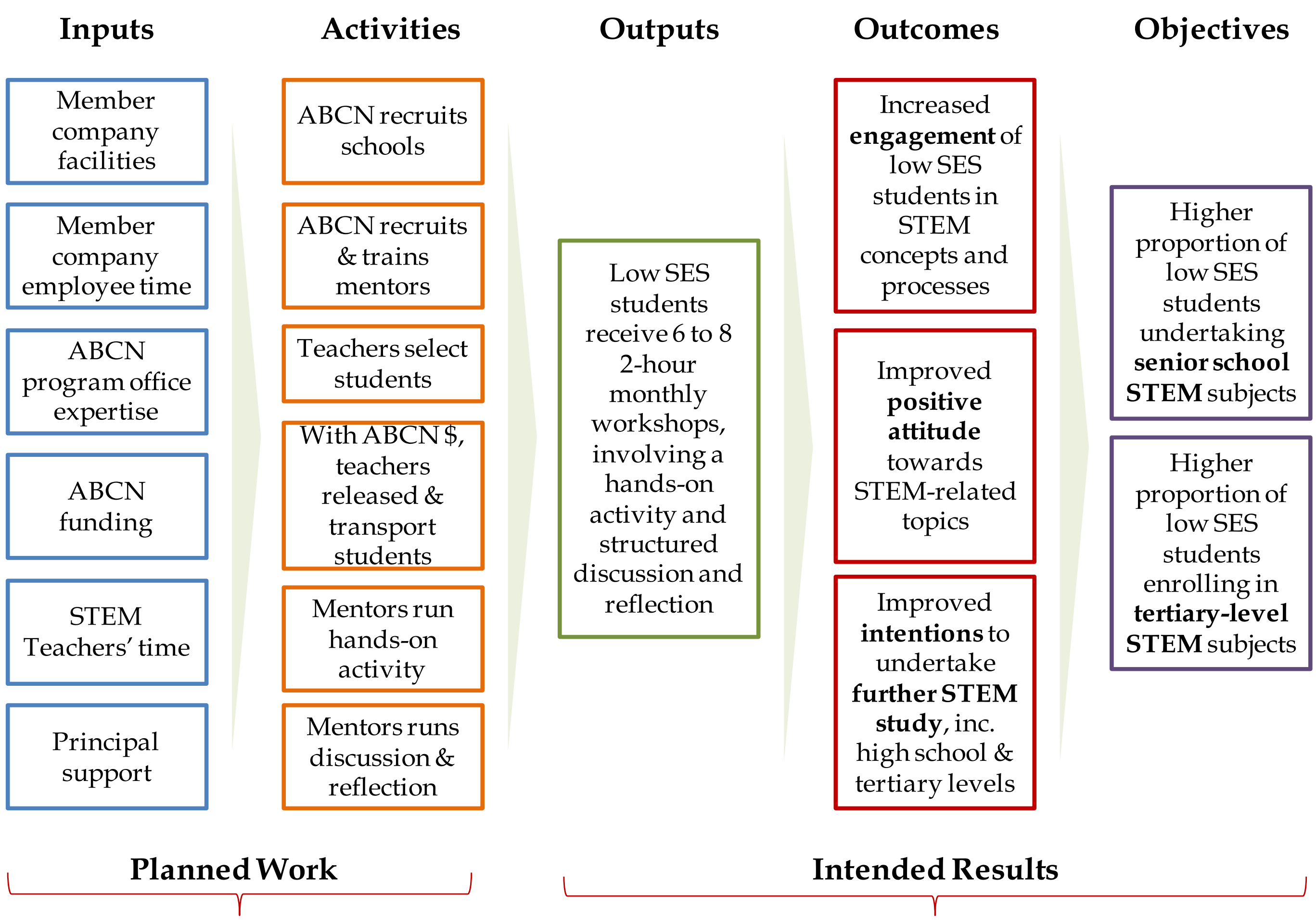
- **Inputs**, which include the "human, financial, organizational and community resources a program has available to direct toward doing the work."[86] For this program, inputs include member company facilities, member company employee time, ABCN program office expertise, ABCN funding, STEM teachers' time, and principal support.
- **Activities**, which include the "processes, tools, events, technology, and actions that are an intentional part of the program implementation." For this program, activities include ABCN recruitment of schools, ABCN recruitment and training of mentors, teacher selection of students, teacher release and transportation of students to member companies, mentors running hands-on activity, and mentors running discussion and reflection process.

The **intended results** are comprised of:

- **Outputs**, which include the "direct product of program activities and…types, levels and targets of services to be delivered by the program."[87] For this program, the outputs are low SES students receiving 6 to 8, 2 hour monthly workshops, involving a hands-on activity and a structured discussion and reflection process.
- **Outcomes**, which include the "specific changes in program participant's behavior, knowledge, skills, status and level of functioning."[88] For this program, the outcomes include increased engagement of low SES students in STEM concepts and processes; improved positive attitude towards STEM-related topics; and improved intentions to undertake further STEM study.

- **Objectives,** which are the "fundamental intended…change in organizations, communities or systems as a result of program activities."[89] For this program, the objectives include a higher proportion of low SES students undertaking senior school STEM subjects (grade 11 and 12 physics, chemistry, and advanced mathematics); and a higher proportion of low SES students enrolling in tertiary-level STEM subjects.

Figure 6: Program Logic Model



The following section recommends a program design that meets the proposed objectives in Section 3 and incorporates the best practice elements uncovered in the research in Section 4.

4.3 Target Audience

The target audience includes specifications around the age, type of student and recruitment method.

4.3.1 Age

A number of Australian studies have demonstrated that the decline in student interest and enjoyment of science is particularly sharp during the transition from primary to secondary school.[90] A study commissioned by DEEWR into STEM engagement during the transition from primary to secondary school found “considerable evidence that, for the majority of students, their life aspirations are formed before the age of 14.”[91] The study concluded that the evidence implied that “engaging students in STEM pathways becomes increasingly difficult after the early secondary school years.”[92] The Australian Council for Education Research has similarly found that students have made ‘identity-related decisions’ about their futures by the age of 14.[93] The Australian Chief Scientist has concluded that students “will probably have developed an enduring interest in science, or the contrary, before senior secondary school.”[94] This conclusion is corroborated by other research that has found that resources targeted at the encouraging STEM interest in the senior grades of high school “attacks the problem too late in the decision cycle.”[95]

Promisingly however, students who undertake senior-level science subjects have attributed the origins of their interest in senior-level science to experiences in junior grades. Specifically, in a 2012 survey of around 1200 Australian students undertaking senior science subjects, around half “traced the origin of their interest to junior secondary school.”[96]

Accordingly, it is recommended that the program target secondary school students in the early grades of high school, up to and including Year 9. Due to operational considerations, which make it difficult to run activities in the first year of high school, the program will likely be best suited to students in grades 8 and 9.

