



The Positive Influence of Inquiry-Based Learning Teacher Professional Learning and Industry Partnerships on Student Engagement With STEM

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School teachers in science, technology, engineering and mathematics (STEM) face challenges in developing and maintaining high levels of student engagement and achievement in those disciplines. Consequently, declining numbers of students are electing these subjects beyond the compulsory years of schooling. A major factor in student engagement often is curriculum content being relevant to the lives of students outside the classroom. Two key ways teachers can enhance the real-world relevance of their lessons are inquiry-based learning and localising the curriculum to provide an authentic context for teaching and learning. In this paper, we report a qualitative study into the perceived influences of inquiry-based learning on student engagement, as facilitated through teacher professional learning in the context of two major infrastructure programs in Sydney, Australia. Semi-structured interviews and focus groups were conducted with primary and secondary teachers who participated in professional learning about inquiry-based pedagogies, as well as with their students who undertook inquiry-based learning projects based on the infrastructure programs in their local community. Inductive and deductive content analyses using Attard's Framework for Engagement with STEM illustrated how the combination of teacher professional learning, student inquiry-based learning, and localised industry-school partnerships enhanced student engagement across operative, cognitive, and affective domains. Another significant finding was the extent to which professional learning as the vehicle for inquiry-based learning and industry connections enhanced teachers' pedagogical relationships and pedagogical repertoires in ways not possible with more conventional approaches to industry-school partnerships.

Keywords: inquiry-based learning¹, science, technology, engineering and mathematics², engagement³, industry partnerships⁴, contextualized learning⁵

INTRODUCTION

Science, Technology, Engineering and Mathematics (STEM) related disciplines continue to experience challenges in the development and maintenance of high levels of student engagement, ultimately influencing students' decisions to continue their study beyond the compulsory years of schooling (Attard et al., 2020). It is well documented that high levels of engagement are a significant contributing factor to academic success (Barker, Dowson, and McInerney, 2005; Hughes et al., 2008; Maltese and Tai, 2010; Attard, 2013; Wang and Degol, 2014), yet improving student engagement in the disciplines of mathematics and science continues to challenge educators. Given that mathematics and science form the foundations of STEM (Berger, Mackenzie and Holmes, 2020), it is reasonable to suggest that issues of engagement within these two disciplines must be addressed to ensure that STEM education delivers the intended results. Improvements in academic success within mathematics and science are critical if students are expected to apply knowledge and skills from these individual disciplines to STEM-related learning.

A major influence on student engagement is often reliant on curriculum content having relevance to their lives outside the classroom (Attard et al., 2020). The ability of an inquiry-based learning (IBL) approach to promote connections within and across curriculum disciplines provides a powerful argument for the use of the approach, particularly in the context of significant local infrastructure projects where the potential for STEM curriculum integration is significant (Fielding-Wells, 2015). In addition, industry partnerships with schools provide opportunities for experts to engage with students and teachers, increasing awareness of the relevance of the curriculum and their learning (Torii, 2018). While research relating to industry partnerships and schools exists, the focus is typically related to the development of vocational opportunities and school-to-work transitions for upper secondary students (see for example Flynn et al., 2016). There is little existing research exploring the relationships between industry-school partnerships combined with IBL to improve student engagement through teacher professional learning.

Shifting teacher practice to provide improved support for the implementation of inquiry-based approaches requires more than the traditional types of professional learning activities such as workshops, seminars or conferences (Bednar, Fiorentini and Huang, 2011). Darling-Hammond et al. (2009) suggest changes in teacher practice and student development are promoted by professional learning activities that are intensive and sustained and include applications of knowledge to teachers' planning and instruction.

This paper reports on the impact of two sustained professional learning programs that were aimed at building the capacity of primary and secondary teachers to design, implement, and evaluate IBL units of work. The programs consisted of a combination of face-to-face and online sessions spanning two school terms (6 months). Two significant infrastructure programs in New South Wales (NSW), Australia (Sydney Metro and Parramatta Light Rail) were used to provide a real-life local

context as stimulus for student inquiry. Qualitative data from teacher interviews and student focus groups were collected from participating teachers and a sample of their students in each of the programs. This paper explores the perceived impact of the two professional learning programs on student engagement using an adapted version of the Framework for Engagement with Mathematics (Attard, 2014) as a lens to assist us in understanding the influence of the professional learning program and industry partnerships on the students' engagement.

