Secondary school students exploring careers in the space industry: A South Australian work experience program

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We describe a space industry work experience program and report on the design, implementation, and evaluation of this program, including its purposes, organisation, participants – hosts and students – and its outcomes. The program was a collaboration between the South Australian Department for Education, the South Australian Space Industry Centre, universities, and space sector enterprises. We found that the program was in-demand among students, although places at this stage are quite limited. It was well-received by participating industry partners, all of whom indicated an intention to continue their involvement in the program. Student placements were designed to be immersive, but the extent of this varied between what might be described as work-shadowing through to structured and challenging project work. The most challenging and structured placements were highly valued by students and were more effective for informing an academic stream of student participants about the range of space industry careers currently available. Implications for future work experience placements are drawn for the organisation and structure of placement programs.

Introduction

The Space Industry Work Experience (SIWE) program was established as part of the Advanced Technology Program (ATP) within the Department for Education in South Australia, in collaboration with the South Australian Space Industry Centre (SASIC). The ATP was established to encourage secondary students to consider defence industry careers that involve STEM (science, technology, engineering and mathematics) studies. The Commonwealth-funded ATP, as part of the Defence Industry STEM and Skilling Strategy (Australian Government, Department of Defence, 2019) complements a broad agenda to improve STEM teaching and learning in South Australian schools. The multi-faceted strategy (Department for Education and Child Development, 2016) comprised 12 major projects, including projects to enhance STEM teaching in primary schools (*STEM 500*), to encourage the sharing of excellent practice in STEM teaching at all year levels (*STEM Lead Learning*), and to ensure schools had the facilities necessary to support effective STEM teaching and learning (*STEM Works*).

Specifically, the SIWE program was designed to enable students to:

- Gain first-hand experience of and insights into the space industry in South Australia;
- Find out about the types of jobs that are available in the space industry;

- Gain relevant work experience and/or skills;
- Align school studies and subject selection with career aspirations.

Context

Historically, South Australia has been highly dependent on manufacturing, however a decline in those industries (white goods and car manufacturing) has prompted the state to embrace new directions for its economic development. A *Growth State Strategy* now identifies nine key sectors offering substantial growth, including: space; defence; hi-tech; food, wine and agribusiness; international education; tourism; energy and mining; health and medical industries; and creative industries (South Australian Government, 2021).

In the defence sector, South Australia has successfully attracted large industry programs such as ship and submarine manufacturing programs; with many small, medium, and large enterprises establishing offices in the state. The next phase of these projects requires the development of a growing, skilled workforce to deliver on their aspirations. Space is similarly seen as a future growth area, and although the industry is smaller, its workforce will need to be specialised and skilled to support future growth. Today, the capabilities of South Australia's space sector spans small satellite design and manufacture, including components and sensors; launch operations; mission control and ground stations; connectivity and bespoke applications; and data analysis and processing.

From a national perspective, the Australian Space Agency has a clear objective to grow Australia's space industry; tripling the space sector's contribution to GDP to AUD$12 billion per year, and creating an additional 20,000 jobs by 2030. South Australia, with its vibrant space ecosystem, is already playing an important role in achieving this goal and fuelling a thriving and enduring South Australian space sector, supporting Australia's national space strategy, while capitalising on the commercial opportunities of the merging space sector.

An entrepreneurial hub has been established at Lot Fourteen, comprising the Space Innovation Precinct which is home to the Australian Space Agency, SmartSat Cooperative Research Centre, key space organisations and the future Mission Control Centre and Space Discovery Centres (Lot Fourteen, 2021). Many of the industry partners who participated in this project are based at Lot Fourteen.

Demand for STEM skills

The space sector requires individuals with highly developed STEM skills in engineering, software development, communications, and data analysis. However, the oft-asserted claims that STEM skills contribute to productivity and that STEM-skilled graduates are in short supply have been contested (Stevenson, 2014). Numerous reports in Australia and internationally have estimated that STEM skills are a substantial driver of economic growth and face skills shortages (Australian Industry Group, 2015; Centre for International Economics, 2016; Office of the Chief Scientist, 2016).

The projected demand for graduates with STEM skills is complex. Graduates' STEM skills are underutilised, partly because of low levels of innovation in Australian industry (Productivity Commission, 2016), although this is not true of the space sector. Of the occupations projected to experience the greatest growth in demand to 2024, STEM occupations – specifically in engineering and ICT – account for six of the top 20, all of which have expected demand growth of more than 20% on current employment levels (Australian Government, 2020; Department of Education Skills and Employment, 2019). While projected demand for science graduates is modest (3% to 15% growth), defence industries (to which the space sector is closely aligned) have continued to recruit despite the COVID pandemic (Levick, 2020). Thus, there appears to be an emerging shortage of STEM-skilled workers in Australia, especially for several fields of engineering and for ICT professionals, both of which are central to growth in the space sector.

