RETRAINING AND RETAINING STEM PROFESSIONALS: WHAT WORKS TO ADDRESS TEACHER SHORTAGES

A literature review report prepared for NSW Department of Education.

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Centre for Social Impact

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1.EXECUTIVE SUMMARY

This literature review examines strategies and sets out recommendations for recruiting, engaging and retaining experienced and qualified professionals working in STEM-related industries to teach in classrooms in NSW public schools.

The review, prepared for the NSW Department of Education, forms part of a research project undertaken by UNSW's Centre for Social Impact, to lay the foundations for addressing teacher shortages in science and mathematics subjects and increasing STEM knowledge and skills among students in NSW public schools.
The provision of effective learning experiences, implemented by highly qualified teachers, is a core responsibility of all governments. In recent years, Australia and other jurisdictions have increasingly prioritised for its people to become STEM (Science, Technology, Engineering and Mathematics) skilled and digitally empowered. The ubiquitous nature of digitisation, and recent health and climate crises combined with worldwide shortages of relevantly trained STEM professionals have made STEM literacy a priority. We need to future proof our young people with skills so that they move from being consumers to becoming creators and designers. Industry professionals can play an important role in classrooms to bridge the theory-practice gap and empower students with problem solving, entrepreneurial and critical thinking skills. They also serve as great role models to drive positive change and remove misconceptions about STEM careers.

The purpose of the report is to develop a set of recommendations derived from evidence informed literature, for recruiting, engaging and retaining high-quality experienced and qualified STEM specialists in classrooms. These preliminary recommendations will be tested in the data collection phase of the project to formulate a set of final recommendations. An action policy plan for the Department will be created laying down steps for a sustainable pipeline of STEM specialist teachers for schools which will form the foundations for a strong STEM education policy framework for Australia.

The review proceeds from a systematic strategy of gathering evidence from academic and grey literature (such as government reports). Informed by the research questions, the purpose was to understand commonly identified and workable strategies to attract and retain STEM career changers in teaching, including any policies required to create a pipeline of professionals from industry to teaching. Publications that reported on ways to incentivise STEM professionals to join and stay in the teaching profession were included in the review. Literature on ways to sustainably retain such teachers in classroom teaching or in other suitable roles in schools was also explored, though there were limited studies identified in this area.

Themes have been organised according to whether the focus is at the micro or individual level, or if they were more at a more macro or structural level. All strategies need to be approached from a system thinking lens (Abercrombie R. et al., 2017) to understand the interrelationships and roles that stakeholders have in implementing them, with a view to building a strong STEM education policy framework.

Strategies that benefit industry professionals at the individual level include:

- Financial incentives
- Flexible, seamless and tailored entry pathways into teaching
- Better opportunities for career competency and leadership development.

Strategies at the school, education jurisdiction and societal level are:

- Raising the professional status of teaching and effectively promoting teaching as an attractive career option within industry and society
- Improved working conditions and a conducive teaching environment
- Leveraging existing school-industry partnerships.

Based on the review, the report makes the following **recommendations** to the NSW Department of Education and the wider education sector:

1. That teacher salaries be made competitive to match other comparable professions, and to address the loss in remuneration for STEM specialists switching to teaching
2. That STEM expertise and industry experiences of aspirant teachers be properly assessed and credentialed, to count towards long term successful career pathways in schools
3. That the teaching profession offer flexible study and work conditions and tailored opportunities for personal and professional growth, with sufficient autonomy for STEM career changers to thrive and succeed
4. That existing school-industry STEM partnerships be effectively leveraged to identify prospective career changers interested in pursuing a teaching career
5. That targeted recruitment campaigns be implemented to attract more STEM women to teaching, address the low rates of Indigenous teachers in STEM subjects and persistent shortages in in hard-to-staff schools
6. That a long-term systemic approach to address supply-demand issues in STEM subjects be considered: one that promotes teaching as an intellectually satisfying and financially rewarding career.

2.INTRODUCTION: Issue and significance

The significance of this research that leads to prioritising a STEM qualified teacher workforce in schools, derives from several key factors.

2a. Teacher shortage

We have insufficient teachers to meet increasing student demand

One in four teachers intend to leave the profession for reasons other than retirement, with 56% of those, intending to leave within ten years.

Australia, and in particular NSW, is facing a teacher shortage crisis. Nationwide, one in four teachers intend to leave the profession for reasons other than retirement, with 56% of those, intending to leave within ten years. In NSW, just under half intend to stay till retirement with another one third unsure if they will continue (Australian Institute for Teaching and School Leadership, 2021a; Hobbs et al., 2017). These figures apply at both primary and secondary levels. The most common reasons cited for leaving are workload demands, insufficient pay and lack of recognition (Australian Institute for Teaching and School Leadership, 2021a).

In addition, teacher demand is driven by demographic trends and student population growth. For example, ABS data suggest that from 2024-2029, we can expect growth of 7% in primary school aged children and 4% at the secondary level (Australian Institute for Teaching and School Leadership, 2021b). We have insufficient teacher numbers to meet this increasing student demand.

Recruitment and retention of qualified staff in less advantaged schools is a persistent challenge.

While this crisis is not a recent phenomenon and has been predicted for some time (Buchanan, 2020; Ingersoll, 2001), the ongoing climate and health crises have exacerbated the issue (Baker, 2021; Wilson & Carabetta, 2022). With increasing numbers of teachers having to take sick leave over the past two years or consider early retirement (Zamarro et al., 2021), teacher shortages have worsened across NSW. The impact has been felt acutely in schools that were already experiencing shortages prior to COVID, such as those in non-metropolitan locations and in low socio-economic areas. While education departments have proposed solutions to address this critical shortage, (for instance, calling upon retired and trainee student teachers to meet COVID related staff shortfalls), these are temporary solutions that fail to address the long-term problem (Wilson & Carabetta, 2022).

Teacher shortages are particularly acute in STEM (Science, Technology, Engineering and Mathematics) subjects[1]. They present a challenge to education jurisdictions, in terms of assuring quality of education to the students in their care, and in the long term, in ensuring 'STEM capital' to contribute to Australia's workforce. As is outlined in section 2b below, specialist teacher shortages result in students being taught by non-qualified or out-of-field teachers. Rural and remote and low socio-economic schools face ongoing challenges in recruiting specialised teachers. While teacher shortages in STEM subjects is a not a new phenomenon, Covid-19 and its ongoing impacts have brought the shortage issue into sharp focus. **The pandemic has reminded us of the significance of building a STEM skilled workforce to meet changing economic, social, health, environmental and technological challenges facing society, but we have insufficient teachers to build a STEM pipeline.** Building a STEM pipeline involves taking steps from the start of a child's education - promoting STEM literacy at the primary and secondary level that then leads to more students taking up STEM in higher education studies and in careers which then has a flow on impact of creating a sufficient pool of STEM-skilled workforce for economic prosperity.

[1] In secondary schools, mathematics and the natural science subjects (biology, chemistry, physics) are taught as separate subjects. Engineering and technology are not taught as discrete subjects. They are subsumed by technology and applied studies (TAS) which is a broad subject that can also include agricultural and food-related knowledge and skills, ICT knowledge and skills (programming), textiles design among others (NSW Government: Department of Education n.d.).

2b. Impact of teacher shortage

OUT OF FIELD TEACHING ERODES CONFIDENCE:

Fewer than 25% of years 7-10 students have a qualified mathematics teacher.