5.3.2 Type of student

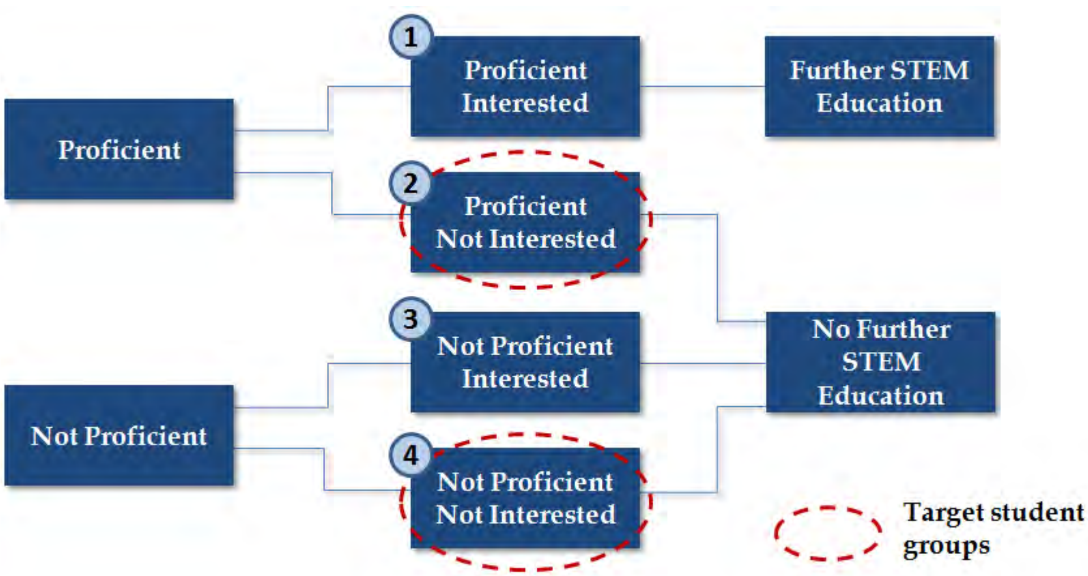
Figure 7 divides the student population into four groups: 1) Proficient & Interested in STEM; 2) Proficient & Not Interested; 3) Not Proficient & Interested; and 4) Not Proficient & Not Interested. ‘Proficiency’ can be determined according to teacher assessment and Year 7 NAPLAN numeracy scores. While the assessment by the STEM teacher is subjective, the NAPLAN assessment involves standardized testing that all Year 7 students are required to take. A STEM teacher should assess the student to be ‘close to’ or ‘above’ national averages (potentially using Year & STEM subject results) and Year 7 NAPLAN scores on numeracy should be ‘close to’ or ‘above’ national averages. ‘Not proficient’ would therefore be comprised of any students below national averages.

‘Interest’ involves a more difficult, subjective and qualitative assessment. Interest can be assessed in two ways and depends on the process for evaluation that is implemented. If evaluation involves a pre-intervention survey given to an entire class or year group, then interest can be assessed by answering affirmatively to a question such as ‘I will definitely enroll in science and / or advanced mathematics subjects in Grades 11 and 12.’ If a whole-of-class survey is not rolled out, then the teacher can nominate students based on their assessment of interest and the level of interest can be checked against the level that is subsequently reported in the pre-intervention survey.

It is recommended that the program target students who are not currently interested in STEM subjects. Targeting the first group, 'proficient, interested', is not an effective use of resources and represents 'cream skimming' because the group is already interested. Group three, 'not proficient, interested' is likely to be a small sub-section of students and this group is likely to be better served by a remedial program that is exclusively focused on lifting student achievement. Given the focus of the proposed program objectives on improving student interest, it is recommended that the program target students who are not currently interested in STEM subjects; groups two and four in Figure 7. The focus on students who are 'not interested' is designed to prevent cream skimming and to respond to a concern, expressed by the Harvard Family Research Project regarding out-of-school STEM activities, that "predisposed participants have limited room for improvement in STEM interest levels and exposure."[97]

Having said this, it is not necessarily appropriate to encourage students who have a strong interest or passion for humanities subjects into a STEM-based program. The survey or teacher assessment could therefore attempt to reflect other subject matter passions and students with strong inclinations towards non-STEM subjects could also be excluded.

Figure 7: Target student groups



4.3.3 Recruitment Method

It is recommended that the principal or STEM teacher nominate students and inform the students that they have been selected for the program, subject to their interest and parental consent. This method is recommended instead of expression of student interest, in order to avoid the evaluation biases associated with programs comprised only of motivated and self-selecting students. In addition, the generalizability of any program findings will be limited if the program relies on student self selection. The exact recruitment process will likely depend on the evaluation process that is selected (see Section 5).

4.4 Key Pedagogical Methods

As outlined above in Section 2.1, a number of key program components are found across high performing US and UK programs targeted at improving STEM interest, including among higher need students. These components should be built into the proposed program as key design elements. Specifically, the program should incorporate at least a majority of the following elements, in rough order of priority (the proposed program structure and delivery outlined further below includes all of the following elements and it is not perceived that the inclusion of these elements would be unduly costly or ineffective):

- A consistent **mentor or role model** from a STEM-related occupation.
- A **hands-on** STEM-related project.
- **Collaborative work** in a small group.
- **Relevance** and linkages to real world contexts.
- **Inquiry-based** methods.
- **Career guidance** and knowledge about STEM-related occupations and work environments.
- **Breadth or diversity** of subject matter content beyond traditional curriculum, with a particular focus on engineering and technology as these commentators have suggested these fields remain underdone in the high school curriculum.

Group setting

The proposed mentor-mentee relationship structure is one mentor for a small group of three mentees or two mentors for a group of five to six mentees. Much of the literature on group mentoring recommends a one-mentor-to-four-mentees model and encourages a two-to-six model where risk of mentor absenteeism is high.[98] There are a number of distinct benefits of group mentoring, including:

- Attracting a higher number of volunteers. Group mentoring programs have historically attracted more volunteer mentors than one-to-one mentoring, perhaps due to a perception of reduced intimacy and commitment.[99]

- Harnessing and capitalizing on peer relationships. Sherk argues that group mentoring "can use peer-to-peer relationships to empower mentees and influence them in positive ways.
- A two mentor-to-group-mentee structure reduces mentee disappointment when one mentor is absent and allows "mentors to provide support and feedback to each other."[100]

Given that STEM participation is associated with a STEM-involved peer network, the creation of small group structures may help to build a STEM-involved peer network for participants.

Professional background of mentor

Given that the mentor will need to conduct a STEM-related activity, discuss STEM concepts and careers, and help to break down negative STEM-occupation stereotypes, it is necessary that the role model be working in a STEM-related occupation. This restriction should not be a problem for most of ABCN's member companies. In fact, many of the member companies, operate within STEM fields, including Blackmores, Investec, Fuji Xerox, Microsoft, iinet, and Optus. Mentors from companies that operate in broader fields can be drawn from the companies' finance, IT or engineering teams.