LITERATURE REVIEW

Student Engagement and Science, Technology, Engineering and Mathematics

Declines in engagement with STEM disciplines are often attributed to similar factors. Negative influences on student engagement include a lack of curriculum relevance, pedagogical practices that focus on content consumption, a lack of connection within and amongst discipline topics, and perceptions that mathematics and science are difficult and inaccessible (Patrick, Ryan, and Kaplan, 2007; Boaler, 2009; Maltese and Tai, 2010; Simon and Osborne, 2010; Christidou, 2011). However, in order to address declining engagement, it is critical that the actual construct of engagement is appropriately defined as something deeper than students simply being "on task".

The construct of engagement can be characterised within education as students' *meaningful participation* in a context where knowledge and learning are valued and used. A critical element of engagement is the maintenance of interpersonal relationships and identities within the classroom community, in addition to positive interactions within the environments in which the student has significant personal investment (Attard, 2014). Hence, the use of local contexts that were familiar and relevant to students' lives within the projects reported in this paper, along with the collaborative nature of an inquiry-based approach was a significant factor in the design of the professional learning programs.

In a seminal review on student engagement, Fredricks, Blumenfeld and Paris (2004) define engagement as a deeper student relationship with classroom work, multi-faceted and operating at cognitive, affective, and behavioural levels. It is this multidimensional view of engagement that informs the definition utilised in this paper. That is, engagement is defined as the coming together of cognitive, operative, and affective domains (Fair Go Team NSW Department of Education and Training, 2006; Munns and Martin, 2005), leading to students valuing and enjoying school STEM related learning, and seeing connections between the STEM concepts and practices they learn at school and their own lives. Within this definition, engagement includes student thoughts that are projected outwards in relation to the individual's investment and effort towards learning, and those relational behaviours that occur within classrooms (Attard, 2014).

The above definition forms the theoretical foundation for the *Framework for Engagement with Mathematics* (FEM) (Table 1),

TABLE 1 | Framework for Engagement with STEM (adapted from the Framework for Engagement with Mathematics, Attard, 2014).

Aspect	Code	Element
Pedagogical Relationships		In an engaging STEM classroom, positive pedagogical relationships exist where these elements occur
	PK	Pre-existing Knowledge: students' backgrounds and pre-existing knowledge are acknowledged and contribute to the learning of others
	CI	Continuous Interaction: interaction amongst students and between teacher and students is continuous
	PCK	Pedagogical Content Knowledge: the teacher models enthusiasm and an enjoyment of STEM-based content and has a strong Pedagogical Content Knowledge within each of the curriculum areas
	TA	Teacher Awareness: the teacher is aware of each student's STEM-related discipline abilities and learning needs
	CF	Constructive Feedback: feedback to students is constructive, purposeful and timely
Pedagogical Repertoires		Pedagogical repertoires include the following aspects
	SC	Substantive Conversation: there is substantive conversation about STEM-related concepts and their applications to life
	CT	Challenging Tasks: tasks are positive, provide opportunity for all students to achieve a level of success and are challenging for all
	PC	Provision of Choice: students are provided an element of choice
	ST	Student-centred Technology: Technology is embedded and used to enhance STEM understandings through a student-centred approach to learning
	RT	Relevant Tasks: the relevance of learning within the STEM disciplines is explicitly linked to students' lives outside the classroom and empowers students with the capacity to transform and reform their lives
	VT	Variety of Tasks: STEM-related lessons regularly include a variety of tasks that cater to the diverse needs of learners

Students are engaged with STEM when

- They enjoy STEM-related learning
- They value STEM-related learning and see its relevance in their current and future lives, and
- They see connections between the STEM concepts and practices learned at school and the STEM concepts and practices used beyond the classroom

introduced by Attard (2014) as a tool to analyse teaching and learning and a framework to assist teachers in planning engaging learning experiences in mathematics. The FEM describes the influences on engagement as two separate but inter-related elements: pedagogical relationships (the interpersonal teaching and learning relationships that optimise learning) and pedagogical repertoires (the teaching practices employed in day-to-day teaching). The development of positive pedagogical relationships provides an important foundation for engagement that is necessary for substantive, sustained engagement, incorporating operative, cognitive and affective domains. The design of engaging pedagogical repertoires should be considered in alignment with pedagogical relationships. That is, teaching activities and tasks are specifically tailored to learners' needs that are identified via pedagogical relationships. The FEM identifies specific elements that contribute to the establishment of positive pedagogical relationships and pedagogical repertoires.

