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Building educational pathways for tomorrows workforce: Factors influencing children's decisions regarding STEM careers?

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ABSTRACT

CONTEXT

Engineering and other STEM professionals made decisions about their career choice as early as primary school. During this time there are significant developmental biological changes in the body, with a tendency for gender differences, cultural differences and access to STEM rich environments having strong influences in final choices.

PURPOSE OR GOAL

Understanding the key factors in career decisions and in particular the timing of those decisions is critical to attracting students to STEM professions, as well as addressing key barriers to participation based on gender, socioeconomic status, and cultural differences. For tertiary educators who spend significant resources in attracting students to degree programmes through outreach programmes, this research will help better tailor and target these experiences and redress areas of historical disadvantage and develop diversity.

APPROACH OR METHODOLOGY/METHODS

This paper will examine the literature across a range of disciplines including educational, developmental biology, skill acquisition, the gifted and talented, socioeconomic advantage (in particular indigenous) and psychological research to uncover signposts and drivers of STEM interest and ultimately career choices.

ACTUAL OR ANTICIPATED OUTCOMES

The review reveals adolescence, late primary school is when STEM choices are made by students. Biological and social differences largely explain gender differences, with socioeconomic advantage also playing a large role. By mitigating these differences STEM activities can be better tailored and delivered more suitably to improve outcomes.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

This paper has shown there are multiple variables on when and why young people make career decisions about STEM. By untangling these variables that drive their decision-making processes, we can ensure that students don't inadvertently opt out of STEM early in their schooling, thus more students will have the opportunity to undertake STEM at a tertiary level. In particular examination of the innovation literature and targeting domains of student interest rather than 'things' can help with groups that are traditionally under represented, such as females, physically active youth and those with significant socioeconomic factors

KEYWORDS

STEM, career choices, education pathways, innovation.

Introduction

With recent changes in the workforce stemming from automation, critical thinking that is often associated with STEM careers is widely seen as an essential employment trait of the future, in both STEM disciplines, such as engineering, as well as many other disciplines, including the humanities, business and trades.

One of the challenges of educators, and educational administrators who must forecast future programme demands, is that by the time students arrive at tertiary level, the die is often already cast (Rozek et al., 2019). If STEM is to be a viable career choice, this must be taken into account: acquisition and orientation toward STEM skill development requires early intervention (Perna, 2005).

STEM education at the tertiary level builds upon skill sets that have begun development from a much earlier age. It is possible that students, through a variety of mechanisms, including societal drivers and expectations, can have self-selected out of developing those necessary skills early on.

Tertiary educators in increasingly invested resources into late secondary school educational activities in the hopes of attracting students into STEM-based degree and educational programmes (Sevier, 2000). However, the pool of prospective students is often comparatively small at the pre-tertiary level, relative to the total school population.

This paper investigates the reasons for this relatively low interest at the late secondary level. Through a careful examination of the literature, from the STEM, educational and business fields, we identify that students make STEM based decisions much earlier than late secondary school, and explore the reasons for this as they affect particular cohorts of students, including gifted and talented students, disadvantaged groups and the different genders. We also propose tools to redress this. The research evidence uncovered allows tertiary educators to take a longer-term view of students as future customer acquisition (Blank, 2103), by looking and supporting students almost a decade prior to their entering tertiary education. In such a case a clear evidence portfolio is required to convince university administrators who are often focused on much shorter time frames and returns on budgets.

Methodology

This paper begins with a snowball search from the Gonski (2019) Australian government report examining the many aspects to achieving educational excellence. Our premise here is to examine factors contributing to students not reaching their educational potential, as fertile ground for improving educational engagement and by association STEM educational outcomes. Major categories are explored by a snowball approach (Johnson, 2014) using peer reviewed literature. A snowball approach is a useful methodology for semi-structured exploration of the literature from a known beginning. Further, insights from our multidisciplinary research team of authors from the engineering sciences, education practitioners, gifted and talented and indigenous education were also used to drive the snowball search from our preliminary work (James, 2022) through each discipline. To implement change and develop practical recommendations based on the findings, the literature around innovation, consumer marketing (student as consumer), disruptive innovation and product-based marketing is also explored.

Results

Gonski insights

The priority outcome of the “Gonski Education Report” was to deliver a year of learning for a year of effort in schools through personalised learning (Gonski et al., 2018). The report noted the importance of this potential learning regardless of disadvantage, where areas of disadvantage were identified as those in rural and remote locations, Aboriginal and Torres Strait Islander peoples, those from non-English speaking backgrounds, and gifted and talented students. These areas of disadvantage seem to be particularly important when considering access to STEM education and can be considered in combination with age and historical gender differences (Finkel, 2017). To untangle these factors, we examined them through the view of various contributing disciplines.