One of the impacts of teacher shortages is that a large proportion of students are being taught by 'out-of-field' teachers: teachers who have not been trained in content and associated pedagogy and are not suitably qualified to teach a subject. Out-of-field teaching rates for STEM subjects vary across the literature. They are seen as a key reason for declining enrolment numbers of senior students taking higher level mathematics (Hobbs et al., 2022). National Teacher Workforce Characteristics Report cites 29% for science out-of-field teaching and anywhere between 36%-46% for mathematics (Australian Institute for Teaching and School Leadership, 2021a). Fewer than 25 percent of Australian Year 7 to 10 students have a qualified mathematics teacher across all four years based on recent data from Australian Mathematics and Science Institute (Prince & O'Connor, 2018). Shah et al. (2020) cite figures of around 20 percent for out-of-field maths and physics teaching, and slightly under 10 percent for chemistry and biology. Unsurprisingly, the shortfalls are more drastic at junior secondary level, and in hard-to-staff schools (See Department of Education, Skills and Employment, 2021; Queensland Audit Office, 2013). In government schools, almost four in ten classes (39.1%) being staffed out-of-field (McKenzie et al., 2014). By any means, these figures are alarming.

Schools with difficult choices to make, may deploy their most highly qualified teachers to the senior years. While this is understandable, it compromises opportunities for junior students to be taught the fundamentals of STEM subjects. Limited teacher knowledge in a subject is unlikely to go unnoticed by students, which then contributes to erosion of teacher confidence and disengagement in learning (Crisan & Hobbs, 2019; Ní Ríordáin et al., 2019). Moreover, out-of-field teaching contributes to teacher dissatisfaction and attrition, further exacerbating overall shortages (Vale & Drake, 2019).

DECLINING STUDENT PERFORMANCE:

Teacher shortages and a lack of qualified teachers in science and mathematics are likely to influence student outcomes and test scores. Australian students' performance in STEM subjects appears less than stellar currently. In the most recent data available from the Programme for International Assessment (PISA) which assesses results from 2018 (Thomson et al., 2019) in mathematical literacy, Australian students achieved a mean score similar to the OECD average. This was the occasion on which Australian students failed to score above the OECD mean. Australian students performed lower than 23 of the OECD's 38 countries (Thomson et al., 2019). New South Wales sustained the steepest decline in mathematical literacy performance in PISA between 2006 and 2018, the decline being the equivalent to one-and-a-half years of schooling (Thomson et al., 2019, p. 176). In scientific literacy, Australian students achieved a mean score that was slightly higher than the OECD average, but still lower than 12 other comparable countries (Thomson et al., 2019).

Students from disadvantaged backgrounds are likely to fare worse in learning outcomes compared to the national average. For instance, there is a 92-point gap (representing the equivalent of three full years of schooling) between students who are socio-economically disadvantaged and advantaged in the mean science score in 2018 PISA results. Indigenous students, too, perform 15% lower than non-Indigenous students in mathematical and scientific literacy (OECD, 2018; Thomson et al., 2019).

Teacher shortages combined with a somewhat fragmented STEM curriculum further exacerbates the issue with fewer students now pursuing science and mathematics subjects in senior secondary years than in previous years (Timms et al., 2018). Again, this further compounded Australia's STEM capital aspirations and the capacity to respond to global environmental, social, geopolitical and economic challenges.

2c. Girls and women in STEM

Fewer girls elect to study science and mathematics in schools and only 10% of graduates from STEM programs in tertiary education are female.

A perception that girls are not 'good' at STEM (Australian Academy of Technology and Engineering, 2019) has resulted in fewer girls pursuing STEM subjects in school and beyond. For instance, in 2016, slightly more than a quarter of girls (27%) elected to study science and mathematics in school, compared with 76% of girls in China and 68% of girls in India, two of Australia's major regional trading partners (Andrews, 2019; Australian Academy of Technology and Engineering, 2019). The take-up rates of STEM subjects among girls at the senior secondary level have also significantly declined (Australian Academy of Technology and Engineering, 2019; Timms et al., 2018). World Bank data indicate that just over 10% of all graduates from STEM programs in tertiary education in Australia are female. This proportion is lower than those of New Zealand, the United States, the United Kingdom, and most European countries (Schomer & Hammond, 2020).

Australia's STEM Education Challenges Discussion Paper (2019) provides further data on the continuing gender imbalance in STEM tertiary education: of domestic engineering graduates in 2015 at doctorate level, fewer than a quarter were female, while at bachelor level, only one in seven was female (Consult Australia, 2019). (See also Hobbs et al., 2017). This results in lower female workforce representation, accounting for only 16% of STEM-skilled workers even though women comprise 47.5% of the total Australian workforce. Women and students from low SES backgrounds fare worse, both in terms of pursuing STEM studies and transitioning into the STEM workforce (McMillan et al., 2021).

In summary, there are numerous reasons to be concerned about Australia's STEM capital and its implications for our future (Department of Education, Skills and Employment, 2021).

- Australia's position is declining in international ranking tables as other countries improve. In 2003, only four countries or economies significantly outperformed Australia in PISA mathematics. In 2018, 23 did so.
- Around 40% of Australia's Year 7 to 10 mathematics classes are taught by a teacher unqualified in mathematics.
- Declining student performance and lower numbers pursuing science and mathematics demonstrate that Australian students continue to have either an inaccurate perception about STEM and/or don't recognise the importance of the field and STEM career opportunities, until it is too late.
- This has long term consequences including gender inequity issues and our ability to respond to critical national challenges.

2d. Implications and what next?

75% of the fastest growing occupations now require STEM skills and knowledge and some of the top-performing STEM economies value deep knowledge and entrepreneurship skills

Prioritising a strong STEM qualified teacher workforce has societal and global benefits.

STEM Education is one of four key pillars in the 2015 National Innovation and Science Agenda (NISA), that precipitated the National STEM School Education Strategy 2016-2026 (Education Council, 2015). Attracting and retaining STEM qualified teachers contributes to meeting government policy priorities of creating a STEM pipeline flow to have "clear pathways from the classroom to a career in the STEM economy" (Office of the Chief Scientist, 2014, p. 21).

In an increasingly interconnected world, Australia's store of technological knowledge, vis-a-vis that of other nations, will serve to advantage or disadvantage us internationally, and will determine options for both work and leisure. Developing strategies to improve STEM literacy skills of our future workforce will

enable Australians to (1) be job ready to thrive in the 'known unknown' of future careers and communities (2) drive economic prosperity and (3) contribute to solving 'wicked problems' of the world (Timms et al., 2018).

Shifting just one per cent of the workforce into STEM roles would add $57.4 billion to GDP (net present value over 20 years

A strong STEM skilled workforce is both an economic and a social imperative. While the stakes and potential costs of improving STEM literacy in Australia are high, so are the potential benefits (Ingvarson, 2018), as are the costs of inaction. Modelling by *PriceWaterhouseCoopers* (2015) found that shifting just one per cent of the workforce into STEM roles would add $57.4 billion to GDP (net present value over 20 years).

STEM literacies and qualifications can prepare young people for a career not just in science, mathematics, engineering and technology but also equip them with general capability skills – problem solving, creativity, effective communication and entrepreneurship – skills that are highly regarded among employers and in society (Timms et al., 2018). Research indicates that 75% of the fastest growing occupations now require STEM skills and knowledge and some of the top-performing STEM economies value deep knowledge and entrepreneurship skills (Office of the Chief Scientist, 2014).

Recruiting STEM industry professionals into teaching is one strategy to address some of the above challenges (Office of the Chief Scientist, 2014; Timms et al., 2018), while contributing to STEM NSW policy priorities. Governments at the state and federal level are starting to recognise the benefits of career change industry professionals. These professionals have qualifications and experience working in STEM or STEM-related roles in industries and are potentially considering switching careers to teaching.