The potential for careers in the space sector

Young people face challenges as they seek to enter the workforce. They experience significantly higher levels of unemployment and underemployment than do older individuals. This appears to be exacerbated in established industries, but new industries without older incumbents against whom to compete may offer new opportunities to younger workforce entrants. The Australian Space Agency (2019) has set a goal to create 20,000 new jobs by 2030. These jobs will only materialise if the prospective workforce is aware of the opportunities and has the knowledge, skills, and dispositions required for these roles. Roles available include the design and development of satellites and launch vehicles and remote imaging, communications, and data acquisition and analysis. Knowledge of these opportunities requires students to develop an aspiration to work in the sector, be aware of the opportunities, and pursue the education and training pathways that will enable them to curate their careers accordingly.

Influences on students' career decision-making

Theoretical models of career selection

Holland (1985) proposed a relatively deterministic model of career choice, in which he argued that certain personal interest characteristics were related to vocational preferences and that students, like those in this study with very high STEM subject enrolments, are predicted to pursue STEM-related careers. However, Holland's model is not useful for study as there is little opportunity to test a counter-case. By comparison, Gottfredson's (2002) theory of 'circumscription, compromise, and self-creation' has some value in analysing the career decision-making of the students in this study. Most students had developed an interest in STEM from a young age and they appear to be in the self-creation phase in which they are exploiting opportunities to develop and refine their career intentions. The chaos theory of careers (CTC) (Bright & Pryor, 2011; Pryor & Bright, 2003, 2014) postulates that students' career intentions are influenced by numerous unpredictable actors and events and their interactions. It is of interest largely because the SIWE program is designed to inject opportunities that counter the "unpredictable" nature of career influences.

Influences on students' career aspirations and intentions

In addition to internal factors, for instance self-efficacy and past achievement, parents, peers, teachers, and other actors all influence, to varying extents, students' career aspirations and intentions. Lloyd, Gore, Holmes, Smith and Fray (2018) showed that gender was a strong influence on students' career intentions, with female students less likely than males to pursue STEM careers, with the exception of the life sciences. Jeffries (2019) showed that a complex relationship existed among internal factors that influenced subject choice and career interests. For example, gender, socioeconomic status (SES), and immigrant status all influenced subject choice, with young women displaying lower levels of interest than males for all STEM subjects except biology, and immigrant-background students showing higher levels of interest than did non-immigrant students. However, the effects of these characteristics (gender and immigrant status) were mediated by students' interest in and perceived value of STEM subjects. Low-SES students were found to be less likely to pursue STEM subjects, but that influence was mediated by students' attitudes towards science.

Jeffries (2019) found that parental and peer influences were variable between students and in its direction. In some cases, parents had minimal influence on career aspirations, while in others the influence was very strong and, in most cases, supportive, but quite negative in others. Discouragement was related to parents' experiences of the gendered nature of STEM occupations. Jeffries (2019) also found that, while students did discuss their career aspirations with peers, peer influences were uniformly quite weak. Lloyd et al. (2018) found that parents were influential and that mothers or female carers were less keen than fathers or male carers for their children, especially girls, to pursue STEM careers.

Industry partnerships, work exposure and career information

Partnerships between industry and education providers create a pathway for students to be engaged in relevant industries, and enable them to conceive possible careers in those industries. One important aspect of these partnerships involves students gaining exposure to work through work experience, work-shadowing, workplace visits, and structured workplace learning. Additionally students can gain experience of work through paid part-time work and experience transition success because of this exposure (Patton, 2008; Smith & Patton, 2013). In this paper, while we acknowledge the importance of paid part-time work by students in facilitating their transitions from school, we do not consider it here. Work exposure through schools depends on the stream students are taking. Those in general or academic streams are more likely to undertake work experience, work shadowing or workplace visits, while students in vocational programs are likely to undertake structured workplace learning (Gemici & Curtis, 2012).

Relationships between schools and industry are valuable, but highly varied. They may be quite informal and involve minimal contact between schools and enterprises, and this is a common feature of work experience as it is frequently arranged by students and subsequently endorsed by the school to ensure that student safety protocols are in place (Torii, 2018). Buzzeo and Cifci (2017, p.6) reached the qualified conclusion that work experience is "potentially effective". Their qualified support was based on the limited evidence base for it and variability in the way in which work experience is organised. If student led, it is less effective than if schools take an active brokerage role in which they develop stronger relationships with enterprises. Work experience does have the potential to develop employability skills, e.g. communication and teamwork skills (Buzzeo & Cifci, 2017; Torii, 2018), but only if students are prepared for the placement and undertake "purposeful and challenging work" (Buzzeo & Cifci, 2017, p.3) as part of the placement. Torii (2018) suggested that teachers lack the time to establish industry partnerships but that if the work experience is facilitated by brokers with knowledge of the industry and who can undertake the administration, for example, of child safety protocols, the programs are more likely to be beneficial for students. Buzzeo and Cifci (2017) found that work shadowing and workplace visits were less effective than work experience.

Structured workplace learning was found to be more beneficial than work experience for students undertaking vocational studies as part of their senior secondary programs (Gemici & Curtis, 2012). These benefits included a greater likelihood of completing their studies and of undertaking post-school education and training or paid work. The key features of structured work experience are that it is purposeful – being related to the studies that students undertake; it is planned – as the school and workplace must negotiate what the student will do; and it is assessed – as the outcomes are related to the requirements of the vocational qualification that is being undertaken. Woodroffe, Kilpatrick, Williams and Jago (2017) found that partnerships between schools, vocational and higher education providers and enterprises can generate benefits for regional and rural teachers, who develop career-related information and networks, and for students, enabling them to contemplate a wider range of pathways than they might otherwise consider.