After school hours

Where possible, the program should be offered in the afterschool hours. Over the last 15 years, "attention to afterschool hours has increased substantially…as policymakers, child development professionals, and parents see this time as 'one of unusual risk and opportunity.'"[101] The afterschool period represents a period during which young people risk boredom or engagement in self-destructive behavior.[102] Given the potential risks and opportunities for the development of enriching peer or adult relationships during after school hours, Halpern argues that afterschool programs have the potential to become the "third critical developmental setting for low-and moderate-income children."[103]

Other features

- **Out of school setting:** Given that higher effect sizes were reported for mentoring outside schools, such as in the workplace or community, it is proposed that all activities occur at the company. Tytler from the Australian Council for Education Research also recommends that science "be studies in community settings that represent contemporary science practices and concerns."[104] Unfortunately, in a 2012 survey of around 1200 Australian students undertaking senior science subjects, "78 to 93 percent of science students reported that they seldom had the opportunity to study science outside of their classrooms."[105]
- **Duration:** Given that mentor-mentee relationships demonstrate more positive outcomes where relationships are longer in duration and that relationships of less than three months exhibited negative effects, the program should run for at least 6 months and preferably for the school year.

- **Frequency of contact:** Given that frequency of contact is less relevant than expectations around contact, it is proposed that firm expectations and requirements around frequency of contact be established at the outset of the relationship.
- **Parental involvement:** Where possible, parents should be involved. A natural point at which to involve parents could be the final session, where students present some of their projects and publicly speak to any STEM-related study and career intentions that have formed during the program.

4.5 Program Structure and Delivery Method

US-based research has found that students are more likely to remain in STEM subjects when they experience "a combination of:

1) Socio-emotional mentoring functions, such as encouragement or role modeling, and
2) Instrumental mentoring functions, including academic support, college navigation, and career coaching."[106]

Given the importance of both emotional and instrumental mentoring functions, it is proposed that each meeting of the mentor with their small group of 3-4 students be comprised of a STEM-related activity followed by reflection and discussion. For example, the mentor can model STEM-related confidence and provide encouragement during a hands-on STEM-related activity; and subsequently provide encouragement, insight into STEM occupations and career guidance during a structured reflection and discussion session.

While a longer mentor-mentee relationship is preferable, given the structure of school terms and holidays, it is likely that 6 x 2 hour monthly sessions is the logistically optimal setup. The 2 hour session can be comprised of a 1 hour STEM-related activity, a 15 minute afternoon tea break, and a 45 minute reflection and discussion process.

4.5.1 STEM-related Activity

It is recommended that the one hour STEM-related activity involve a hands-on group project that involves all 3-4 group members. The project should help to demonstrate the breadth and diversity of STEM fields by being distinct from traditional school mathematics and science curriculum. Activities could include reverse engineering a hairdryer, designing a website, extracting DNA from a banana, cleaning up a small oil spill, and traffic engineering. In an interview with Techbridge, a nonprofit that encourages STEM subject interest among low-income female school students, the Executive Director suggested that reverse engineering and reconstruction projects were particularly popular with 8th graders in their afterschool girls' engineering program. Rather than time-intensively developing intellectual property around hands-on projects, ABCN could use publicly available resources. Specifically, a number of nonprofit organizations that run existing STEM promotion programs provide their lesson plans and materials lists publically online. Please see Appendix D 'Program tools' for examples of hands-on projects that could be used with mentees.

In addition to a stock of activity ideas and equipment that could be provided by ABCN to mentors, participating mentors should also be invited to submit ideas for their sessions to ABCN. Submission of ideas by mentors should help to ensure the program tools remain most relevant to the real world and to maximize the engagement of the mentors.

Where possible, the mentee should be involved in selecting the activities for each session. Numerous studies have demonstrated that "relationships in which the youth and mentor jointly decide on activities and goals…(were predictive of) greater relationship quality and duration"[107] and were associated with improved relationships between the mentee and other adults.[108] With specific regard to STEM education, the Australian Council for Educational Research has argued that students should be encouraged "to make decisions about their learning."[109]Assuming that a bank of potential hands-on projects will accompany the program (see Appendix D 'Program tools and resources'), mentees could be given a choice as to which types of projects most interest them.

To provide a sense of progress, the projects or activities could be iterative (that is, build on the previous week's activity and learning) or increase in complexity and sophistication. In a survey of principals and STEM teachers conducted for this research, respondents noted the importance of activities being integrated or cumulative rather than ad hoc, to sustain student interest and provide a sense of progress. Activities that are cumulative and build on the previous week are also likely to be better suited to a final student presentation. Some US programs incorporate parent involvement at a student presentation at the end of the program, where students present a final product and explain their learning.

The STEM-related activity should incorporate, where possible, the successful inquiry-based teaching methods outlined in Section 2. In Appendix D, 'Program tools and resources', the stages of inquiry-based learning are outlined and examples of the roles of mentors and mentees at each stage are provided. Of relevance to this particular program design and in addition to the benefits of inquiry-based science education outlined in Section 2, these methods have been found to better realise "opportunities for involving firms, scientists, researchers, engineers, universities, local actors…and other kinds of local resources" and promote "relationships between the stakeholders of both formal and informal education."[110]

4.5.2 Reflection and Discussion

After a 15 minute afternoon tea break, the mentor/s will conduct a 45 minute reflection and discussion exercise. Mentors should receive structured discussion points (see Appendix D 'Program tools and resources') to help guide a discussion about what the students observed and learned; how the activity links to the real world; and how the activity links to the mentor's job. In a survey of employees in ABCN member companies (See Appendix A for methodology and survey materials), respondents noted their desire to have very clear materials provided to conduct the sessions. The mentor can also use this time to discuss their own STEM study choices, undergraduate experiences and work experiences.

The structured reflection and discussion process serves a number of purposes and seeks to invoke a number of successful practices. First, the reflection and discussion component is designed to help students identify with STEM subjects and "envisage (STEM) careers in a manner that is consistent with their self-identity."[111] In 2010, Lyons and Quinn reported that the most common reason Australian year 11 students gave for not selecting science subjects was that "they could not pictures themselves as scientists."[112] In support of these qualitative findings, Aikenhead advances a theoretical argument that appreciating science often requires a shift in a student's self-perception as "science-friendly" or "to learn science meaningfully is identity work."[113]

Second, creating a structured discussion for mentors and mentees "to ask each other questions in an attempt to better understand one another, their unique experiences, and their respective goals and interests" has been found to "facilitate perspective taking and…strengthen the mentor-mentee bond."[114]

Third, time for discussion allows the mentor to provide information about STEM-related careers. As mentioned above, non-science students reported that they could not envisage themselves as scientists, a view that Lyons and Quinn argue is likely to be "based on an inadequate appreciation of the diversity in science career pathways."[115] The reflection and discussion process will be particularly important for imparting career guidance and assisting with students' understanding and knowledge of STEM careers.

SECTION 5: MEASUREMENT AND EVALUATION

5.1 Purpose and Stages of Evaluation

Broadly speaking, Harris suggests that out-of-school learning programs typically conduct evaluations for two primary reasons:

- "To demonstrate accountability", particularly to participants, volunteers, funders, or other stakeholders.[116] A demonstration of accountability could include whether the program is serving the intended audience, total students served or services delivered, and assessment of outcomes achieved.
- "To aid learning and continuous improvement." Evaluation enables decision makers to understand what is and isn't working about the program and therefore make both program improvements and more optimal resource allocation.[117]

These dual purposes can be reflected in different stages of the evaluation process. Figure 8 depicts the five tiers of evaluation outlined by the Harvard Family Research Project, which serve different purposes.