The NSW Teacher Supply Strategy, including the 'Mid-Career Transition to Teaching' Program (NSW Department of Education, n.d., 2021) is a recent initiative, with its commitment to making teaching attractive and bringing qualified experts into classrooms. However, there needs to be a more concerted and sustained effort from policy makers to attract, a diverse STEM-qualified competent teacher workforce. There is also insufficient data about career changers or their contributions to the teaching profession despite being an emerging cohort in schools. Previous research conducted by the authors indicates their experience and expertise are either unknown or under-utilised in schools (Varadharajan et al., 2021).

This literature review seeks to understand how government and policy sectors can develop an effective plan to recruit and retain STEM professionals from industries and constructively utilise their skills and experience to increase student engagement and interest.

3.LITERATURE REVIEW METHODOLOGY

A systematic search was conducted to identify barriers, opportunities and enablers to attract and retain career-change STEM professionals to teaching.

For this project, we define STEM professionals as individuals with STEM qualifications and experience working in a role closely aligned to their qualifications (for instance, as a mechanical engineer). They may be looking to switch careers (hence referred to as career changers) to enter teaching or could potentially be 'head hunted' by education jurisdictions.

The key research questions that this review focused on are:

1. What strategies or mechanisms exist to attract industry workers from STEM fields to classroom teaching in NSW and across Australia?
    - What contributions do industry workers bring to the classroom?
    - What factors impact their successful transition to teaching?
2. What practices or policies are required to create a pipeline of career change professionals from industry to teaching?

Full details of steps and approach involved in the literature review methodology can be found in **Appendix A**

4.WHY HIRE STEM PROFESSIONALS IN CLASSROOMS?

Industry professionals who are considering switching careers can play an important role in addressing the gap of providing real-world experience to students, boosting student engagement in STEM, and remedying critical teacher shortages.

Countries that lead in STEM education and workforce skills have well-trained, inspirational and confident teachers in STEM disciplines who promote curiosity and inquiry-based thinking in students

Research indicates teachers have a strong influence on students' engagement, interest and performance in STEM subjects, and on how students view STEM in terms of future careers (see, for instance, (Hobbs et al., 2022; Marginson et al., 2013).Countries that lead in STEM education and workforce skills have well-trained, inspirational and confident teachers in STEM disciplines who promote curiosity and inquiry-based thinking in students (Marginson et al., 2013). It means students benefit from being exposed to opportunities, environments and experiences that trigger that curiosity, such as the opportunity to understand the connections between their lesson content and its application in practice, exposure to real-world and real-work problems and solutions, and capacity to value the potential and possibilities that STEM careers offer, in addressing global challenges. More broadly, students stand to benefit from being taught by diverse educators who have worked in different settings and sectors beyond the school, bringing 'life-beyond-school' perspectives more authentically to classrooms.

Career change individuals with STEM expertise bring unique and rich insights to the classroom, namely:

- Wide content **knowledge** and a deep understanding of the field (Grier & Johnston, 2012)
- practical real-world **examples** and experiences from previous roles in STEM or STEM-related fields
- technological and entrepreneurial **skills** gathered from prior work experiences, as well as soft skills such as collaboration, communication and presentation skills with the drive to pass these on to the next generation (Cuddapah & Stanford, 2015; Varadharajan et al., 2021).
- intrinsic **qualities** of self-confidence, maturity, commitment, creativity and passion (Varadharajan, 2014; Watters & Diezmann, 2015).

Teachers from STEM backgrounds can make science and mathematics teaching more relevant and engaging, helping to:

- make connections between scientific concepts and their practical applications in lesson plans and delivery (Grier & Johnston, 2012)
- provide stimulating learning opportunities integrating science with other subject areas (Ambrose, 2016)
- spark interest and enthusiasm for study in STEM discipline areas and better preparing students for post-secondary opportunities (A. Koehler et al., 2013a)
- prepare students and the future workforce for a career not just in STEM fields, but also equip them with general capability skills and attributes that are highly regarded by employers (Varadharajan et al., 2021)
- act as role-models enabling more girls and women to pursue learning and careers in STEM.

Career-change teachers' experiences render their teaching "qualitatively different" from that of their first-career counterparts, in terms of, *inter alia*, their "inner drive" (Steiner & Caspi, 2018, p. 259). They typically find alternative and flexible ways to engage students in more authentic learning experiences. The literature indicates career changers are adept at providing practical examples or case studies from their own

previous career or roles to help students understand the connection between subject matter content and its real-world application (Grier & Johnston, 2012; Varadharajan, 2014).

However, the journey to becoming a teacher for STEM professionals and building a career in the profession is not necessarily straightforward. Because they enter the profession at a later stage in their career, typically with family and employment responsibilities, their priorities, needs and circumstances are different. These are not always well-understood by schools and jurisdictions (Varadharajan, 2014; Varadharajan & Buchanan, 2021). While most may make the transition to teaching because of intrinsic motivations and social and personal factors, it does not automatically lead to long term engagement or satisfaction in their new career. STEM professionals themselves may come with certain expectations and understandings and may be under-prepared about the working conditions of a school. This results in a 'culture shock' for many (Varadharajan et al., 2021).

The following sections outline key issues faced, and mechanisms to address them. Themes that emerged from the literature were developed at the individual or micro level and at the sector or macro level.

While the literature review set out to identify strategies to attract STEM specialists, that is, career changers with a STEM background, not all of the findings deriving from the literature are specific to this cohort. Most incentives to join and remain in teaching apply to career changers more broadly. This is important to recognise when Government and education jurisdictions are considering strategies to diversify the teaching workforce.

5.FACTORS THAT IMPACT SUCCESSFUL TRANSITION AND WHAT WORKS

5a. Financial considerations

Uncompetitive salaries continue to be one of the primary reasons for teachers leaving the profession, both in Australia and internationally (Kini, 2022). Low salaries are likely to 'promote' the profession as a second- or last-rate option. In recent years and months, particularly post-pandemic, representatives from various school sectors, education unions and peak bodies have expressed their frustration about low teachers' salaries and demanded action be taken to correct this inequity (Wilson & Carabetta, 2022). We note the salary-based industrial campaign by NSW teachers at the time of writing.

For STEM professionals, the reduction in salary can serve as a major disincentive to taking up a career in teaching. As participants in Varadharajan & Buchanan's study noted, mathematics and science graduates tend to command much higher salaries than those of teachers (2021).Those who have transferred to teaching have typically done so for reasons other than salary but are acutely aware of the impact of the steep fall in their earnings as compared to their previous earnings in the STEM profession. This may be a particularly stark decision for those with children. Governments and education jurisdictions need to address this fundamental issue as part of any teacher recruitment strategy to fill STEM teacher shortages.

Performance or merit-based pay is quite common in industries whereas it can be unpopular or contentious in the teaching profession. This can also be a sticking point for prospective career changers coming from industry.

Career-change pre-service teachers also cite financial hardship in the transitioning process (Varadharajan et al., 2020). Compared to their school-leaver counterparts, career-changers are less likely to have parental support, and indeed, might be supporting their ageing parents. They are likely to have dependent children of their own and may be the primary or sole household breadwinner. Varadharajan et al., (2020) found that these problems are acute for many career-change teachers, particularly during Professional Experience, which is typically undertaken in full-time mode. This challenge and corresponding solutions are also identified under section 5d which discusses 'pathways and entry into teaching'.