In reflecting on the influence of various forms of work exposure, it is useful to consider Lave and Wenger's (1991) notion of 'legitimate peripheral participation'. In inducting novices into work environments, the novices' initial interactions in the work context are acknowledged to be peripheral as they cannot perform tasks that are central to the occupation, since they lack the required knowledge and skill, and because other constraints operate. For example, McGrath and Murphy (2016) reported that accounting work experience students were not able to sit in on consultations with clients as those meetings were confidential. It was a challenge for mentors to find tasks that were meaningful, i.e. authentic or legitimate and reflective of the 'real' work of accountants, rather than simply photocopying and making coffee.

Organisation of the Space Industry Work Experience program

Engaging hosts

The ATP team was initially approached by the Defence SA South Australian Space Industry Centre (SASIC) Chief Executive, as they had been inundated with requests for space related work experience after the announcement in 2017 that the Australian Space Agency would be located in Adelaide at Lot Fourteen. Potential hosts were approached by Director, Space at SASIC with ATP, and asked if they would be able to provide a 2-5 day placement for students at a time of the year suitable to their schedules. It was suggested that placements would involve a minimum of two students, but this was not mandated and the development of the placement program was left open to the hosts. It was made clear that ATP would organise the student applications and conduct initial screening, with the hosts able to choose from a list of students or offer their projects through ATP to students who fulfilled their requirements (such as year level, currently undertaking physics or senior mathematics, or an interest in coding/programming).

Hosts that eventually offered placements for students included; the University of Adelaide (Department of Engineering, Computer and Mathematical Sciences (ECMS) and Institute for Photonics and Advanced Sensing (IPAS)); University of South Australia (Institute for Telecommunications Research (ITR)); Flinders University - Tonsley (College of Science and Engineering); and companies Myriota, Inovor Technologies, Neumann Space, Silentium Defence, and Nova Systems. Projects included space mining, satellite data, communication and propulsion, quantum mechanics, designing a Mars rover, space situational awareness, robotic capabilities, and processing NASA images.

Student applications and selection

The pilot Space Industry Work Experience program was advertised on the SASIC website, the South Australian Department for Education website, and ATP networks for the month of July 2019. Students had to complete a rigorous online application which included:

- A 5-hour certificate from an online workplace learning course (Department for Education et al., 2019), endorsed for all workplace learning undertaken by school students in South Australia;
- A 300-word statement on why they wanted to participate in the program;
- A teacher reference (up to 250 words);
- School endorsement signed by the principal;
- Parental signed endorsement;
- Industry aligned interests and current subjects studied;
- A signed media release including external promotion of material developed within the work experience.

Of the 88 applications received (32% female, 68% male), 44 were from South Australian schools (8% rural, 92% metropolitan; 58% government and 42% non-government schools). These applications were then shortlisted by SASIC and ATP team members with the highest weighting given to the student written 300-word statement demonstrating students' interest in space, their understanding of how the work experience could benefit their future careers and pathways, and participation in school and extracurricular activities (robotics and other STEM team events/ competitions, involvement in space camps and other STEM activities). Of the 31 shortlisted students, 42% were female, 58% were male, from 23 schools including 13% rural, 87% metropolitan; 45% non-government and 55% government schools.

The students were individually 'matched' to the host by the ATP team based on host requirements, student interests and current STEM subject enrolments. As the space sector in Australia currently has many small to medium enterprises (SMEs) that did not have the capacity for a 5 day placement, a 'supply chain' situation was trialled for Myriota (2 days - data sensors linked to satellites), Inovor (1.5 days - build and program satellites) and Neumann Space (1.5 days - ion thruster engine which is planned to be utilised by satellites).

Methods

Each of the hosts placement sites was asked to provide contact details for a 'host mentor' who students could contact before and during the placement and all SIWE students had a mobile phone number and email details for the ATP Manager and assured they were a 'priority' during the placement, with the ATP manager responsive to answer any phone calls (including during meetings if needed). The host risk assessments were completed by the ATP team visiting the SIWE placement site in person before the placements and students were met and introduced to their hosts by the ATP team on pre-placement visits or on the first placement day. Each host site developed their own program for the placement and the only requirement was that students have a 'final presentation' which could be multimodal (e.g. a written report and a video presentation). The ATP team also helped organise final student presentations and the award of certificates if the hosts wanted to finalise the placements in this manner. A wide range of people attended the final presentations for the University of Adelaide ECMS group and Myriota-Inovor and Neumann Space groups, including two state government ministers, professors, other academics, teachers, parents and industry/research personnel.

Placements were offered to 27 students (40% female) during November and December 2019 and January 2020, comprising 25 shortlisted and 2 from the remaining application pool (as these placements required senior students currently studying physics or chemistry and mathematics and there were more positions than shortlisted students). The remaining 6 shortlisted students were originally planned to be placed during the 2020 April, July and September school holidays but due to COVID-19 limitations, placements will be prioritised in the SIWE 2020-2021 program for these six students.

Data collection

In order to gather information on students' and hosts' perceptions of the program, students completed an online survey both before and after the placement, and interviews were conducted with representatives of the host organisations and with students after the conclusion of the program.