Figure 8: Stages of Evaluation

Evaluation Tier	Task	Purpose	Methods
Tier 1	Conduct a needs assessment	To address how the program can best meet the needs of the local community.	Determine the community's need for an OST program.
Tier 2	Document program services	To understand how program services are being implemented and to justify expenditures.	Describe program participants, services provided, and costs.
Tier 3	Clarify your program	To see if the program is being implemented as intended.	Examine whether the program is meeting its benchmarks, and whether it matches the logic model developed.
Tier 4	Make program modifications	To improve the program.	Discuss with key stakeholders how to use the evaluation data for program improvement.
Tier 5	Assess program impact	To demonstrate program effectiveness.	Assess outcomes with an experimental or quasi-experimental evaluation design.

Given that the current STEM supports available to schools have been mapped (see Appendix C) and problems associated with STEM performance in low socio-economic schools have been identified, a Tier 1 needs assessment is not recommended. Instead, the program could first undertake Tier 2 and Tier 3 evaluations and subsequently undertake a Tier 4 assessment.

More specifically, a Tier 2 and 3 assessment could be simultaneously undertaken at the half way and concluding points of the program's first cohort; in order to understand whether program services are being implemented as intended. These tiers attempt to capture 'measures of effort', which "describe whether and to what extent outputs were implemented as intended."[118] The most important type of assessment, a Tier 4 assessment, attempts to determine program impact and effectiveness and helps to guide program improvements. Distinct from Tiers 2 and 3, Tier 4 attempts to capture 'measures of effect', which "convey whether you are meeting your outcomes." This assessment would likely require the collection of pre and post data and is recommended for each cohort.

5.2 Measures of Effort and Effect

Tiers 1 and 2: Measures of Effort

Measures of effort include input measures such as number of mentors, % attendance by mentors and total resources deployed by ABCN; and output measures such as number of sessions, number of mentor hours, number of students served and % attendance by mentees. Other less traditional but important phenomena could also be measured, such as whether the key design elements of the program were being implemented. Specifically, observation or student survey could determine whether the sessions were collaborative and inquiry-based, for example. There are a number of tools to measure effort, including observation and program data collection.

Tier 4: Measures of Effect

Program success should be measured against the program outcomes established in Section 4, including increased engagement in STEM concepts and processes; improved positive attitude towards STEM topics; and improved intentions to undertake further STEM education. There are a number of different methods for measuring program effect, with varying levels of empirical validity. Two methods that are commonly used by out-of-school programs are not recommended, namely the simple pre-program versus post-program estimator and the simple treatment versus control estimator (See Section 5.3). Instead, it is recommended that the program use a randomized controlled experiment which, in this instance, is not prohibitively resource intensive or logistically difficult and does not raise serious ethical concerns. If randomization of participants it not preferred, a second but empirically inferior evaluation method can be used called difference-in-differences (See Section 5.4).

The applicability of the findings of the evaluation depends on the recruitment method used. If students are nominated by their teacher, based on being 'proficient and not interested' or 'not proficient and not interested', then the findings are applicable to a broad population of low SES students that fall into either category. If students self select into the program, then the findings are applicable to a subset of motivated low SES students who self select into programs.

5.3 Measuring Effect: Methods that are not Recommended

- Simple pre-program versus post-program estimator: A survey could be conducted to determine the average differences in the outcomes before and after the mentoring program for participating students. However, this method is highly problematic because it does not account for other factors that may have influenced the students' outcomes before and after the program, such as a quality teacher or natural maturation. It is therefore not recommended.
- Simple treatment versus control estimator: A survey could be conducted to determine the average differences in the outcomes between program recipients and a control group of non-recipients. This method is also highly problematic because it does not account for differences between the participants and non-participants in outcomes before the mentoring program was provided. There may be permanent differences in the participating and non-participating groups, such as levels of motivation, which existed prior to participation in the mentoring program. If the program coordinator believed that these differences were all observable and had data on these factors, such as IQ or prior student achievement, then these factors could be controlled for in a regression. However, it is more likely that there are some important unobservable differences between the students, such as motivation, that both influence participation and the outcomes we are trying to measure.

5.4 Recommended Alternative Methods

5.4.1 Randomized Controlled Experiment

A randomized controlled experiment is where participation in a program or receipt of the 'treatment' is randomly assigned. When participation in the mentoring program is randomly assigned and the treatment and control groups are compared, we can observe the causal impact of a program because "the only systematic difference between the treatment and control groups is the treatment."[119] The correlation between participation and other factors that also might affect the targeted outcomes is eliminated when participation is randomized.[120]

Randomized controlled experiments are considered the idealized or 'gold standard' of experimental design. Guidance from the White House's Office of Management and Budget on program evaluation suggests that randomized controlled trials "are generally the highest quality, unbiased evaluation to demonstrate the actual impact of a program."[121] However, such experiments are often not possible because they are "unethical, impossible to execute satisfactorily, or prohibitively expensive."[122] In this program design, it is not clear that random assignment of a select group of students to a mentoring program or a control group is unethical, particularly if managed carefully and given that the program is not likely to have unlimited mentee places available. It is also unlikely to be logistically difficult or much more costly than standard pre-program and post-program surveys.

Specifically, the method could involve the following steps:

1. Within the program parameters outlined under 'Target audience' in Section 5.3, STEM teachers nominate a list of students who might benefit from the program that is twice the capacity of the program. These students should be identified as from groups two or four in Figure 7, that is, either 'Proficient and not interested' or 'Not proficient and not interested.' A teacher-nominated list of students avoids the ethical problem of student disappointment if they self select into the mentoring program and are then subsequently placed in the control group.
2. Prior to notification of the program's existence, the selected list is given the pre-program survey. It is important to administer the pre-program survey prior to notifying the group of their potential participation in the program so that students do not distort their responses in the hope of participating or misreport their responses due to the salience of STEM subjects at that point in time. The Coalition for Evidence-Based Policy recommends seeking consent to participate in the evaluation prior to the random assignment process. Specifically, the advice argues that "if they provided consent afterward, their knowledge of which group they are in could have affected their decision on whether to consent, thus undermining the equivalence of the groups."[123]
3. Half of the list is randomly assigned to the program; half is randomly assigned to the control group.
4. The treatment group is notified of their nomination by teachers and invited to participate. If the program is conducted out of school hours (as is recommended), the problems and biases associated with attrition are likely to arise. There are ways of managing attrition in evaluating results, which would be subsequently addressed if the problem arose. If the program is conducted during school hours (as ABCN is likely to prefer given duty of care and teacher resourcing) and is compulsory (subject to parental approval), then the biases that attrition create would be reduced.
5. Both groups are given the post-treatment survey at the conclusion of the program. Given those students are not aware that they were on a short list, it is not anticipated that any effects created by rejection or placement in the control group will be observed.
6. The treatment and control groups would need to be sufficiently large to enable causal observations to be drawn. Individual school groups would not need to be sufficiently large; rather, the total number of participants and control group members across the school groups would need to be sufficiently large.