Financial considerations also surface where STEM professionals choose to, or are deployed in, hard-to-staff locations such as in low socio-economic or rural and regional areas where there is a chronic STEM shortage. Failure to recognise and reward commitment to work in these most difficult-to-staff schools is likely to result in high attrition rates, with negative implications for the career-changer, the profession, and the school and community concerned. More broadly, any disillusioned ex-teachers are likely to serve as a mouthpiece to future career changers for avoiding becoming a teacher.

WHAT WORKS:

Teacher salaries need to be competitive and commensurate with those of other comparable careers. Increasing teacher pay scales to the level of those of, for example, lab technicians and scientists, would likely attract more career-changing individuals from these fields (Dos Santos, 2021a). Higher salaries can also increase the appeal and profile of the profession (Jeanes & Scull, 2021). A review of the literature conducted by Podolsky et al. (2016) indicates even a slight increase in salary could result in a substantial increase in the proportion of those considering a career in teaching. Proposed strategies include:

- offering competitive rates of pay for teachers of mathematics and science with honours qualifications or higher degrees (Marginson et al., 2013)
- provision of bonus starting pay for mathematics and science teachers employed in low-SES schools and regional and remote schools (Marginson et al., 2013)
- Scholarships to attract high achievers (Goss et al., 2019).
- Financial support during career changers' period of pre-service education. Also refer to solutions identified under section 5d.

The current federal government has committed to scholarships to attract high achievers and part-time salaries to attract experienced mathematics and science professionals (Australian Labor Party, n.d.). This is a welcome and promising first step. Similarly, there have been significant investments being made by governments at the state and federal level to attract teachers in hard-to-staff schools (examples: (Department of Education and Training, 2022; Victorian Government, 2022). In NSW, the rural incentive scheme under NSW Teacher Supply Strategy implemented by the government is one strategy to incentivise current and potential teachers in rural, regional and remote areas to address current critical shortages (NSW Department of Education, 2021).

Implementing changes to ease financial hardships is a partnership effort. Though fundamental changes in pay structures are required to be examined and implemented at the government level, other agencies such as education focused philanthropic organisations can play a role in supplementing these efforts. Bonus pay provision or paid support schemes during teacher training period are other possible incentives (Timms et al., 2018). Similarly, professional experience or placements that are informed by strong relationships between providers, placement settings and communities can yield positive learning experience and rich learning opportunities for the student teacher (Australian Institute for Teaching and School Leadership, 2022).

The application of financial incentives as a blanket measure may need to be treated with caution. In a critical review of international evidence of interventions to recruit and retain teachers, See et al. (2020) found one-off or short-term financial bonuses to be effective only for the life of the incentive, least so in areas of disadvantage, and tend to fail as a mechanism to retain such teachers. A recent US study (Judson, 2022) identified no public appetite for differentiated salaries based on field of teaching. Similarly, 'remote bonuses or bonuses to attract teachers to remote areas might serve to stigmatise such communities while having relatively short-term benefits (Roberts et al., 2020). On the other hand, compensation for costs incurred to undertake rural placements, extra opportunities for professional development and promotion and extra leave options could be attractive to incentivise career change professionals to teach in rural settings (Roberts et al., 2020). A lack of rigorous evaluation of such projects, however, prevents us from drawing clear conclusions about the effectiveness of short-term incentives or success in retaining teachers over a sustained period.

It is also important to note that while higher salaries for STEM teachers would be an attractive measure, it can also present an inequity issue and an uneven playing field for and among teachers. A healthy balance is required to ensure fairness, cohesiveness and collaboration while striving for highly competent teachers who are well rewarded for their expertise and experience.

5b. Working conditions and teaching environment

Schools as workplaces need to be understood in terms of their function, as well as their particular ideology and culture. In addition, teachers' work conditions including job security, their workload and other administrative non-teaching related burdens have also long been a significant problem and the reasons for many leaving the profession or being less effective in it (Mayer et al., 2015). Many STEM professionals' workplace conditions would be quite different from those of schools. For these reasons, career changers can struggle with adjusting to the school environment including dealing with administrative bureaucracies and rigidities in curriculum (see for example, (Varadharajan et al., 2021; Watters & Diezmann, 2015). Other barriers faced by career changers could be facing scepticism and a lack of encouragement from leadership. This can stifle creativity and prevent professionals from curating a classroom environment that combines their skill set along with enabling students to be 'researchers' and 'scientists' (Ambrose, 2016). 'Casualisation' of the profession poses a further barrier to attraction and retention (Stacey et al., 2022). It adds to 'career' unattractiveness sending a dismissive message to teachers and beyond. It also appears counterintuitive in a climate of teacher shortages.

An overcrowded curriculum or poorly resourced schools, such as lack of functioning equipment in school laboratories, are also likely to serve as inhibiting factors in implementing ideas to nurture student interest and engagement in science (Varadharajan & Buchanan, 2021). Hence, even though, as is evident in literature, career changers' reasons for entering the profession are altruistically and intrinsically motivated, including even a willingness to be financially 'short-changed', they tend to become frustrated with the environment in schools (Varadharajan & Buchanan, 2021).

WHAT WORKS:

Staff and departmental heads in schools should recognise, support and encourage STEM specialist interests and enthusiasm. Ideas and new ways of doing should be promoted enabling a positive work and team culture. These steps not only benefit career change professionals but any new teacher. Strategies relating to working conditions and teaching environment include:

- A welcoming, inclusive and flexible school culture that values STEM experience and expertise, and qualities of entrepreneurship and creativity
- Well-funded schools with sound investment in resources and equipment to support practice-based learning
- Reduced administrative burdens that also affords educational leaders more scope for nurturing newcomers to the profession.

5c. Career competency and career development

Studies indicate middle aged and older workers entering the job market tend to enjoy a higher degree of 'career transition competency', that is being competent in transitioning from one career to another (Lin et al., 2020). In the case of teaching, pedagogical and content knowledge is specialised, and not, in the main, intuitive. Content knowledge and pedagogical knowledge are each necessary but, by themselves, inadequate conditions for successful teaching. M.J. Koehler et al., (2013) speak of TPACK, technological, pedagogical and content knowledge. To this, Varadharajan and Buchanan (2021) add the importance of relationship, TPRACK. This makes teacher preparation a complex undertaking.

While some research on career changers shows little conflict between professional (content-related) competencies and teaching experiences, (Antink-Meyer & Brown, 2017; Brindley & Parker, 2010) there is also evidence that challenges the assumption of the transferability of industry knowledge to pedagogical school applicable knowledge (eg. Diezmann & Watters, 2012).

STEM professionals can struggle to successfully transfer their industry skill set in classrooms (Varadharajan et al., 2018). The transition from being mathematicians, scientists or ICT specialists, to students, to teachers (Navy et al., 2021) can be described as, both a "process of individuals' own career re-

building and a process that is amplified by school structures and systems" (Korhonen & Portaankorva-Koivisto, 2021). For instance, classroom management is a huge problem for many beginning teachers and career changers are no exception. During this transition process, if access and opportunities such as mentoring or tutoring support are not evident within education jurisdictions or schools, achieving a smooth career transition competency becomes more challenging.