Gifted and Talented

Gifted and Talented (G&T) students have been identified as some of the most marginalised in education (Gonski, 2020) where students are stratified into age year levels. Precocious students are a large component of typical STEM cohorts (Wai et al., 2010) Gross (2009) found that, when hamstrung due to inadequate subject differentiation, potentially high performing STEM students can disengage with education early on. Some become bored and leave the education system altogether, while others simply coast, not learning the necessary strategies to work problems out when the answer is not quickly apparent. Once disengaged, this cohort are not able to develop the necessary skills and learning pedagogy to undertake STEM education at the tertiary level. It is perhaps best summed up by the following analogy: we don't restrict how fast children run or how high they can jump in sport, yet we do just that when learning is constrained to year level, which leads to significant disengagement. Gross (2006), in her celebrated longitudinal study on the exceptionally gifted, found that those who did not receive acceleration were much less likely to achieve tertiary qualifications and other indicators of life satisfaction. The importance of clustering and dyads for learning as well as open ended "passion project" based learning have good evidence as being a solution that can help with the development of cognitive peers for socialisation as well as learning gains in a student centric orientation (Rodgers, 2002).

Areas of disadvantage: Opportunities for First Nations engagement

Researchers have identified that areas of psychosocial disadvantage such as isolation, cultural minority and remote areas can have an enormous impact on engagement in learning. Efforts here to remove these as functional limitations on educational pathways can improve educational pathways significantly. Anderson (2003) conducted a meta-analysis of the literature within early childhood development uncovering the important of nutrition, home life and early role models. Whilst these are not necessarily the purview of tertiary educators, awareness of these pathways can help understand and mitigate these effects. These are especially important when considering "first in family" as targets for educators hoping to build tertiary pathways. For regional and rural tertiary institutions, this can be particularly helpful as well. The literature surrounding STEM and Australia's first peoples provide particular insight for identifying and addressing many areas of disadvantage.

There are many complexities when attempting to engage First Nations students in STEM (Bonny, 2018). In Australia, these range from the impact of racism to the dispossession from existing and continued colonisation. Literature internationally has sought to address these factors by embedding First Nations' ways of knowing, being and doing into STEM learning pathways (Borden, 2016). Decolonising STEM through this approach has been shown to improve agency for First Nations students and promote ownership of STEM disciplines for Aboriginal and Torres Strait Islander students (Ball, 2015). This sense of belonging seems important for promoting STEM pathways, but efforts to date have not necessarily translated to greater participation of Aboriginal and Torres Strait Islander peoples in the STEM workforce, including when controlling for socioeconomic factors.

One issue is the lack of visible role models promoting the education pathways to up-and coming students. It is not good enough for research programs to embed Aboriginal and Torres Strait Islander ways of knowing, being and doing into programme design, when the programs themselves are not implemented by Aboriginal and Torres Strait Islander peoples through community ownership models. Unless the community has ownership of the program and can adapt the programs consistent with local drivers, then the program will lack authenticity and meaning for Aboriginal and Torres Strait Islander students.

Skill Acquisition

Learning a complex skill takes time. This is true of both physical skills (which many STEM disciplines require) and cognitive skills. The ten thousand hours principle, whereby it takes around 10,000 hours of practice to obtain mastery (Gladwell, 2008), provides a useful insight as to why it is necessary to start early to hone and develop one's skills well before entering the tertiary environment. For example, fine motor skills are frequently required in STEM environments: be it the humble screwdriver or handling pipettes, these skills require delicate touch, control and haptic feedback that develop with time and age (Piper, 2011). The sports literature highlights that general skill development is important with specialisation following later (Baker & Young, 2014), whilst Redish et al, (2008) highlights that the first step is engagement in the learning. Thus, a learning environment needs to be rich in many areas, in particular STEM experiences to spark interest, develop skills and give the student a broad base from which to specialise later. The concept of error free learning (Baker and Young, 2014) extends to the STEM domain as discovery or play based learning (Honey, 2013). Where there is an environment for experiential learning, without measures of success there is more likely to be engagement in the activity, development of skills which build a foundation for the future. (Honey, 2013)

Biological factors

Vinner (2017) highlights that adolescents, the target group for early STEM engagement, are undergoing significant biological changes at that time of their lives, and the biology of cognitive development, physical maturation and gender differences are key considerations in understanding potential barriers and opportunities for reaching this group. It is at the cusp of these developmental changes that the prerequisites for skill development are occurring, whilst students engage in learning that contributes to longer term career decisions through orientation (Holmegaard et al., 2014) and develop higher order conceptual thinking prevalent in STEM and other disciplines. Van Tuijil et al (2016) identifies that these decisions are often made in early to late primary school.