Students were asked to complete pre- and post-placement surveys (Appendix 2), for which all 27 students completed the pre-placement survey and 25 the post-placement survey. The pre-placement survey sought information on students' future study and career intentions, their approaches to learning (e.g. "I try to connect what I am learning to things I have learned before"), and their interest in STEM subjects. The post-placement survey asked about their reasons for wanting to participate in the program, their perceptions of the organisation of the program (e.g. "The work placement was well organised"), feedback they had received from mentors (e.g. "I received helpful feedback from my workplace mentor(s) during the work placement"), information about study requirements and career opportunities, and skills they had developed through the placement. In addition, students were invited to add personal reflections on their experience of the placement.

Email invitations to participate in interviews were sent to the 27 students who participated in the program. Fourteen students responded to the invitation and agreed to participate in a telephone interview. The students who did not participate had provided their school email addresses which were no longer functional, as the students had left school, so they could not be contacted. An interview protocol was attached to the email. The 14 student interviews were completed during late January 2020. Interviews were expected to take about 15 minutes, on average taking 17.6 minutes. Students were asked about their interest in space and how it developed, their role in the placement, the knowledge and skills they gained from the placement, and whether the placement had altered their aspirations for a career in the space sector. The interviews were conversational and students were encouraged to raise issues other than those that were alluded to in the questions.

Interviews were recorded and notes were taken during the interviews. These notes were reviewed following the interviews to ensure the accuracy of the notes and to fill in any gaps. The notes were analysed by seeking themes that emerged consistently between students and by comparing records of interviews for differences between them. Most of the themes that emerged related to the interview protocol structure.

Findings

Results from the student surveys (pre- and post-placement) and interviews are consolidated in the findings presented below. Results of the host interviews are discussed separately. Of the 31 short-listed students, 27 participated in the placements that occurred between November 2019 and January 2020.

Student perspectives

Students heard about the SIWE opportunity from a variety of sources – most from teachers at school, but some through other networks, e.g. having attended a National Youth Science Forum (NYSF) camp.

Interest in STEM and space

In the pre-placement survey, students were asked about their interest in learning about STEM. The questions and a summary of students' responses are shown in Table 1. It is apparent that these students had very high interest in STEM, as indicated by the high mean scores on all items. This is unsurprising as this had been a criterion for selection into the SIWE program.

Table 1: Summary of students' pre-placement interest in STEM responses

Interest in STEM items	Almost never	Some-times	Often	Almost always	Mean
I talk about science, mathematics and technology outside of classes	0	3	12	10	3.28
I look forward to science, mathematics and technology classes	0	2	10	13	3.44
I enjoy learning new things about science, mathematics and technology	0	1	8	16	3.60
I want to understand what I learn in science, mathematics and technology classes	0	0	3	22	3.88
I feel good when I am in science, mathematics and technology classes	0	0	11	14	3.56
I often feel frustrated in science, mathematics and technology classes [R]	9	14	2	0	3.28
I think that science, mathematics and technology classes are boring [R]	18	7	0	0	3.72

Note: [R] denotes a reversed item. Means are based on recodes to reflect a positive sentiment.

In the post-placement interviews, we sought to determine the trigger for students' interests. Most had become interested in space from a young age, often by the time they were eight years-old. Their interests were triggered by reading books about space, by watching videos about it or as a result of lessons at school. Some students had a specific interest in space: "I remember reading a book about the solar system in Year 1 at school. Later I watched a video presented by Brian Cox." [S1, f (Student 1, female)]

Students were not merely interested in space or STEM; they had become proactive in pursuing their involvement in space and STEM activities. Several students had attended the SA Space School camp or the NYSF camp. One had previously applied to participate in the NASA Summer School.

Another student reported that a parent had been a member of an astronomical society and that 'star-gazing' had been a family activity [S3, m]. Other students described interest in STEM more generally, e.g. "having an interest in robotics" or undertaking a "school project on the colonisation of Mars" [S5, m].

Students' interest in STEM was also indicated by their senior secondary subject enrolments. Many who are now in Year 12 or have just completed it are doing (or did) Specialist Mathematics, Mathematical Methods, Physics, and Chemistry. Interestingly, one of the students who had completed the two high level mathematics subjects (Specialist Mathematics and Mathematical Methods) also enrolled in Drama and Music.

Students' activities during the placement

Based on reports from students and from their industry hosts (see below), it is apparent that the activities students undertook were quite varied. Most activities were very hands-on and involved combinations of literature research, laboratory activities, and the production of a report and presentation. In other placements, the activities are best described as work shadowing in which students attended lectures and observed activities being undertaken by others, e.g. staff or research degree candidates.

Examples of activities gleaned from interviews with both students and hosts and observations of student presentations, included planning for deep-space communications constrained by weak and intermittent signals; mining asteroids, which involved comparing alternative methods of solvent extraction of cobalt and nickel in a laboratory; and designing a Mars vehicle to accommodate four scientists, collect samples and data, and to communicate with a base station.

Within activities, the level of challenge varied. Most students reported that the placements were very challenging, but students were almost unanimous that the level of challenge was worthwhile. Indeed, the most challenging placements were the ones most valued by students.