WHAT WORKS:

Schools should take steps to support STEM professionals in their career transition journey. Research suggests they are likely to develop a sense of autonomy and confidence as teachers within a supportive work environment (Diezmann & Watters, 2015; Schuck et al., 2012). While the provision of content and lesson plan instruction and practice in pedagogy in STEM learning is vital for all career-change pre-service teachers, it is equally important for schools to:

- unpack industry skills gained in non-school settings and how this may translate into classroom settings and in everyday STEM teaching
- create awareness in changes in personal and professional identity for STEM professionals due to significant differences in the workplace
- recognise and draw upon any para-teaching experience including prior experience within subject disciplines that STEM career changers may have previously gained. For example, there could be instances where STEM professionals had wider experience working with high school aged pupils (for example through youth groups and/or sports coaching or tutoring) (Dawes & Wheeldon, 2020), or in mentoring or advising colleagues
- provide opportunities to boost career-changers' confidence in STEM hands-on activities through ongoing professional development workshops (Chalmers, 2017)
- offer targeted mentoring and other forms of learning support during the career transition journey to meet the needs of career change professionals (Morettini, 2014).
- offer opportunities for better collaboration between career change colleagues within or between schools can be beneficial
- match teacher experience and expertise with a school's curricular needs, particularly where senior science courses are concerned. Shah et al. (2020) suggest that where schools have greater autonomy over recruitment and hiring staff, they are able to employ the 'right' kind of teachers suited to the learning needs of their students.
- build greater preparedness for classroom management- building competencies through targeted mentoring, professional development, and assignment design (A. Koehler et al., 2013b)

Strategies to *engage and* ***retain*** STEM professionals in schools should include improved promotional pathways and opportunities for leadership development. These can include:

- Offering of 'teaching' professional pathways (that is, promotion into higher-order teaching roles) rather than administrative pathways. This creates opportunities for STEM teachers to progress to 'STEM leaders' as part of nurturing and sustaining their career development journey (Hite & Milbourne, 2021).
- Engaging with current STEM career changers who have made the switch to teaching to understand what works to retain them (Ambrose 2016).
- Developing a clear and sustained retention strategy and plan for STEM professionals, moving from an 'attrition focus' to a 'career advancement or career progression focus' (Cuddapah et al., 2011).

Achieving or working to achieve these steps are likely to pay dividends, so that the industry experiences professionals are leveraged purposefully rather than teaching becoming an 'educational detour' for STEM professionals (Navy et al., 2021).

The DoE can also leverage ***existing*** programs and opportunities to tailor them for career change professionals. Examples:

- Tailoring existing mentoring programs
- Examining ways of how current opportunities to do with the establishment of literacy and numeracy instructional leadership roles can be tailored for career change professionals
- Role of 'Expert' and 'Lead' teachers in supporting the development of career change professionals

The above is just some of the programs that the researchers are aware of, but there may be more opportunities to tailor to specific groups like career change professionals.

5d. Pathways and entry into teaching

Career changers can face barriers to entry into teaching. The system and the sector are not set up to capture and formally recognise prior experiences and the diverse trajectories of career changers wishing to teach in the public education system. This failure to understand and suitably credential prior expertise and experiences leads to providers treating this cohort the same as other entrants, without understanding the subtle differences that are inherent in this group (Varadharajan & Buchanan, 2021).

Certain aspects of the traditional model of initial teacher education (ITE) training programs can serve as barriers to entry into teaching for industry professionals. These relate to loss of income during study, program length and the timing and duration of professional experience (Department of Education, Skills and Employment, 2021; Morettini, 2014; Varadharajan et al., 2020a). Barriers associated with teacher education courses are not unique to the STEM career change cohort but are common across all those switching careers from various fields (Varadharajan, 2014). Because they are likely to have higher responsibilities than the average school leaver (financial and family-related), career-changers may find undertaking full-time face-to-face study and the associated demands such as attendance and meeting assignment submission deadlines particularly challenging. In-school professional experience, where student teachers spend extensive periods in schools as part of their teacher education program, are also stressors for many career changers as they struggle to satisfy financial, family and study demands (Varadharajan et al., 2020).

Alternate modes of teacher education delivery are gaining momentum with more than a quarter of students studying their ITE programs either in hybrid mode or entirely online (Australian Institute for Teaching and School Leadership, 2020). Their flexible nature makes them an attractive option, especially for mature aged students. Alternate pathways, for instance, 'Teach for Australia' are becoming increasingly popular within the career changer group (Teach for Australia, n.d.).

WHAT WORKS:

Embedding flexibility in all teacher education program models is crucial. Alternate routes and flexible pathways to enter teaching make the profession more accessible, and act as an attractive incentive for academic and industry professionals (Donitsa-Schmidt &do Weinberger, 2014; Timms et al., 2018). Strategies for education institutions and leaders of existing and future transition-to-teaching programs include:

- Reducing rigidity in the times and locations of classes to ensure teaching courses are more accessible for career changers (A. Koehler et al., 2013b)
- Developing tailored options for entry selection process in all programs. For example, through interviews, personal statements and the use of online screening tools such as the Teaching Capability Assessment Tool (TCAT)
- Identifying and removing systemic barriers in public education, enabling STEM professionals' expertise to be formally credentialed.
- Offering scholarships, paid internships, or similar financial incentives to compensate career change student teachers' time during their teacher course and/or professional experience (Haggard et al., 2006). Some institutions already offer such schemes; however, these need to be scaled up to widen reach across providers and student teachers.
- Establishing peer support groups for student teachers to know the diverse backgrounds of each other and what each bring to teaching (A. Koehler et al., 2013b)

In its NSW Teacher Supply Strategy, the NSW Department of Education (2021) has committed to providing accelerated mid-career pathways for experienced subject matter professionals, which includes a plan to recruit more than 500 experienced and qualified STEM and TAS teachers over the next five years. The federal government has also committed to providing "practical paths into teaching for experienced professionals with skills in high demand areas like maths and science…with part-time salary and mentoring" (Australian Labor Party, n.d.).

These changes will be welcome by prospective industry professionals. Steps must be taken to ensure incentives and strategies apply to all teacher education training program pathways: no career change individual, irrespective of the training stream they are undertaking, should miss out.

Alternative routes to teaching provide flexibility (for example, in attendance and participation) and are popular among career changers. Precipitated in part by COVID-19, online or blended approaches are likely to proliferate, adding to flexibility in the delivery of teacher education courses and contributing to an increase in individuals switching to teaching. However, some of these 'fast track' courses may need to be treated with caution to ensure the quality of pre-service teacher preparation is not compromised and those graduating from these courses have the 'foundational knowledge and skills necessary for ongoing learning of teaching' (Mayer et al., 2015) and are as competent and 'classroom prepared' as any other student teacher undertaking traditional courses (Haim & Amdur, 2016). Similarly, paid professional experience, while attractive, can present an expensive burden on the system (Varadharajan & Buchanan, 2021).

5e. Perception and promotion of teaching profession in society

Teaching as a profession does not enjoy the same elevated status and value in Australian society as other skilled professions. At times perceived as a 'fall back' option, it is not seen as a lucrative career that rewards staff proportionate to workload demands (Fray & Gore, 2018). Ingvarson (2018)investigated pay rates for teachers at AITSL's Highly Accomplished and Lead levels, and concluded that adequate remuneration for such teachers would attract higher-achieving students into teaching, reduce out-of-field teaching, and promote professional learning among teachers. A Turkish study that investigated the motivating factors of Alternative Certification Program (ACP) students majoring in different subject areas to become tertiary teachers found mathematics graduates were least likely to be motivated by job transferability, and rated teaching poorly in terms of salary and social status of teaching and career satisfaction (Akar, 2019). While motivations to become a teacher are often altruistic rather than fiscal in nature (Whiteford et al., 2021), this goodwill shouldn't be assumed, particularly in the current context of increasing prices of, for example, housing in Australia.