No doubt, a design of a randomized controlled experiment would require more thoughtful design than the steps outlined above. Appendix D provides a list of high quality resources on evaluation design, including the design of valid randomized controlled experiments.

5.4.2 Difference-in-differences

If ABCN or the school is not comfortable with random assignment of potential program participants, a second but less empirically valid evaluation method is possible. This method is called 'difference-in-differences' and determines the causal effect of a program by subtracting the average change in outcome for the control group from the average change in outcome for the group participating in the program. If students were self selecting or accepting a teacher nomination for the program, this method would helpfully remove the biases that result from permanent differences between the participants and the control group around levels of motivation, for example.[124] Figure 5 provides a tabular representation of the method, as applied to the mentoring program, and an illustrative example.

Figure 9: Difference-in-differences method for mentoring program

	Group 1 (G1): Control group	**Group 2 (G2): Program participants**	**Difference**
Pre program	Pre Outcome G1	Pre Outcome G2	Pre Outcome G2 – Pre Outcome G1
Post program	Post Outcome G1	Post Outcome G2	Post Outcome G2 – Post Outcome G1
Difference	(Post Outcome G1 – Pre Outcome G1)	(Post Outcome G2 - Pre Outcome G2)	(Post Outcome G2 - Pre Outcome G2) - (Post Outcome G2 – Pre Outcome G1)

Using numbers to illustrate the example:

	Group 1 (G1): Control group	**Group 2 (G2): Program participants**	**Difference**
Pre program interest in further STEM study	10%	20%	(20% - 10%) = 10%
Post program interest in further STEM study	15%	30%	(30% - 15%) = 15%
Difference i.e. effect of program	(15% - 5%) = 5%	(30% - 20%) = 10%	(10% - 5%) = 5% Or (15% - 10%) = 5%

A key and problematic assumption of the difference-in-differences estimator is that the change in the control group is the change that would have been observed in the treatment group. This is known as the parallel trends assumption, which allows for:

- the existence of unobservable differences between the two group (e.g., motivation levels) but assumes these differences do not affect changes over time; and
- events that affect both groups over time (e.g., maturation or a quality teacher) but assumes the effects are not different for different groups.

Unfortunately, it is not clear that we can assume the change in the control group is the change that would have been observed in the treatment group. We can assume the existence of unobservable differences between the groups, such as level of motivation or IQ. These differences are accounted for only if they do not affect outcome for different groups in different ways. However, it is possible that other factors or inputs in the students' lives during the program will impact the students differently, based on their unobserved differences. For example, students with different levels of motivation or IQ may respond to a high or low quality teacher differently; or students with low levels of motivation or school engagement may decline further in engagement over the course of the school year than students with higher levels of motivation.

Despite the problems associated with this method, this method is more empirically valid than the two methods outlined in Section 5.3 that are not recommended and are commonly used in program evaluation. Some of the potential biases may be reduced if the teacher were to select the students based on a set of criteria, rather than the students self selecting, and may be further reduced if the program was during school hours and therefore compulsory, reducing the likelihood that only motivated students remain in the treatment group. Accordingly, if the ABCN or schools are not inclined to adopt a randomized controlled experiment, as outline above, a difference-in-differences method is a second albeit inferior alternative.

APPENDICES

Appendix A: Research Methodology

Appendix B: Background for Advocacy: The Case for Investing in STEM

Appendix C: Existing External STEM Supports to Australian Schools

Appendix D: Program Tools and Further Resources

Appendix A: Research Methodology

The research methodology for the report involved both secondary and primary research.

1. Secondary Research

Secondary research was used to identify the problem; understand the importance of STEM; map potential program options; understand what works in promoting interest in STEM; avoid duplication of existing efforts in Australia; follow sound program design techniques were followed; and understand and measure the program impact.

1.1 Identify Problem

Secondary research was used to understand the association between socio-economic status and student engagement and performance. Various Australian and international standardized testing data and government reports were used to understand this relationship and the specific relationship between socio-economic status and participation and performance in junior and senior high school STEM subjects. I drew on large national surveys in the UK and US to understand why students were disengaged from STEM.

Statements and reports by Australian and international governments and think tanks were used to understand the importance of STEM participation and performance to economic growth and productivity. This data and commentary formed the background advocacy document provided in Appendix C.

1.2 Map Potential Program Options

Having established the problem, secondary research (in addition to primary research – see below) was used to understand the landscape of actors in the education sector in Australia and the potential program options available to each category of actor.

1.3 Understand What Works

STEM Promotion Programs

I undertook a very involved search of hundreds of resources from Governments, think tanks, universities, engineering and science associations, advocacy groups, and nonprofits to understand the landscape of potential programs to encourage interest in STEM in low socio-economic students. Having understood the broad landscape and categorized programs, and selected mentoring as the focus for the recommended program, I then undertook extensive research into examples of exemplary out-of-school, mentoring-related STEM promotion programs in order to understand the most effective elements and prioritize these elements. I also drew on large national surveys in the UK and US to understand why students were disengaged from STEM and what types of strategies and pedagogies they self reported as being engaging.

Mentoring Programs

I used academic research, university center manuals and research (particularly centers focused on mentoring); government research and best practice documents; nonprofit manuals and program evaluations to understand the key features of effective adult-student mentoring, particularly involving low socio-economic students. The final list of key features that I developed reflects a synthesis of robust evaluations and meta-analyses and less robust but nevertheless instructive examples and qualitative evidence from governments and nonprofits.

1.4 Avoid Duplication of Effort

I undertook online secondary research of existing corporate, university and nonprofit programs to encourage interest in STEM to understand the existing supports and external resources that were provided to Australian secondary schools, in order to avoid duplicating existing efforts.

1.5 Follow Sound Program Design Techniques

I used guidance from foundations' publications, nonprofit journals and academic resources on developing a program theory of change; logic model; and indicators to ensure that the proposed program followed sound program design techniques.

1.6 Measure Program Impact

A variety of measurement and evaluation resources were used to create the broad principles for measuring the program and the proposed approaches. Specifically, I used textbooks on econometrics, academic research on econometrics and program evaluation, and applied university center guidance on M&E.

2. Primary Research

Primary research was used to both understand the most effective mechanisms for promoting interest in STEM among low socio-economic students and then to sense check the preliminary program design with potential participant schools and employee mentors. Both interviews and surveys were used.

2.1 Interviews

Interviews were conducted for two purposes. First, interviews were conducted to scope the types of programs that were relevant and appropriate to different types of actors in the education sector in Australia.

This informed the development of the actor map and program options in Section 2. Second, interviews were conducted with senior members and volunteers at programs that were exemplary in encouraging interest in STEM subjects among low socio-economic students. The purpose of the interviews was to understand the various types of programs and the key effective elements of these programs. Interviews focused on gleaning the respondent's view on the barriers to interest in STEM among low socio-economic students; and the highest priority or most effective program elements.