Knowledge and skills gained through the placements

The students' reflections on the placements suggest that the placements varied. Some students were located in a university only, some were in a university and visited an industry partner of the university, while others were located in a space-related enterprise. Almost all found the placement very beneficial. Most were able to talk about the discipline-specific knowledge they had gained, e.g. learned about the chemistry of solvent extraction or about how satellite communication works. Most spoke about more general knowledge benefits, e.g. what doing research entails, teamwork skills and communication and presentation skills. Most spoke about the benefits of group work – communication and teamwork. The survey results were consistent with students' interview comments – with 23 of the 25 respondents indicating they had developed both teamwork and problem-solving skills, and 19 also nominated analytical skills as an outcome.

The students who were located at universities and who visited enterprises as part of the placement valued those visits highly. Some students wanted more exposure to companies like them.

Other outcomes arising from the placements

Some students maintained contact with others in their group, but some had no further contact. One group, who was placed at one of the universities, set up a *Messenger* forum and have remained in contact sharing resources and opportunities, e.g. connecting at the SASIC 9th Space Forum that was held in February and helping promote the 2020-2021 SIWE program. The networking that students did as a consequence of the placement was valued. This is consistent with findings reported by Clayfield, Samardzic and Roach (2017).

Study and career intentions

Students were asked about their study intentions and were offered four options in the pre-placement survey, namely: leave school as soon as possible, undertake a VET course, seek an apprenticeship, or study for a bachelor degree. Students were unanimous that they would complete Year 12 then undertake a bachelor degree program.

All students had a strong interest in careers in STEM and space, as those interests were criteria used in the competitive selection process. In the pre-placement survey, students were asked about the job they expected to have at age 30. Only three students were unsure; many (12) nominated an engineering job, e.g. aerospace engineer; three wanted to do "something heavily mathematical"; three nominated programming or software engineering; while two wanted to work in physics or astrophysics. In short, their career intentions prior to the placement were very strongly STEM-oriented.

Some students reported having general interests in STEM, e.g. "I have always been interested in mathematics," or in engineering, e.g. "I had planned on doing a Bachelor of Mathematical Science" or "I intended to do mechanical engineering". Others had been less sure about their careers, e.g. "I am tossing up between science and engineering" or between "medicine and engineering." Most students indicated that they had discussed study and career options with their mentors and with peers during the placement.

For most students, the placement confirmed their career and study plans or helped them to refine their plans.

> I got to learn skills and ideas … which gave me important insights at how much you can do with robots and programming and also how my studies at school (physics, maths) are important in robotics [S7, f]
> Participating in the placement did expose me to the wide array of careers that are required to support a space industry. [S24, m]

None were dissuaded from the career and study plans they had formed, although one student reported changing a planned subject enrolments as a consequence of the placement:

> I am now undertaking Specialist Mathematics, Physics, Chemistry, and University Extension Studies in mathematics at Flinders University. I did this to get ahead in my mathematics education. [S15, m]

Student impressions of the SIWE placement

In the post-placement survey students were asked about aspects of the placement. These items and students' responses to them are shown in Table 2. On most items, e.g. feedback from mentors, students' ratings were very high. However, their understanding of what was expected of them and how the placement would be assessed are areas that warrant attention. In part, the lack of clear expectations is possibly related to the need to alter the intended program, as one of the hosts reported (see below). They had unrealistically high expectations of students' knowledge of coding and, in their words, had been required "to pivot at short notice" to accommodate the capabilities of the students.

Table 2: Summary of students' post-placement survey perceptions of their placements

Placement perception item	SD	D	N	A	SA	Mean
The work placement was well organised	0	1	4	9	10	4.17
I was well-prepared for the placement	0	0	4	17	4	4.00
I knew in advance what would be expected of me during the work placement	1	6	10	5	3	3.12
I knew in advance how the work placement would be assessed	1	6	10	5	3	3.12
I received helpful feedback from my workplace mentor(s) during the work placement	0	0	2	10	13	4.44
I received helpful feedback on the report/ present-ation/ video I prepared during the work placement	0	2	7	13	2	3.63
I received advice from my workplace mentor about space-related study and career pathways	0	2	2	11	10	4.16

Note: SD=Strongly disagree; D=Disagree; N=Neutral; A=Agree; SA=Strongly agree.

In order to gauge students' overall impressions of the placement, they were asked during the interview if they would recommend the SIWE to fellow students at school. All students but one indicated they would strongly recommend the program "absolutely" or "definitely" – with few qualifications. Two students, who had completed Year 12, said they would return to their schools to talk to other students about the program. Two added the qualification that it is a valuable experience "if you are interested" [S9, m] and that you must "be prepared to work hard and be challenged, but it is worth it" [S14, m].

One response from a student reflects several of the themes broached by her colleagues. She was appreciative of the opportunity, had her study and career intentions affirmed while new options were revealed, and developed new knowledge and skills.