In addition, the contributions of educators are undervalued, and teachers tend to be disproportionately blamed for the quality of teaching in schools and student performances in national and international tests. The profession also tends to be portrayed negatively in the public sphere, including 'horror stories' of dispiriting workload and disrespect. The roles and impact of other systemic and structural factors that influence student outcomes are not fully understood or largely ignored (Buchanan, 2020; Gore & Mockler, 2022). Professionals who have had careers in other fields, including in STEM areas are less likely, therefore, to be attracted to teaching due to its poor public image and lack of esteem.

Nevertheless, studies indicate that after having made the switch, STEM professionals are keen to promote teaching as an attractive career option, for instance, to their ex-colleagues and potential career changers (Bauer et al., 2017). This type of dialogue to promote teaching does not occur in a systematic way, even though it is considered a valuable strategy to attract, engage and retain prospective high quality diverse professionals (Nguyen & Redding, 2018). Hearing about the teaching profession and making career decisions through this type of anecdotal but reliable and credible way is far more likely to be an effective strategy to create the right perceptions and draw more professionals in teaching.

Access to online tools can also help prospective career changers in their decision making. A UK study offered university students in STEM-related subjects with 'Realistic Job Previews' (RPJ), an online intervention tool to provide a realistic view of situations that can be expected from a job (Klassen et al.,

2020). The use of such mechanisms can be explored in industry settings among prospective career changers.

WHAT WORKS:

Teachers' roles and responsibilities must be recognised, respected and rewarded by our society. Public regard for the profession has the potential to improve its popularity as a career choice and reduce attrition (Australian Institute for Teaching and School Leadership, 2021b). The status and profile of teaching as a career can be elevated and maintained by implementing one or more of the following:

- Salary and pay structures to commensurate with other, similar professions (e.g. (Ingvarson, 2018); this would make teaching a more attractive and viable option for many, and would likely raise the esteem in which the profession and its members are held
- Ensuring a balanced analysis in media representations, in response to the release of national and international tests, avoiding alarmism that can have a dispiriting effect on students and teachers (Bahr et al., 2018)
- Leveraging the voices of teachers and parents more effectively. This can entail lobbying the media to include:
    - Teacher perspectives in discussions of matters relating to student behaviour and achievement.
    - The perspectives of parent associations in commentary on matters relating to school management (Bahr et al., 2018).
- Targeted strategies for promoting and 'selling' teaching as a career option include:
    - Posting regular article snippets in professional journals about teaching career benefits (Bahr et al., 2018)
- Targeted strategies for promoting and 'selling' teaching as a career option include:
    - Posting regular article snippets in professional journals about teaching career benefits (Bahr et al., 2018)
    - Celebrating outstanding achievements, 'good news' teacher stories and commitment of teachers in new outlets and social media (Bahr et al., 2018). This might include model influences, for example, a former teacher or a parent who influenced a person to think about teaching (Morettini, 2014)
    - Celebrating stories of influential teachers in 'celebrity' or 'public figure' people's lives. Industry professionals sharing stories of their own inspirational teachers.
    - Capitalising and building on the positive public relations occasion of the teaching profession generated during COVID-19, with many parents coming to understand the complexities of teaching (Barnes, 2021; Jeanes & Scull, 2021)
    - Utilising current STEM specialist teachers to promote teaching as an attractive career option
    - Directing potential mature age teaching applicants (at the time of their application to educational institutions) to websites and credible sources that provide accurate information about future teaching employment prospects and the day-to-day realities of teaching in the secondary classroom (Bauer et al., 2017). This approach might be extended to those in STEM-related industries.

6.OTHER STRATEGIES TO ATTRACT AND RETAIN STEM SPECIALISTS IN TEACHING

6a. Leveraging and building upon existing frameworks of school-industry partnerships

Community connections in the form of school-industry STEM partnerships already exist in various forms by way of:

- industry experts from local industries and sectors being invited to classrooms (virtually or otherwise) to increase students' awareness of beyond-school life;
- joint curriculum development; professional development for teachers;
- opportunities for students in the form of industry work experience, STEM education programs and industry scholarships (Flynn et al., 2016).

In addition, frameworks for optimising industry partnerships has been developed such as the one by The Education Council's STEM Partnerships Forum (2018). This includes collaboration with industry to develop a more detailed understanding of future workforce needs and create a narrative for students and parents on how STEM skills and knowledge can solve real world problems.

The above framework, current connections and partnerships, such as STEM education programs, that already utilise the industry sector can be **further innovatively leveraged, adapted or upscaled to include ways to permanently and sustainably attract STEM industry professionals to enter teaching**. Foundations and corporate sponsors that have a focus on building a STEM-literate workforce also have opportunity to lend financial support to such school-industry partnerships (Foster, 2010).

Examples:

- Utilising networking opportunities at school STEM education events, communications through industry peak body association newsletters and university faculty representatives during school visits to reach out to prospective professionals
- Utilising knowledge and networks available through the Indigenous STEM Education Project (Walker & Banks, 2021) in encouraging Indigenous STEM professionals into teaching. Such programs and professionals in classrooms might also encourage more Indigenous students to pursue teaching, building confidence by raising the profile of Indigenous knowledges and ways of knowing to the curriculum
- Developing pathways for classroom teaching transition: In partnership with teachers and with government and industry support, work arrangements that engage STEM professionals working in industry to transition into meaningful, ongoing and accountable roles can be developed. Such opportunities allow for industry professionals already engaged with students, to ease into classroom teaching, to settle in, and get familiarised with the school culture (Cuddapah et al., 2011; Varadharajan et al., 2020). This can include:
    - job sharing or team teaching with industry colleagues of current teachers.
    - extending one off 'incursions' or visits by scientists to say, 'scientist in (virtual) residence' in a school.

7.REPORT RECOMMENDATIONS

Informed by themes drawn from literature, the report makes the following key recommendations.

- **Prioritise financial compensation**:

  That teacher salaries match those of comparable professions, addressing the current loss in remuneration for STEM specialists switching to teaching.

  There needs to be a more nuanced approach to industry professionals' salary structures and other reward systems upon transition to teaching. Such approaches, whether short term incentives such as scholarships or long-term salary increases, should consider factors such as loss of income during study and in-school professional experience while managing other responsibilities, and industry workers' capacity to relocate to rural and regional locations to fill critical shortages in STEM subjects.

- **Embed recognition, seamless career transition and effective** '**after sales service**':

  That STEM expertise and industry experience to be suitably recognised and credentialled by all education jurisdictions including schools, teacher education providers and accreditation bodies, and more broadly by governments.

  Industry workers need to know their prior STEM qualifications and expertise count when they transition and as they progress on in their new role. Teaching pathways and programs to transition should be of high quality, flexible, free from administrative and bureaucratic barriers and tailored to the needs of industry professionals.

  Recognising the distinct characteristics and needs of career change professionals, a tailored teacher education pathway for this cohort of students could be considered.

  The teaching profession should be cognisant of the personal and professional growth aspirations of career changers (both as students and as teachers) and their desire to be autonomous and to lead. Making the right information available at the right time to prospective career changers about the roles and responsibilities of classroom teaching as a career is likely to pay dividends in retaining them. Tailoring support and providing the right environment from the outset will enable them to effectively fulfil the work they are paid - and some would say, born - to do (Buchanan, 2020).