Interview questions were tailored to the respondent's role and background and types of program or institution in which they were involved. An example of the questions used for the interview with Linda Kekelis, Executive Director of Techbridge is provided below.

Interviews were conducted with:

- Leslie Loble
  - Chief Executive, Office of Education, New South Wales Department of Education
- Megan Enders
  - Program Director, Fogarty EdVance
- Rosemary Conn
  - Program Director, Beacon Foundation
- Jacqui Jones
  - General Manager, Australian Business Community Network
- Linda Kekelis
  - Executive Director, Techbridge for Girls
- Carlo Parravano
  - Executive Director, Merck Institute for Science Education
- Courtney Walsh
  - Volunteer, Science Club for Girls

<u>Example – Interview Questions</u>

The following is an example of an interview of a director of an exemplary STEM promotion program in the US. The interviewee was Linda Kekelis, who is Executive Director of Techbridge for Girls.

- What is your role? How long have you worked with this institution?
- I noticed that you involve companies primarily through field trips or role model visits. How does this work?
- How does the one-on-one component of your role model program work?

- Has it been effective?
- What types of relationships are most effective e.g. length, intensity of contact?
- I noticed you have a strong emphasis on training role models. What do you do? How do they respond? What are the most important things to teach?
- What age groups do you target and why? Who responds best?
- In your view, what types of activities best encourage interest in STEM?
- How do you recruit your students?
- What are the current barriers towards interest in STEM subjects by secondary students?
- What are the key needs of disadvantaged secondary students that should be represented or met in a business-to-school mentoring program?
- In your view, what are the key characteristics that contributed to the failure or reduced the effectiveness of the program?
- Are you aware of other models in this field that you think represent high quality?

2.2 Surveys

Purpose of Surveys

Two surveys were conducted once the preliminary design of the program had been established. A copy of each survey is provided at the end of this Appendix. The surveys aimed to elicit feedback on the key elements of the proposed program. The first survey targeted principals and STEM teachers in low socio-economic schools with whom ABCN had relationships and in which the program would be likely rolled out. This survey sought feedback on prior experience with STEM promotion programs and what made those programs effective; barriers to low socio-economic student interest in STEM subjects; proposed key elements of program and views of effectiveness of elements.

The second survey targeted STEM employees in ABCN's member companies, who might be prospective mentors or whose peer group might participate. The survey sought feedback on whether the proposed program elements would be likely to increase student interest in STEM; ideas for hands on activities; interest in serving as a mentor and what program features/changes would increase their interest in participating.

Sample and Sampling Method

ABCN sent both surveys to a select group of contacts in schools and in member companies. Respondents were invited to circulate the survey to other interested parties. The sample was considered to be a group that would be responsive. Given that the sample was designed for feedback purposes on the program design only, the sample was not random and probabilistic inferences will therefore not be drawn. The first survey, of principals and STEM teachers, returned 14 responses. The second survey, of ABCN member company employees, returned 1 response.

Survey Delivery Method

Both surveys were web-based and self administered based on discussions with the client regarding the preferences of the respondents. Given that all respondents would be accessed through their employment setting, where they had access to the internet, web based surveys were an appropriate medium. Given that all respondent groups were educated adults, supervision of survey administration was not required. Finally, given the busyness of all respondent groups, particularly the unyielding schedules of principals and teachers, ABCN indicated that respondents would likely prefer to self administer the survey. Participants were invited to contact me via email if they had any questions. While the self administration of the surveys risked higher unit nonresponse rates, the fact that probabilistic inferences were not being made reduced the necessity for a supervised survey setting.

Types of Questions

Respondents in both surveys were asked a combination of open and close-ended questions. For example, respondents in the first survey of principals and STEM teachers were asked a number of open-ended questions about what made STEM promotion programs they had observed either ineffective or effective. Open-ended questions were valuable in allowing the respondents to answer in their own terms and ensure that my own biases and preferences as a researcher weren't built into the possible answers. Open-ended questions also served as a helpful sense check of the program features that I had identified as the most important. Respondents were then provided the stimulus of the recommended program outline and asked to react to this stimulus. Scales were used for the respondents to provide a subjective judgment of the value of each program element. Close ended questions were also used to help ensure that respondents provided answers in a consistent scale and to help with memory.

Actual Surveys

Survey Monkey was used to administer the surveys. The actual surveys are available at:

- Survey for Schools – Principals and STEM Teachers: http://www.surveymonkey.com/s/NC9S766
- Survey for STEM Employees: http://www.surveymonkey.com/s/NF59XDK

Screenshot of part of survey of principals and STEM teachers:

	Very ineffective	Ineffective	Neither effective nor ineffective	Effective	Very effective
- A group of 5/6 students mentored by 2 STEM employees					
- The group meets for 2 hours once a month for 6 – 8 months					
- The group meets at the company site					
- The students are in Years 8 and 9					
- The first hour is dedicated to a hands-on STEM-related project					
- The project is clearly linked to real-world contexts					
- Students is work in small groups					
- After a break, there is a 45 minute group reflection and discussion about the project and STEM careers					

7. Please comment about why you listed some characteristics as effective or very effective

<u>Example of survey questions to ABCN STEM employees</u>

1. **What area of STEM do you currently work in? (e.g. IT, engineering, finance, science)**
   [Comment box]

2. **If you undertook study after high school, what field/s were you trained in?**
   [Comment box]

3. **What is your highest level of education?**
   [Drop down menu:
   - High School
   - TAFE certificate

- Undergraduate
- Postgraduate]

4. **Imagine a business-to-school mentoring program that seeks to encourage the participation and interest of low socio-economic students in STEM subjects. The program has the following characteristics:**
   - A group of 5/6 students mentored by 2 STEM employees
   - The group meets for 2 hours once a month for 6 – 8 months
   - The group meets at the company site
   - The students are in Years 8 and 9
   - The first hour is dedicated to a hands-on STEM-related project
   - The project is clearly linked to real-world contexts
   - Students is work in small groups
   - After a break, there is a 45 minute group reflection and discussion about the project and STEM careers

   Does this program sound like it would increase the participation and interest of low socio-economic students in STEM subjects? Why?
   [Comment box]

5. **The hands-on project could include projects like reverse engineering a hairdryer, designing a website, extracting DNA from a banana, cleaning up an oil spill, and traffic engineering. Do these projects sound like they would build interest in STEM subjects among 12 – 14 year olds?**
   [Comment box]

6. **What other hands-on projects would you suggest? (Feel free to include examples relevant to your work)**
   [Comment box]

7. **How interested would be you in serving as a mentor in this program?**
   [Scale with:
   Very uninterested
   Uninterested
   Neither interested or uninterested
   Interested
   Very interested]

8. **What changes would you recommend to increase your interest in participating?**
   [Comment box]

9. **Is there anything else you would like to say about how to best design a business-to-school mentoring program that encourages participation and interest in STEM subjects by low SES high school students?**
   [Comment box]

Appendix B: Background for Advocacy – The Case for Investing in STEM

As referenced in Section 1, the following represents a summary of the value of the STEM education and employment and the existing and forecast problems related to a STEM workforce in Australia. This background is designed to equip ABCN to make a specific case to member companies regarding the value of a STEM mentoring program, in addition to the equity case.