> This was a really fantastic opportunity that I am so thankful to have been a part of. I feel much more comfortable with studying my chosen degree in engineering at Adelaide University this year, and have met so many wonderful people, both students and Adelaide staff I'm sure I'll get to see around campus! It was very well organised and I loved the opportunities we had to visit space companies, as well as learn more about publishing in academia, which I had no idea about before this work experience placement. Overall it was a really invaluable experience that taught me a lot about current trends in space technologies, and has opened my eyes to all the possible careers the space industry in SA has to offer! [S20, f]

While most students were very happy with the program as they experienced it, a few suggestions for improvements were made. These included spending "more time in the companies" and that the program should be longer. A student who had sat in on lectures for honours and postgraduate students indicated that it was "way above my level" suggesting that the program does need to be targeted to the level of these high-achieving senior secondary students.

Host perspectives

Representatives from 11 host organisations were interviewed to find out why they chose to be involved, the burden placed on them, and their expectations and experiences of the students.

Reasons for participation

Two sets of reasons emerge: For most, their involvement can be represented as altruistic – wanting to give back to the community and wanting to promote the space industry specifically, and STEM more broadly. For example, a desire to show that a range of careers are available was by far the majority view. This was illustrated by a comment from one of the space sector enterprises. That organisation had hosted teachers in order to show what was being done in the sector. They found that teachers perceived the space industry as being about “sending astronauts into space” [M9 (Mentor 9)]. They were determined to correct this misconception. The altruism was most evident in the space companies, and in one of the university responses. An instrumental purpose was also apparent – a desire to attract students to the institutions and to “show what we do” [M11].

When asked what benefits the host organisations expected to gain from their involvement, few hosts expected to derive any direct benefits. Some wanted to promote the industry or STEM. An interesting reason was that it benefitted their own staff, e.g. by “boosting staff morale” [M2]. This view is consistent with the altruistic reasons for involvement.

Expectations and experience of the student participants

Expectations of the program were that it would provide the organisations with highly motivated, knowledgeable and thoughtful students and that all the administration of the program would be managed by the Department. These expectations were borne out, as the organisation of the program and the selection of students was praised and the students created very favourable impressions on the hosts.

Overwhelmingly, hosts were very impressed with the calibre of the students who were selected. One host commented that the students did not seem to be driven by an interest in space and one commented that one student was there to ‘tick a few boxes’ rather than out of a genuine interest in STEM or space. However, this was very much a minority view. Almost all students created an extremely favourable impression on the hosts. One commented that they hoped those students would later return as employees. Another commented specifically on one student from a regional school. That student created a very favourable impression on the host organisation. The representative noted that the students demonstrated a level of commitment and maturity they would have expected of university graduates. This particular host raised an awareness of equity of access for rural and remote students. This respondent indicated they would be willing to run a video conference session to “reach out to students in regional and remote locations because it is hard for them to get these opportunities” [M9].

Most organisations expected students to have a very solid grounding in STEM, including programming. One host organisation had prepared a project that required substantial coding skills but when they found that the students did not have the level of coding knowledge, they pivoted and switched to a second project they had also prepared. They expected students to be motivated, interested and engaged. Others were not sure what to expect. Given that the hosts have now experienced the first wave of students, they may have more refined expectations, which are likely to be high, given the high calibre of students who have been selected to date.

The planning and hosting burden

Hosts were asked about the workload involved in preparing for the student placements. One reported "minimal" workload in preparation; another described it as "considerable" but did not quantify it, while several others indicated it varied from 12 hours to about 10 person-days.

Comparing the preparation burden reported by hosts and the reflections of the students, it is clear that the organisations that devoted most time to preparation were those that were most valued by the students. The sites that had the greatest impact on students were those that generated challenging and authentic experiences. These were projects that required students to work in teams and on tasks that required a range of skills, including the need to develop new knowledge where their current knowledge was lacking. In contrast to the authentic task approach, some hosts seemed to have implemented a form of work shadowing – i.e. follow us around and watch what we do. This was much less successful. An implication of these findings is that future hosts need to be made aware that there is a workload in preparation and hosting and that the value of the experience is directly related to that work and to the challenge they provide for these very able students.

The 'supply chain model' for Myriota, Inovor and Neumann Space was highly successful. This model was adopted because each company was small and did not have the capacity to host groups of students alone, so, being co-located at Lot Fourteen, they operated as a collective enterprise. All three companies thought it both helped with capacity and exposing the students to a wider variety of space careers and pathways. Therefore this model will be suggested to all future space industry SMEs that wish to be involved in the future, but who may be worried about their capacity as a 'start-up' or small company.

Perceived benefits for students

Responses from the companies were very insightful. While all referred to students' development of communication, teamwork and presentation skills, the companies also talked about students' growing awareness of the need to develop their STEM skills and knowledge, Some were quite specific about the need to develop a very solid basis in mathematics (calculus, trigonometry), chemistry and physics, and programming. Hosts also referred to students' growing awareness of career opportunities in space and engineering.

Host impressions of the SIWE program

None of the hosts wanted to see changes in the structure or organisation of the program. All were very pleased with it and with the support that the program organisers had provided. This was raised in responses to several of the questions, e.g., the expectations of the program and student selection.

Discussion and implications

In reflecting on the responses from hosts and students, we were struck by a pattern of reasons for involvement, expectations of the program and student satisfaction. Those hosts who were altruistic, who had high but flexible expectations of students, and who deliberately invested time and effort in preparation for the program were those of whom students had the most favourable impressions. In those cases, the students worked hard, often overcoming deficits in their knowledge, in order to achieve the goals of the placement projects. The hosts who had instrumental motivations for their involvement tended to invest less in preparation and experienced lower levels of student satisfaction.