- **Develop targeted recruitment campaigns:**
  - That steps be taken to leverage existing *school-industry partnerships* to target potential industry workers - identify the right individuals from the right industry who fit the needs of the school and its plans in the STEM area.
  - That recruitment programs be targeted to attract *Indigenous students as STEM teachers*. As with the inclusion of women, this is not merely an issue of social justice, but also potentially the inclusion of alternative ways of knowing, thinking and problem-solving. The visibility of, respectively, Indigenous and/or female STEM teachers will serve as role models for future generations
  - That recruitment programs be targeted to attract *women into STEM* teaching. While this may potentially be seen as 'taking away' women from their STEM careers, a long-term view enables us to see the benefits this will bring to address the current gender equity issue in STEM workforce. Women teachers who have held prior STEM careers are likely to be excellent role models for students (including girls) in pursuing careers in the area as well as prompting important conversations about stereotypes and gender biases (Australian Academy of Technology and Engineering, 2019). Their presence in schools value-adds to the future workforce STEM-base. A targeted recruitment campaign ensures drawing those women who are looking to change careers anyway (for a variety of reasons) after being in a STEM profession
  - That a '*rural recruitment' campaign* be prioritised to identify what works to incentivise

current STEM teachers and potential individuals to join and remain in schools in rural, regional and remote areas. This may involve seeking government, industry and philanthropic/NGO support (financial and/or in-kind) to further partnerships between industry/ies, school/s and communities that struggle to attract schoolteachers

- That a targeted and efficient approach based on *school and sector contexts* be utilised by education jurisdictions and teacher employing bodies to:
  - identify areas of greatest relevance to school curricula and develop a campaign to target industries that potentially hold the greatest promise of career change individuals
  - recommend a more comprehensive understanding of employment environments in local contexts, to improve the efficiency of career-change recruitment in STEM areas suited to the needs of the school and community (Bauer et al., 2017)
  - identify prospective individuals working in the local industry in the country to teach in country schools, as they are more likely to stay (Burke & Buchanan, 2022).

- **Develop a multi-faceted, sustained and systemic approach**:

  That a multi-faceted approach be devised and implemented to address long-term teacher shortages and diversify the teaching profession. Recruiting industry workers can be one mechanism to address the issue but government and policy makers need to consider other effective strategies to solve the STEM problem. A range of measures that support and reward new and existing teachers will pay dividends (see for example (Kini, 2022).

  Other examples:

  - implement specific reforms in partnership with different sectors, to ***improve the societal status and attractiveness of teaching*** as a profession
  - embed ***STEM specific professional development for all teachers*** in all schools to increase educators' skills and confidence (Timms et al., 2018)
  - Work in partnership with early childhood educators to build awareness and embed STEM training in early childhood education
  - ***Upskill school career advisors*** to increase their knowledge about STEM career opportunities for students.

8.REPORT CONCLUSIONS

COVID-19 has presented both opportunities and challenges in how we can re-imagine our teacher workforce. While shortages in key subject areas and in disadvantaged locations have become more acute, there is now an urgent push for all Australian students to be STEM-literate with the capability to solve global problems. The challenges and opportunities illustrate the need for experienced and qualified STEM specialists in classrooms who can not only fill these gaps, but also contribute to addressing 'diversity deficits' in the teaching profession.

Developing a strong STEM-skilled teacher workforce is not only a critical conduit to building a skilled future economy but also delivers a pool of industry-qualified, experienced teachers, with real-world expertise. STEM professionals contribute to building a diversified teacher workforce that will better meet the learning needs of students from diverse settings and backgrounds. At the same time, it raises the teaching profession's image and status by valuing diverse and differentiated career paths into teaching (Varadharajan et al., 2020).

STEM professionals serve as excellent role models to help bridge the theory-practice gap in classrooms and build students' aspirations, interest and employability in the sector. They also find ways to share, connect and integrate their experiences and STEM applicability in school learning.

State and federal governments are already beginning to recognise the value of industry professionals and take action to address teacher shortages (Australian Labor Party, n.d.).

By attending to some of the micro and macro level recommendations outlined in this report, the Department, schools, education jurisdictions, policy makers, and teacher educators can better assist highly qualified scientists and mathematicians in their transformative journey toward becoming, and remaining, teachers. Attracting, engaging and retaining industry professionals must be seen as a collective responsibility. To summarise,

- A spirit of partnership between different stakeholders must exist if STEM professionals' career trajectories in teaching profession are to be successful.
- A recruitment campaign that is targeted and inclusive of gender and Indigeneity is likely to generate better outcomes in terms of retaining professionals in teaching.
- Strategies and non-linear approaches that address issues from a systems perspective, such as lifting teacher's status in society, are likely to be far more effective than single quick fix solutions.

Australian students deserve to be taught by qualified and experienced teachers. The provision of quality maths, science and IT teaching for all students is essential for Australia's economic and social wellbeing, and an inescapable responsibility and reality for governments if they are to pursue equity as a fundamental way to achieve progress. Employing highly qualified, experienced and aspirational career-change teachers with STEM backgrounds can introduce students to content and concepts from real-world perspectives, foster a love of STEM learning, ignite an entrepreneurial mindset that empowers students to own their future and ultimately breed a generation of 'change makers' to solve global problems.

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APPENDIX A: REVIEW METHODOLOGY

Research Questions

A systematic search was conducted to identify strategies to attract and retain career-change STEM professionals to teaching.

The key research questions were:

1. What kinds of strategies or mechanisms exist to attract industry workers from STEM fields to classroom teaching in NSW and across Australia?
2. What are the practices or policies required to create a pipeline of career change professionals from industry to teaching?

Review Methodology

1. SEARCH FOR SOURCES

To conduct this literature review, a search strategy (see Table 1 below) was established that involved the key concepts from the above research questions to find accurate results.

Table 1 provides the keywords used in search strings across academic databases and other search engines to find relevant results. Depending on the parameters of the database, minor variations were made to the search string to ensure the capture of all relevant results. Inserting 'mechanisms' or 'strategies' to search terms were not considered to be useful or appropriate as it resulted in different results not related to industry workers switching careers to teaching. The below search strings yielded articles that examined and discussed factors that impacted career change and strategies to attract industry workers.

Inclusion and exclusion criteria were developed to refine results, based on the research question and cohort groups identified for the study.

2. SCREENING

The next stage involved screening the sources by title and abstract. Sources were removed that were not relevant to the research question, as determined by not meeting the inclusion criteria. Zotero, a referencing software, was used to keep track of the entire process at each stage of the literature review methodology.

This process resulted in the exclusion of 275 sources out of the total 431 articles, leaving 156 articles eligible for full text screening. Following this, a full text screening was conducted in which further articles were excluded due to being outside the scope of the research question focus. The application of the full text screening process further reduced the number of included articles from 156 to 140.

The full screening process is captured in the PRISMA Flow Diagram below.

3. EXTRACTING INFORMATION

The 140 sources were reviewed, and information was extracted and placed in an extraction table. The information extracted included:

- the type of article or publication
- year of publication,
- Aim of article
- Data collection method

- target group
- Results summary and
- Conclusions

4. SYNTHESIS AND ANALYSIS OF THE LITERATURE

From the extracted data, the researchers examined the results presented through the literature, aligned with the research questions. Resultant themes emerged and the literature review was written in accordance to the themes and synthesising responses informed by the research questions.

Summary of the literature review sources

This review looked at (*140*) articles (58 journal articles, 44 reports, 13 webpages, 5 book chapters, 2 conference papers, 3 books, 13 evaluations and 2. thesis) published in the past 10 years (*2011 – 2021*). 86 were in Australia, while 54 were from other countries. 92 articles employed qualitative research methods, 22 employed quantitative research methods, and 26 employed mixed methods approaches. 23 articles examined contributions of STEM industry workers to teaching and 56 articles suggested strategies to attract and retain industry workers into teaching. 43 articles were motivations that had attracted STEM professionals to a career in teaching, 6 examined a combination of both strategies and motivations. The rest (n=22) were informative articles regarding the issue but were still considered relevant for the literature review.