Although the FEM was designed specifically to address engagement with mathematics, it is reasonable to assume that the elements described within the framework would also influence engagement with other STEM-related content. This is because mathematics is key to further study in the sciences, and science and technology offer opportunities for students to understand the practical utility of mathematics (Berger et al., 2020). Previous research has also demonstrated that engagement in STEM subjects is enhanced by promoting student enjoyment and making clear connections with students' lives (Ainley and Ainley 2011; Watt et al., 2012), all of which are emphasised by the FEM. To this end, the FEM has been adapted in **Table 1** as a Framework for Engagement with STEM. To adapt the framework, the word "mathematics" was replaced with STEM, STEM-related disciplines, STEM understandings and STEM concepts.

A brief review of literature pertaining to the use of contextualised learning within an inquiry-based approach to engage students in STEM will now be presented.

Inquiry-Based Learning in Science, Technology, Engineering and Mathematics

Inquiry-based learning is a student-centred pedagogical approach that enables learners to construct their understanding throughout the process of learning (Bonnstetter 1998; Kuhlthau and Maniotes, 2015). Learners uncover first-hand understandings about subjects, their environment, and themselves (Wang et al., 2010) by asking questions, investigating problems, and drawing evidence-based conclusions while collaborating with others (Melville, 2015). While there are a range of definitions for inquiry (Colburn, 2000), research suggests that inquiry-based approaches can support student achievement (Alfieri et al., 2011) and engagement (Darling-Hammond et al., 2020). Inquiry originated in the science disciplines (Melville, 2015), and has long been advocated as an effective and authentic approach to teaching and learning, particularly within STEM areas (Blumenfeld, Soloway, Marx, Krajcik, Guzdial and Palincsar, 1991; Edelson, Gordon, and Pea, 1999; Anderson 2002; Wang, Kinzie, McGuire and Pan, 2010).

While some scholars argue that inquiry is a less effective method of teaching in comparison to direct instruction (e.g., Kirschner, Sweller and Clark, 2006; Hattie, 2009), others highlight the potential for well-designed inquiry that integrates direct instruction in response to learner needs to support student engagement, problem-solving ability, higher-order thinking, and socio-emotional skills (Hmelo-Silver, Duncan and Chin, 2007; Darling-Hammond et al., 2020). Indeed, significant bodies of research reinforce that inquiry-based strategies,

routines, structures, and approaches to teaching and learning are both powerful and effective methods of school instruction (Bednar, Cunningham, Duffy, and Perry, 1992; Bonnstetter 1998; Owens, Hester and Teale, 2002; Kuhlthau and Maniotes, 2015; Olusegun, 2015). For example, specific benefits of inquiry-based learning in mathematics include improved student motivation and understanding (Bruder and Prescott, 2013). Results from multiple meta-analyses indicate that inquiry-based learning is most successful when teachers provide guidance that is matched with the student inquiry experience, individual learning needs, and prior knowledge (Alfieri et al., 2011; Furtak et al., 2012; Lazonder and Harmsen, 2016). Hence, there are several models of IBL that allow teachers to tailor the levels of teacher control and student agency. Fichtman-Dana et al., 2011 describes a range of models from structured inquiry, where the teacher controls all elements of the inquiry, through to free inquiry, where students construct their own question and design their own assessments to demonstrate learning.

Localise to Contextualise Learning in Science, Technology, Engineering and Mathematics

Teaching strategies that enhance the relevance of STEM concepts for young learners are viewed as a critical way forward in improving STEM outcomes (Boda and Brown, 2020). Indeed, research has shown that students' attitudes towards STEM subjects and career aspirations can be promoted by connecting the content taught in science with students' lives (Hulleman and Harackiewicz, 2009; Sheldrake, Mujtaba, and Reiss, 2017). The use of students' local contexts to contextualise their learning is also viewed as a way to emphasise the relevance of STEM for youth from diverse backgrounds (Boda and Brown, 2020).