The SIWE can be considered as a successful venture in generating school, higher education and industry partnerships in the space sector. The consensus of the student participants was that it was challenging and rewarding. All host organisations indicated that they intended to continue their involvement.

While all students were pleased to have participated, some variation in the organisation of the placements was apparent. Most students found that they were engaging and challenging. A characteristic of those that made greater demands on participants included authentic tasks, e.g. mineral extraction or communications. This is consistent with the Lave and Wenger (1991, pp. 29-36) notion of "legitimate peripheral participation." The students are certainly not apprentices in any conventional understanding of that term, but their experiences in most placements had important elements of legitimate peripheral participation. First, their experience was situated in a workplace context in which they interacted with experienced workers. For example, the students reported having conversations with recent graduates or postgraduate students who told the SIWE students about the work they were doing and about the pathways they had followed into their work. Second, the tasks they undertook were authentic assignments that were or could have been undertaken by their mentors. Third, the students were not mere spectators but were purposefully involved in the tasks. Not all students had this level of involvement; some situations involved work shadowing in which students observed others undertaking tasks or sat in on meetings or lectures.

A characteristic of structured workplace learning, that sets it apart from typical work experience placements, is the requirement for the work to be assessed (Gemici & Curtis, 2012). In the SIWE, while no formal assessment that contributed to a subject grade was required, all students gave presentations to their hosts and to other interested individuals. Thus, while not high-stakes activities, pressure to perform was apparent. All student presentations were attended by two of the authors. The presentations revealed that students had gained substantial content knowledge. Moreover, their group presentations, their responses to the post-placement survey, and the comments they made during interviews indicated that they had developed communication and teamwork skills. This was confirmed by their mentors. The teamwork skills were impressive given that the students, coming from a variety of schools, had not met prior to their placements. In addition, several of these groups subsequently established social media groups and continued to share information, indicating that they had formed cohesive groups around their common interest in space and STEM.

This study has limited generalisability, although it does have important implications for high-ability students with well-developed career intentions. The students who were selected for this program were very capable and highly motivated. Indeed, evidence of their motivation was a selection criterion. It is perhaps a consequence of this selectivity that enabled the students to rise to the challenges presented to them. It seems likely that the work experiences facilitated through this program may not be suitable for a broad cross section of students who are in the early stages of exploring career possibilities. The participants in the SIWE program all had long-standing interests in STEM and in space and were at the advanced self-creation stage of Gottfredson's (2002) career decision-making process. For these students, the challenges of the placements have been shown to be effective (Buzzeo & Cifci, 2017). Students who are at a much earlier stage, e.g. circumscription, where their aspirations are subject to change, would likely find this experience too demanding. There are, however, useful lessons for organisations that host work experience students. If the students are motivated and highly capable, authentic and challenging tasks are appropriate and desirable for them. Creating such experiences can be resource-intensive, and potential hosts should be made aware of this burden. The experience of hosting students can be a valuable learning experience for the mentors in host enterprises.

Discussion of the SIWE program with large consortiums such as the SmartSat CRC (based in South Australia with national nodes) have revealed an interest in expanding the program to improve access for rural and national students. ATP has also received requests from interstate students on whether they could participate in future programs. One way currently being investigated for adding to the 2020-2021 face to face SIWE program is via virtual work experience, based on the virtual work experience model successfully piloted in 2019 by the CSIRO (CSIRO, 2020) which also allows work experience to proceed despite Covid-19, geographical or other restrictions.

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We thank the students who participated in the SIWE, who responded to the surveys and who volunteered to participate in the telephone interviews. We are especially grateful to the host organisations – universities and space sector enterprises – who allocated considerable time and resources in preparing the student experiences and in hosting the students. All participating hosts willingly took part in telephone interviews.

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Appendix 1: Interview protocols

Interview protocol for students

Background
Students have taken part in work experience related to the space industry. The work experience program is designed to ensure students

- Gain first-hand experience of and insight into the space industry in South Australia
- Find out about the types of jobs that are available in the space industry
- Gain relevant work experience and/or skills
- Align school studies and subject selection with career aspirations

In order to evaluate the effectiveness of the program it is necessary to collect stakeholders' perspectives on the work experience placements and this protocol is the basis for discovering students' opinions through interviews.

Conduct of interviews
I will conduct the interviews by telephone. The interviews will be semi-structured in that the conversations will be framed using a set of opening questions (see below) designed to elicit information relevant to students' experiences, but participants are encouraged to raise other issues. The interviews should take no more than 10-15 minutes.

Confidentiality and anonymity
I plan to record the interviews. Recordings will only be made with the permission of interviewees. The recordings will not be transcribed. They will be retained so that I can analyse the content of the interviews and will be deleted when the analyses have been completed.

The content of the conversations will be confidential. Comments made by participants may be included in a report that will be generated, but comments will not be attributed to individuals or to their schools. The report will be provided to the Advanced Technology Program of the Department for Education who will decide on any further the distribution of the report.

While comments will not be attributed to participants, complete anonymity cannot be guaranteed as the number of participants involved is limited and those who read the report may attempt to infer which participants may have made particular comments.