Table 1 : Search Strategy

TABLE 1: SEARCH STRATEGY	
Keyword search parameters	"STEM OR science OR math* OR chemistry OR physics OR biology" AND ""career change*" OR "professional recruitment" OR "teacher recruit*" OR "alternative teacher certification" OR "second career" OR "prospective teacher*" AND "teach* OR educat*" AND "Industry OR "STEM occupation*" OR "STEM career*" OR "STEM professional*""
Filters	Timeline: 2011-2021 Language English
Sources	*Academic databases:* ERIC, Informit A+ Education, ProQuest Education, PsycINFO, SAGE, Scopus, Taylor & Francis, Web of Science *Other sources:* Google Scholar, Grey literature including technical and government reports and hand search
Inclusion criteria	• Australia, NZ • Industry workers in STEM or STEM related roles focus • Career change teachers who teach science, mathematics or TAS focus • Career change teachers with prior roles in STEM/STEM-related focus • Career change student teachers intending to teach science, mathematics or TAS focus • Career change student teachers with prior roles in STEM/STEM-related focus • Schools focus

	• Empirical research • Grey literature and Government reports acceptable • Education peak body or STEM peak body reports acceptable
Exclusion criteria	• Career change teachers who DO NOT teach science, Mathematics, TAS in schools • Prospective career changers (industry workers) NOT in STEM or STEM related roles • Career change student teachers who DO NOT intend teaching science, mathematics or TAS • Career change teachers or student teachers who were NOT previously in a STEM role • Any individual who wants to become a teacher but IS/WAS NOT in a STEM or STEM related role. • Commentary articles and letters • Published prior to 2010

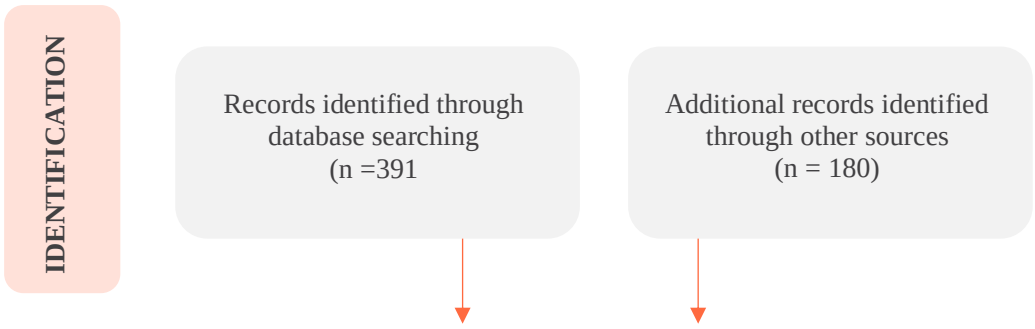
Table 2: Search Results

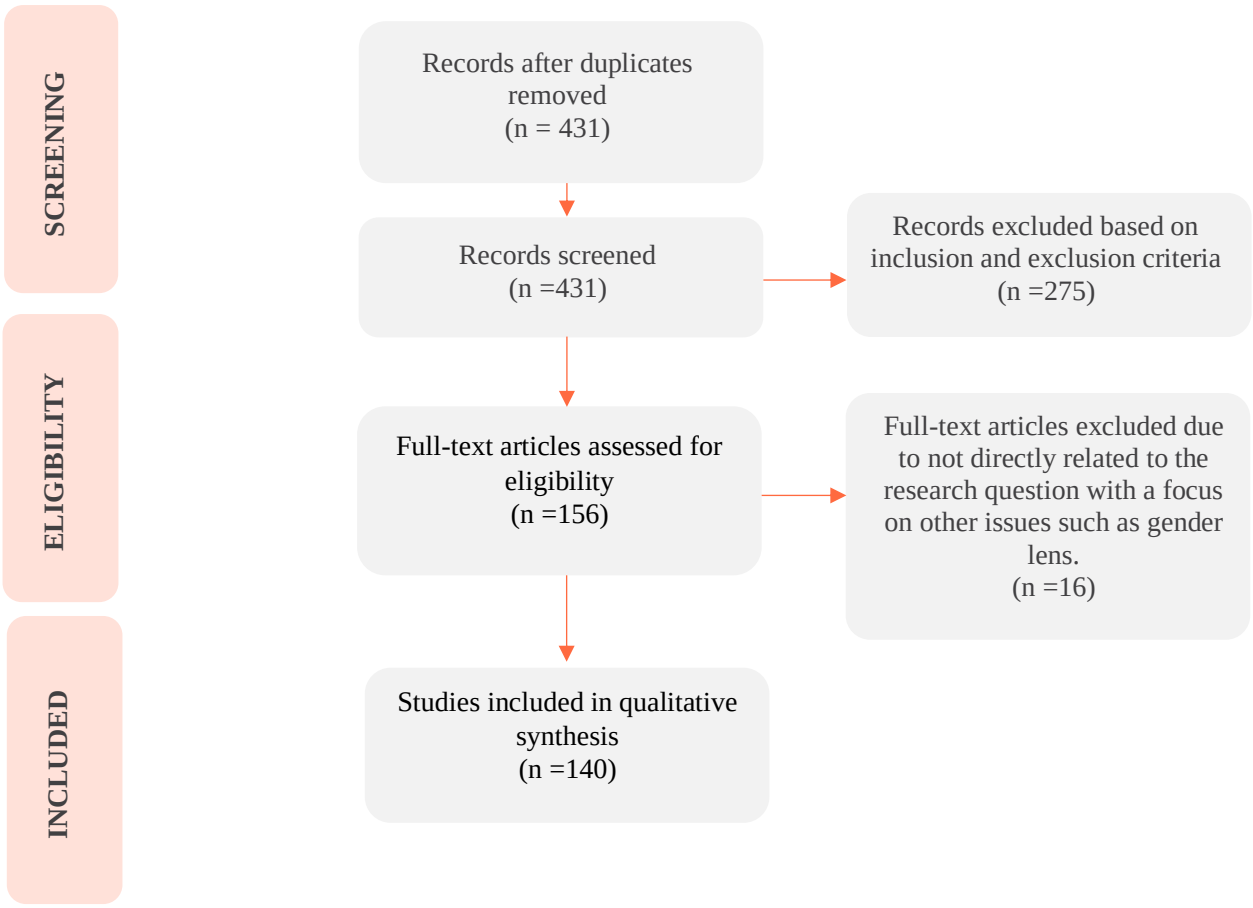
TABLE 2: Search results

Source	Articles returned	Duplicates removed	Abstract screen	Full text screen	Included
ERIC	36	4	32	12	10
Informit A+ Education	0	0	0	0	0
ProQuest Education	33	8	25	9	0
PsycINFO	31	18	13	1	0
SAGE	3	0	3	1	0
Scopus	30	5	25	18	17
Taylor & Francis	338	103	235	37	37
Web of Science	32	2	30	10	8
Google Scholar	26	0	26	26	26
Grey literature	42	0	42	42	42
Total	**571**	**140**	**431**	**156**	**140**

PRISMA Flow Diagram

The PRISMA flow diagram below provides an outline of the process for screening evidence resulting in the final number of reports used in the analysis.




SCREENING
ELIGIBILITY
INCLUDED
Records after duplicates removed
(n = 431)
Records screened
(n =431)
Records excluded based on inclusion and exclusion criteria
(n =275)
Full-text articles assessed for eligibility
(n =156)
Full-text articles excluded due to not directly related to the research question with a focus on other issues such as gender lens.
(n =16)
Studies included in qualitative synthesis
(n =140)