There are a variety of different and related approaches to connecting learning at school with students' lives. For example, context-based teaching is defined as "teaching where contexts and applications of science are used as the starting point for the development of scientific ideas" (Bennett, Lubben, and Hogarth, 2007, p. 348). In contrast, place-based learning situates learning within students' communities, emphasising connections with place (Buck, Cook, and Carter, 2016). (Godec et al., 2017) suggest taking contextualisation of science further, by localising and personalising science "using examples and settings that are familiar and local to students as "hooks" into the science content" (p. 27). In this paper, we adopt the notion of localising to contextualise STEM, using a local stimulus to generate student interest in inquiry-based learning tasks. This approach was selected to allow teachers flexibility in determining how to contextualise the learning, based on the learning needs of their students, curriculum priorities, and other programming considerations in their schools.

Education Partnerships With Industry

The establishment of industry-school partnerships has been identified as an important way in which student engagement, skills, and career aspirations can be enhanced in STEM (Hobbs et al., 2003; STEM Partnerships Forum, 2017; Torii, 2018). The

nature and focus of industry-school partnerships is highly variable, including industry experts visiting schools, exchange of learning resources, and provisions for students to complete work experience and qualifications with industry partners (Lee, Hope and Abdulghani, 2016). While partnerships that focus on enhancing school-to-work transitions have made significant contributions to young peoples' work readiness (Lonsdale et al., 2011), industry-school connections that focus on contextualising STEM concepts in the school curriculum are a relatively under-explored type of industry-school partnership. Such partnerships have the potential to facilitate authentic learning, making the connection between STEM concepts and the "real world" clear to students (van Driel et al., 2018).

As teachers have the largest impact on student outcomes in the classroom, a clear focus on teacher professional learning is required to maximise the benefits of industry-school partnerships (STEM Partnerships Forum, 2017). In this context, teacher professional learning allows teachers to develop their understanding of how the concepts they teach are connected with the reality of STEM careers (van Driel et al., 2018). While these connections are critical, we argue that teacher professional learning should also be focused on enhancing teacher capacity to use innovative pedagogical approaches, such as IBL. However, in many cases, industries do not have sufficient expertise in education and knowledge of schooling to deliver such professional learning to teachers (STEM Partnerships Forum, 2017). Hence, universities with teacher education faculties are well-placed to leverage effective industry-school partnerships.

The Inquiry-Based Learning Context

In the last 20 years, the Greater Sydney region in NSW has experienced a population boom which has placed considerable pressure on public transport infrastructure. To address issues of congestion and connectivity, the NSW government has made significant investments in road and rail projects across the state, but particularly in the state capital, Sydney Metro, billed as Australia's largest infrastructure project, has introduced a mass rapid transit system akin to the London Underground or Dubai Metro to Australia for the first time. It has involved significant infrastructure engineering projects such as tunnel boring, bridge building, track laying, and station development in both green and brown field sites across the city. At the same time, a light rail system is under construction in Sydney's "second central business district" in Parramatta, which has seen extensive re-engineering of road and rail corridors across the locality and surrounding environs.

These two infrastructure projects embody the full range of STEM disciplines. While the connections to engineering seem obvious, there are extensive connections to the other disciplines as well. There are significant environmental science connections in both projects, perhaps best exemplified by the rehabilitation of a heavily contaminated former chemical industry site as part of Parramatta Light Rail. Connections to technology include driverless trains on Sydney Metro and wire-free trams in Parramatta Light Rail. Finally, mathematics underpins a variety of the engineering, technology, economic, and human

geography aspects of the planning approvals of both projects. The projects are also highly visible and impactful on the community in both construction and operation phases. Teachers can use young people's natural inquisitiveness about these significant changes in their communities to engage them in real-world, contextualised inquiry-based learning in the STEM disciplines.

The Professional Learning Programs

Although the two professional learning programs were entirely separate, the format of each was identical due to the success of the initial Sydney Metro education program, which aimed to initiate a community of practice interested in inquiry-based development and develop and promote inquiry-based development pedagogy in local schools. The programs also supported the design, implementation and evaluation of inquiry-based units of work that used elements of the two transport projects as stimuli for student inquiry.

The programs attracted a range of primary and secondary teachers from the public and private school systems as indicated in **Table 2**. Each of the programs spanned approximately 16 weeks to allow the participants enough time to develop and teach their units of work. The teachers were encouraged to design units of work tailored to their students' needs and within the requirements and limitations of their individual school and classroom contexts. Information and resources directly linked to the infrastructure programs were provided, however teachers were also encouraged to use relevant information from other resources as required. The duration of the units was not prescribed, nor were the curriculum areas or content to be covered in order to maximise the flexibility of the professional learning program for teachers. Examples of units of work designed by teachers included data collection and analysis to understand customer requirements, use of ICTs to design and model stations and vehicles, understanding and mitigation of environmental impacts of transport construction, and development of virtual reality tours of transport systems.