Interviews

Introduction
I am David Curtis and I want to ask you about your perceptions of the Space Industry Work Experience program. The interview should take no more than 10-15 minutes.

The content of the interview will be confidential – it will not be shared. However, some of your comments will be used in a report, but they will not be attributed to you or to your school.

I will ask a series of questions that are designed to open a conversation about key aspects of the Space Industry Work Experience initiative. I hope you will raise any other issues that you think are relevant. You are free to decline to respond to any questions that you do not wish to answer.

I would like to audio-record the interview. No-one else will hear the recording, it will not be transcribed, and the recording will be deleted once analyses of interviews is complete. Is that OK with you?

Opening questions
The following questions will be used to open a conversation with students.

- How did you find out about the Space Industry Work Experience opportunity?
- What led you to apply for it, e.g. your own interests, or support from parents, teachers or peers?
- When did your interest in Space start and how?
- What was your role in the placement/project?
- Have you remained in contact with other team members?
- What did you gain from the experience?
  - New knowledge?
  - New skills related to the space industry?
  - Has the experience changed your communication, teamwork or problem-solving skills?
- Has the experience changed your career aspirations, perhaps pointing you in a different direction or confirming your intentions?
  - Did your mentors or other students discuss with you career opportunities or pathways to careers?
  - What further study intentions do you have?
  - Have your study intentions changed as a result of the placement?

Thank you for the time you have committed to the interview and for your views about the Space Industry Work Experience initiative.

Interview protocol for mentors

Background
Students have taken part in work experience related to the space industry and have been hosted by space industry organisations in South Australia. The work experience program is designed to ensure students

- Gain first-hand experience of and insight into the space industry in South Australia
- Find out about the types of jobs that are available in the space industry
- Gain relevant work experience and/or skills
- Align school studies and subject selection with career aspirations

In order to evaluate the effectiveness of the program it is necessary to collect stakeholders' perspectives on the work experience placements and this protocol is the basis for discovering, through brief interviews, the opinions of mentors in the organisations that have hosted students.

The evaluation
The evaluation will be conducted by Associate Professor David Curtis. David is an adjunct academic in the College of Education Psychology and Social work at Flinders University and is director of Transforming Education, a South Australian educational consultancy service.

Conduct of interviews
David will conduct the interviews by telephone. The interviews will be semi-structured in that the conversations will be framed using a set of opening questions (see below) designed to elicit information relevant to mentors' experiences, but participants are encouraged to raise other issues. The interviews should take no more than 10-15 minutes.

Confidentiality and anonymity
David plans to record the interviews. Recordings will only be made with the permission of interviewees. The recordings will not be transcribed. They will be retained so that he can analyse the content of the interviews and will be deleted when the analyses have been completed.

The content of the conversations will be confidential. Comments made by participants may be included in a report that will be generated, but comments will not be attributed to individuals or to their organisations. The report will be provided to the Advanced Technology Program of the Department for Education who will decide on any further the distribution of the report.

While comments will not be attributed to participants, complete anonymity cannot be guaranteed as the number of participants involved is limited and those who read the report may attempt to infer which participants may have made particular comments.

Interviews

Introduction
I am David Curtis and I want to ask you about your perceptions of the Space Industry Work Experience program. The interview should take no more than 10-15 minutes.

The content of the interview will be confidential. However, some of your comments will be used in a report, but they will not be attributed to you or to your organisation.

I will ask a series of questions that are designed to open a conversation about key aspects of the Space Industry Work Experience initiative. I hope you will raise any other issues that you think are relevant. You are free to decline to respond to any questions that you do not wish to answer.

I would like to audio-record the interview. No-one else will hear the recording, it will not be transcribed, and the recording will be deleted once analyses of interviews is complete. Is that OK with you?

Opening questions
The following questions will be used to open a conversation with mentors.

- What led your organisation to become involved as a host for the Space Industry Work Experience program?

- What benefits, if any, did you or your organisation expect to derive from hosting the work experience?
- What are your expectations of the program, for the student participants and for your organisation?
- In advance of the placement, what were your expectations of the students, in terms of their knowledge and skill?
- How much effort was required for your organisation in preparing to host and in hosting the students?
- How satisfied are you with the recruitment of students by the Advanced Technology Program for their placement with you?
- What are your perceptions of the students who you hosted?
- What benefits do you think the students have gained as a consequence of their placement (e.g. knowledge, skills, awareness of the nature of your work and of career opportunities in the industry)?
- Would you like to see any changes in the Space Industry Work Experience program?

Thank you for the time you have committed to the interview and for your views about the Space Industry Work Experience initiative.

Appendix 2: 2019-2020 SIWE student surveys

To view the *2019-2020_Space Industry Work Experience Student Pre-Placement Survey Questions* in the original format, open the link http://www.iier.org.au/iier31/baker-appendix2a-pre-survey.pdf (about 106 kB; select 'in a new window' in your web reader).

To view the *2019-2020 Space Industry Work Experience Student Post-Placement Survey Questions* in the original format, open the link http://www.iier.org.au/iier31/baker-appendix2b-post-survey.pdf (about 118 kB; select 'in a new window' in your web reader).

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