Su et al. (2015) ascertains that STEM activities are traditional solitary activities in the school environment. Su's results show that of students with aptitude in STEM activities, those that have less developed verbal cognition skills are more likely to engage in them. Those with STEM and verbal social skills are less likely to undertake STEM activities, which represents a key variable which partially explains some STEM gender differences: where females tend to develop social and verbal skills at a younger age, they may therefore be more likely to self-select out of STEM activities at a younger age. Given the importance of selecting into STEM activities at an earlier age, this is an important impediment to female uptake of STEM at the tertiary level. Su et al points out that the nature of STEM activities, being largely solitary and about things rather than people, can exacerbate this self-selection. Indeed, looking at STEM uptake in the tertiary, we can observe that STEM disciplines that are more people centric seem to have greater gender balance than those about things e.g. sports science and medicine when compared to engineering and physics (van Tuijil et al., 2016).
Consumer behaviour (using the student as consumer model) suggests that archetypes are an influence here as well (Minichiello et al., 2018). Stereotypes propagated socially may contribute to leakage out of STEM pathways by females (Makarova et al, 2016) and minority or diverse groups (Miller et al., 2020).

Pubertal hormones, a key chemical in physical and risk-taking behaviour also emerges as a key behavioural input with significant sex differences (Bjorklund et al., 2000). Activities that support archetypal role models for risk taking behaviour tend not to be those with STEM careers leading to a separation with boys in-particular as brilliant or bad (Musto, 2019) leading to gender based identity separation in boys that is progressively developed through school as their identity develops (Morris, 2012).

The prefrontal cortex is the part of the brain that joins all the separate segments together, it is not fully formed until an adult has reached around 25 years of age. This structure provides the inhibition circuits for impulsive behaviour, allows for delayed gratification (Bjorklund et al., 2000), and forges longer term thinking that plays a prominent role in behaviour moderation (Stolte et al., 2019). In younger people, the brain biology is not particularly geared towards the long-term thinker and more to the risk-taking behaviours and conforming to social norms (Bjorklund et al., 2000). Therefore, STEM may suffer from an image problem as far as our biology and social-psychology is concerned, even for those with natural talents for it.

Innovation

In the student-as-customer model, we may draw insights from innovation and start-up literature from the business discipline to identify useful strategies and techniques to improve the “sale” of STEM products to young students. Effective marketing first involves seeking to better understand potential student needs and help them transition through the education system into STEM disciplines.
In this sense the “sale” is the engagement of the student-as-customer in STEM-based activities. Key strategies in start-up communities are customer centricity, the concept of pivoting, as well as crossing the chasm to gain mainstream acceptance. Insights from product-based innovation marketing can also help. Further, we can look at the logistics of the STEM supply chain and marketing funnel

Customer Centricity

Customer centricity is critical in the start-up literature where “no business plan survives first contact with the customer” meaning the business must rapidly pivot to what works if it is to remain viable (Blank, 2013). Moore (1999) notes that a product can have all the features in the world, but if it is not what the customer wants, they will not buy it. Consequently, high technology companies, like Apple, have focused on the user experience, beauty, and ease of use of technical specifications, whilst producing their technologically sophisticated product, and this user-focused approach has allowed them to become the largest value company on the planet. When considering students as customers to whom we are hoping to “sell” STEM education, we must recognize that on their likes and interests are critical determinants (Lee et al., 2020). By making the activities the focus, rather than the technology, the delivery of STEM education becomes a customer “pull”, rather than a technology “push” (James et al., 2020). For those of us in the technical disciplines, and world leaders in technology and STEM research areas, this mindset shift has already begun, with ‘student centric learning’ and ‘students as partners’ becoming increasingly common in our vernacular. However, as stated earlier, by the time students reach tertiary education, they’ve already decided somewhat on a career path.

Pivoting

Another significant lesson from the “start-up world” is the concept of pivoting: the rapid iteration and reorientation towards what works (Reis, 2011). This is a vastly unusual approach for slow moving organisations (Mackenzie, 1998) like tertiary intuitions, and may seem at odds with the careful structured pace of academic research. Therefore, our first contact with students (as customers) being able to assess the product (STEM education programme), we must learn what works and what does not work in order to improve the educational experience.