Why does STEM Education and Employment Matter?

The STEM workforce has been widely acknowledged by many OECD Governments and think tanks as a crucial driver of economic growth, productivity and innovation over the past half century. By way of example, the US Department of Labor has noted that "STEM fields have become increasingly central to US economic competitiveness and growth,"[125] to the extent that "scientific innovation has produced roughly half of all US economic growth in the last 50 years."[126]

The importance of a strong STEM workforce has not declined and a robust pipeline of well-trained STEM employees continues to be touted as essential for growth into the future. Again, the US Department of Labor has argued that the "nation's economic future" and maintenance of living standards in the long term "will require coordinated efforts among public, private, and not-for-profit entities to promote innovation and to prepare an adequate supply of qualified workers for employment in STEM fields."[127] The US' Business-Higher Education Forum concluded that "lackluster performance in mathematics and science education and a lack of national focus on renewing its science and technology infrastructure have created a new economic and technological vulnerability as serious as any military or terrorist threat."[128] Similarly, the European Commission has noted that unless more effective action is taken to encourage student interest in STEM education, "Europe's longer term capacity to innovate and the quality of its research will…decline."[129]

Australia, too, is no stranger to dramatic statements about the importance of the STEM workforce. The Australian Government's Chief Scientist has claimed a number of STEM fields to be "vital to Australia's future…and our place in the world"[130] and warned that "no action by Australia (on encouraging further education in STEM) would see the gap between our capacity and those of others widen further…and restrict our opportunity to develop a high technology, high productivity economy."[131]

STEM-related employment and education issues in Australia

Like many OECD countries, Australia currently faces tight labour market conditions in STEM-related industries and ongoing constraints are forecast for the medium term. The pipeline of future STEM employees is hampered by the low proportion of high school graduates pursuing tertiary study in STEM and the declining proportion of Year 12 students undertaking science subjects.

Existing labour supply issues

Australia currently faces tight labour market conditions in STEM-related industries and ongoing constraints are forecast for the medium term. The Australian Government's Audit of Science, Engineering and Technology Skills in 2006 revealed existing tight labour market conditions and recruiting challenges in engineering disciplines; mathematics; and sciences including earth sciences, chemistry, spatial information sciences and entomology.[132]

Numerous OECD countries have reported existing STEM labour supply challenges and have forecasted ongoing challenges into the medium term. DEEWR has noted that supply constraints for STEM employees in other countries will continue to put pressure on the labour market for STEM workers. Specifically, DEEWR has commented that, as international competition for STEM employees increases, "the pool of talent that supplies Australia's STEM skilled workforce may be reduced by offshore migration."[133]

Pipeline of future employees

A robust pipeline of future STEM employees is threatened by both i) an inadequate number of tertiary STEM graduates and ii) declining interest at the senior high school level in STEM subjects.

i) Australia's tertiary institutions are graduating an insufficient number of STEM-qualified students. Further, enrolments in STEM-related tertiary subjects, as a proportion of tertiary enrolments, are declining. The Chief Scientist has noted that "Despite successive government attempts over the last decade to increase student participation in science, technology, engineering and mathematics, the proportion of students commencing in STEM has stabilized around 10 percent or less,"[134] levels below those enjoyed in the early 1990s.[135]

 The proportion of first university degrees awarded in STEM fields in Australia lags behind the international average. In 2002, the ratio of STEM to non-STEM degrees in Australia was 22.2 percent, compared with an international average of 26.4 percent and individual country highs of 52.1 percent for China, 64.0 percent for Japan and 40.6 percent for South Korea.[136]

ii) Fewer high school students are undertaking sciences or advanced mathematics. Between 1992 and 2010, the proportion of Year 12 students undertaking science subjects has declined. Specifically, the proportion of Year 12 students undertaking physics declined by 31 percent, chemistry by 23 percent, and biology by 32 percent.[137] The decline is more stark when observed over a longer time period, from 1978 to 2002, where the proportion of students undertaking biology fell from 55 percent to around 20 percent, in chemistry from 30 percent to 15 percent, and in physics from 27 percent to 12 percent.[138] There is a trend towards participation in elementary mathematics courses, rather than advanced or intermediate mathematics courses.[139]

By contrast, the Australian Chief Scientist notes that other subjects "such as business studies, secretarial studies, hospitality, computer studies, food and catering, music and performing arts, and creative and visual arts have seen a substantial increase in enrolments."[140]

Appendix C: Existing STEM-related External Supports in Australian Schools

Appendix C provides a map of existing STEM-related external supports available to Australian schools. External supports are typically provided by universities and involve on-campus experiences of university student-high school student mentoring / shadowing opportunities.

Who Involved?	Program Detail
Structured Private Scientist-to-School Partnerships	
CSIRO Facilitated; DEEWR Funded	• National program, facilitated by CSIRO and funded by DEEWR, which supports relationships and partnerships between teachers and scientists or mathematicians, designed to support teaching and learning of science and mathematics in schools. • Scientists and mathematicians are invited to volunteer to develop a relationship with a teacher or school. Scientists can nominate who they would like to work with or be matched by CSIRO. • Program makes introduction; provides ongoing support/advice; provides resources such as tips/workshops on working with schools, ideas for type of potential relationship; teaching and learning materials that can be used with students. • 2500 ongoing teacher-scientist partnerships have been created across Australia. • Types of partnerships: presentations; demonstrations; mentoring; teacher support; field trips. • More info: http://www.scientistsinschools.edu.au/index.htm
University-to-School Partnerships	
Macquarie University and NSW DET	• Partnership between Macquarie Univ and NSW DET which est. "Science, Technology, Engineering and Mathematics Project", which aims to enhance student engagement and support teachers in STEM subjects including indigenous communities. • Supports and implements innovative teaching and learning practices to over 8000 students from K-12, including science research work experience program; tutoring by university students; local ecological studies with students and uni students; students assisting PhD students in collection of data; professional learning for teachers to develop understanding of science and research trends; immersion days. • Partnership involves Peninsula Community of Schools.
Lachlan Macquarie College, funded by UWS and DET	• Est. in 2008 as a partnership between NSW DET and UWS to develop and provide innovative specialist programs in maths and science for public school students in western Sydney. • Students attend programs at other schools or at UWS labs and lecture theatres with permission of schools and parents; often a different curriculum is offered. • Professional development workshops are offered for teachers. • Threshold Concept Research project – academics working with secondary teachers in