The ATAR marketing model

Amongst the many marketing models, one that is quite popular for new product development is the ATAR model (Crawford, 2008). This stands for Awareness, Trial, Availability and Repeat. Awareness is how much the market knows about a product; Trial is the ability to try out a product; Availability is the ease of access; and Repeat is where the customer comes back for more. It might be argued that STEM has very good ATAR for a narrow band of students, which we see in our cohorts. We might also consider that ATAR is applied to university outreach programmes to suitable candidates in late years of high school. How could we use the ATAR model to improve each stage?

Under Awareness, we must consider how to maximise the appeal of STEM to more people. Hall (2011) reports that the primary drivers between STEM decisions are personal interest, parents, earning potential, and teachers. For the Trial component, the earlier we can get students to experience (and enjoy) STEM, the better. Availability is about outreach into the marketplace: how accessible are we to prospective students? Finally, Repeat suggests that a longer term and more frequent intervention than a one-off school visit or Open Day is required.

The funnel

Both marketing and supply chain literature talk about a stepwise progression to create a product, and this applies well to the educational context (Perna, 2005). For a student enrolling in university in a STEM discipline, we may consider what steps are required to get there. We may then create the steps and funnel of possibilities from an early age. The goal of the marketing funnel technique is to maximise the retention rate of the potential student (as customer). Ensuring that the funnel is as wide as possible at the beginning, by broadening the appeal of the discipline, and then maximising retention at each stage is critical to improving the outcome of more enrolments in STEM programs.

Reflections on a current intervention

The authors, through the development of STEMfit, a STEM based initiative that has had great traction through the use of sport and wearable technologies (as described in Lee et al., 2020), inadvertently stumbled upon an area of student interest in a disadvantaged community (remote, indigenous community), thereby uncovering attitudes to STEM, awareness of tertiary pathways and barriers to participation. Many of the findings in this paper resonate strongly with the experiences in the educational intervention as well as signposting why it worked and providing ideation on how to improve the efficacy of the programme. It also helped to support the development of ongoing metrics to appropriately capture where it works and where it can be improved.

Recommendations

Reflecting on the literature and experiences in our own initiatives we suggest six areas of focus for consideration for tertiary intuitions to consider for growing their STEM enrolments:

1. Who are your future students? Understand who are your future students demographically, do they have special socioeconomic needs, and how can you target these specifically?
2. Student Centricity: Engage students in STEM subjects through their interests, rather than pushing the domain onto them.
3. Role Modelling: Provide relevant (gender/race/culture/interest group) archetype/role models through vertically integrated relationships between schools and universities.
4. Recognise the power of early experiences with STEM: Engage students early, before they have formed fixed attitudes, perhaps through experiential play-based learning.
5. Marketing: Marketing is a verb and is about engaging the market with its wants and needs, it is not a dirty word beneath the notice of the academic community.
6. Barriers to participation: Identify areas of disadvantage and if they have associated barriers to participation.

Conclusions

This paper has highlighted the variables affecting young people’s career decisions about whether or not to take STEM at the tertiary level, in particular given the importance of early intervention to engage students in STEM fields, given that STEM skills are developed across several years. We identified that uptake of STEM fields may not occur at the expected rate amongst the gifted and talented, despite a natural propensity, due to the potentially disengaging impact of age-based streaming. We examined the barriers to First Nations’ uptake of STEM, including lack of role-modelling, which has implications for effective embedding of Aboriginal and Torres Strait Islander peoples’ ways of knowing, being and doing into STEM learning. The impact of the age of engagement in STEM activities was highlighted, given STEM skills require a significant amount of time to develop. We also identified biological factors that impact decisions to pursue STEM subjects, including cognitive development, social factors, risk-taking behaviour amongst others.

By untangling these variables that drive their decision-making processes, we can ensure that students don't inadvertently opt out of STEM early in their schooling, more students will have the opportunity to undertake STEM at a tertiary level. In particular targeting domains of student interest rather than 'things' can help with groups that are traditionally under represented, such as females, physically active youth and those with significant socioeconomic disadvantage.

This paper also identifies how literature from the Business discipline may help in attracting students towards STEM disciplines, under the student-as-customer model. We identified the importance of customer centricity, including pivoting the approach to meet the needs of prospective students when the current approach is not successful and using marketing techniques like ATAR and funnelling to increase the effectiveness of STEM outreach initiatives and broaden the appeal of STEM in general.

This paper has introduced the reader to a variety of literature across diverse fields. It is the beginning of the rabbit hole providing a way point and direction finder for educators to refine their thinking. Prescriptive recommendations are difficult as they are based on individual institutional demographic and geographical constraints for future students. In developing their own individualised programmes institutions need to identify their own student pathways starting as early as local primary schools together with the needs and interest of those students.

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