Who Involved?	Program Detail
	researching best practice delivery within stage 4 science to enhance student understanding. • For more info: http://www.lmc.nsw.edu.au/
University of Newcastle and Hunter Region schools	• Five schools from hunter central coast region are participating in pilot program with Uni of Newcastle to increase students' attainment in maths and raise aspirations. • 50 students in year 11 participate in one year program involving academic skills building workshops; university student mentoring; shadowing experiences; tutoring by undergrad. • Maths teachers work with experienced academic with view to enabling teachers to better support students participating in pilot. • Student's parents are involved, participating in sessions at Uni and school on ways they can contribute to student achievement.
University of Tasmania and CSU	• Univ of Tas (Primary Industry Centre for Science Edu) and CSU partnered to deliver program to schools in Riverina region to promote careers in agricultural and primary industries. • A university Science Education Officer presents the program in schools, with industry partners, supporting activities like professional development workshops for science teachers, Science Investigation Awards, science camps, field days, industry placement scholarships for senior students.
ACU	• "Extending Mathematical Understanding Specialist Teacher Course" • User pay course 6 day course for specialist teachers focusing on identifying and assisting students who are mathematically vulnerable through a specialized intervention program and within classroom support.
University of Newcastle - Summer camp	• Uni of Newcastle runs "Girls + Maths + Science = Choices" Summer camp (5 day camp). • Targets 180 female students from equity grouping. • Designed to promote maths/science learning through activities; promote pathways to careers in maths/science; expose students to campus life.
Other	
Australian Mathematical Sciences Institute	• 2009- AMSI received DEEWR funding for a national collaborative project to improve mathematics education in schools. Concluded in June 2011. • AMSI staff visited schools in six regions to develop mathematics programs with teachers and build content knowledge in mathematics. Targeted areas included: scope and sequence for teaching maths; meeting mathematical needs of vulnerable students; how to source information about teaching mathematics. • In some of the schools, AMSI seconded a part-time teacher to provide continuing support and help implement advice from visiting AMSI members.

APPENDIX D: PROGRAM TOOLS

Program tools include an example of inquiry-based learning processes; pack of STEM activity ideas for the first hour of the session; suggested goals for pre-service mentor training; and potential evaluation and measurement tools.

6.1 Example of inquiry-based learning process

The program design recommended using an inquiry-based learning model. This model can be integrated into both the STEM-related activity and discussion/reflection period. Inquiry-based learning can be encouraged by following the "five Es" model:

1. "Engage: Connect, activate prior knowledge
2. Explore: Investigate through hands-on activities
3. Explain: Articulate new knowledge and understanding
4. Elaborate: Apply new concepts/skills and extend learning
5. Evaluate: Reflect on and assess learning"[141]

Figure 10 explains the purpose of each stage and role of the mentor and the students at each stage.

Figure 10: Stages and Roles in Inquiry-based Learning

Adapted from California After-School Resource Center materials[142]

Phase	Mentor	Students / Mentees
1. Engagement Purpose: Capture interest and develop questions to investigate	• Activate prior knowledge of mentee • Capture curiosity and interest of mentee • Help students develop questions, including by giving sample questions	• Assess own interest • Reflect on new information to find gap in own knowledge • Harness curiosity to pose new questions
2. Exploration Purpose: Develop answers based on evidence from investigation	• Refine questions • Provides resources and directions • Observes and offers input	• Develops hypotheses and predictions • Designs investigation • Observes and collects data
3. Explanation Purpose: Clarify learning and communicate findings	• Provides feedback • Provides ideas and resources for ways to present findings	• Share new understandings • Formulate explanations • Use different formats to present findings
4. Elaboration Purpose: Expand on findings	• Provide ways to apply knowledge • Provide resources for further inquiry	• Apply concepts to new contexts • Seek resources for further inquiry

Phase	Mentor	Students / Mentees
	• Challenge students to generate new ideas	
5. Evaluation Purpose: Assess and apply new knowledge and understanding	• Provide evaluation instruments • Suggests ways to apply new learning	• Assess new knowledge through discussion and reflection • Think of ways to apply new learning to real world situations

6.2 STEM-related activity ideas

A number of nonprofits and other organizations have produced hands-on activities and have made these materials publicly available at no cost. Some of the exemplary or evidence-based programs with free publicly available material include:

- The US Public Broadcasting Service has produced a wide range of STEM-related educational materials, including hands-on activity ideas for educators and mentors. These materials are broken down by discipline and age group:

  Available at: http://www.pbs.org/teachers/stem/STEMResourcesfromPBS.pdf
- Techbridge for Girls provides free publicly available resources that are designed for mentee visits to industry/corporate sites. Resources include hands-on activity ideas and icebreaker/group management strategies.

  Available at: http://www.techbridgegirls.org/RoleModels/Resources.aspx
- Siemens' STEM Academy has an online bank of hands-on activities and lesson plans for educators and mentors. The activities can be searched by age group and discipline. The materials are available at no cost after you register, also at no cost, with the Academy.

  Available at: http://www.siemensstemacademy.com/index.cfm?event=showResourceLanding&c=37
- The Boston Museum of Science's 'Engineering is Elementary' program, which is widely used and lauded as an effective program by 'Change the Equation' (a CEO-led initiative launched by President Obama to encourage private and philanthropic investment in STEM), makes its lesson plans for hands-on activities publicly available online. Lesson plans includes activities such as designing knee braces, solar ovens, and cleaning an oil spill.

  Available at: http://www.eie.org/resources/pdfsearch

6.3 Goals of pre-service mentor training

While there is less consensus on the role of initial and/or ongoing training in mentoring program effectiveness, "there is general agreement that some type of orientation should be provided."[143] In its best practice manual for training new mentors, George Washington University recommends that any induction or pre-service mentor training be designed to achieve the following goals:

- "Introduce them to the concept of positive youth development;
- Provide information about the strengths and vulnerabilities of the youth in the program;
- Provide information about program requirements and supports for mentors;
- Answer questions they may have about the mentoring experience;
- Build their confidence as they prepare to start working with their mentee;
- Help participants understand the scope and limits of their role as mentors;
- Help them develop the skills and attitudes they need to perform well in their role."[144]

6.4 Evaluation and Measurement Tools

Evaluation Advice and Design Principles

The White House Office of Management and Budget recommend the following resources as useful in thinking about program evaluation and evaluation design.[145]

- Program Evaluation Methods: Measurement and Attribution of Program Results; Treasury Board of Canada, Secretariat; 1998. http://www.tbs-sct.gc.ca/eval/pubs/meth/pem-mep_e.pdf
- Understanding Impact Evaluation; The World Bank Group. http://www.worldbank.org/poverty/impact/index.htm
- "Program Evaluation: An Evaluation Culture and Collaborative Partnerships Build Agency Capacity;" GAO-03-454; U.S. General Accounting Office; May 2003. http://www.gao.gov/docdblite/summary.php?recflag=&accno=A06797&rptno=GAO-03-454
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Evaluation Tools

There are numerous free and research-based evaluations tool available on line, which were designed specifically for out-of-school youth interventions. The Forum for Youth Investment provides an assessment of a range of free and low cost tools for measuring programs targeted toward youth. Relevant tools may include the:

- 'Afterschool Program Practices Tool' developed by NIOST and the Massachusetts Department of Elementary & Secondary Education and available at www.niost.org/content/view/1572/282/ or www.doe.mass.edu/21cclc/ta
- Out of School Time Program Observation Tool, developed by Policy Studies Associates and available at www.policystudies.com/studies/youth/OST%20Instrument.html
- Program Quality Self-Assessment Tool, developed by the New York State Afterschool Network and available at www.nysan.org

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