Support was provided by the course facilitators (university academics in education and teaching) and experts from Transport for NSW (the state government agency responsible for the infrastructure projects) as required. The participants were encouraged to seek advice and interactions with experts such as engineers to assist their students in conducting their inquiries. For example, schools arranged expert-led site visits where students experienced construction firsthand and asked inquiry questions about each infrastructure project. The university academics provided support and feedback in relation to inquiry-based learning pedagogy, as well as the effective use of technology and assessment of/and/for learning. This support occurred during the sessions and in some cases, in between sessions via email correspondence. The participants also had opportunities during the sessions to provide peer feedback.

The structure of the programs was as follows:

Session 1: Introduction to Inquiry-based development and the Sydney Metro/Parramatta Light Rail Transport Project.

This was a full day, face to face workshop conducted at Western Sydney University. During this workshop, participants were introduced to the pedagogy of inquiry-based

development. This included exposure to a range of inquiry frameworks, (eg., Fichtman-Dana et al., 2011; Kuhne, 1995) and theory related to student engagement (Attard, 2014). They were also introduced to the Sydney Metro or Parramatta Light Rail Project by a Transport for NSW representative. The workshop facilitators provided an overview of the activities and expectations of participation in the professional learning program to culminate in a set of units of work to be published and disseminated. By the end of this workshop, participants had begun brainstorming ideas for their units of work. Participants were set the task of drafting a unit of work in preparation for the next session.

Session 2: Designing a Unit of Work using an Inquiry Approach—Aligning with Curriculum and Embedding Technology.

This was a 2-h, after school, online session held via the Zoom platform. In this session the participants shared their progress and received peer feedback on the draft units of work. They then began to align their activities with curriculum outcomes, the General Capabilities and Cross-Curriculum Priorities (Australian Curriculum and Reporting Authority, n.d.).

Session 3: Implementing a Unit of Work using an Inquiry Approach—Assessment Strategies and Evidence Gathering.

This session was a 2-h, after school, online meeting where participants shared the progress of their draft units of work. The session content focused on the development of appropriate assessment strategies and the use of work samples as assessment evidence. The participants provided each other with feedback and were set the task of completing their drafts in preparation for implementation in the following school term.

Session 4: Presentation, evaluation and finalisation of Units of Work.

The final program session was a full day, face to face workshop held at Western Sydney University. In this final workshop, participants presented their completed units, work samples (including assessments) and other evidence to their cohort of participating teachers. They were also provided with time to finalise their units and complete their unit evaluation.

METHODS

The two overarching research studies relating to the professional learning programs sought to investigate the impact and influence of the programs. Student engagement emerged from each study as a theme and major outcome of both program, leading us to conduct a more fine-grained analysis of the combined data. For the purposes of this paper, the following research question is addressed:

What are the perceived influences of the inquiry-based learning professional learning program on student engagement?

The research element of each program utilised a qualitative approach. Each participant group consisted of teachers (program participants), and small groups of their students. Data informing this paper was drawn from teachers participating in each professional learning program who had designed and implemented units of work within STEM disciplines. Data

TABLE 2 | Participant details.

School	Program	School type	Number of participating teachers	Grade	Unit of work discipline	Data collected
1	Sydney Metro	Public Secondary	2	Year 7	Science Mathematics Geography	Teacher Interview (2 teachers) Student Focus Groups (2)
2		Public Primary School	1	Years 3–6	Science Technology	Teacher Interview Student Focus Groups (2)
3		Independent Secondary	1	Year 8	Science	Teacher Interview
4	Parramatta Light Rail	Public Secondary	2	Year 8	STEM	Teacher Interview Student Focus Group
5		Independent Secondary	1	Year 7	Mathematics	Teacher Interview Student Focus Group

derived from program participants who designed units of work from non-STEM disciplines are not included in this paper.

Participants

The professional learning programs included teachers from Kindergarten (the first year of schooling in NSW schools) through to Year 10 (students aged ~16). **Table 2** provides details of the participants who designed and implemented STEM related units of work and agreed to participate in the research element of the program. A number of other participants used STEM concepts within their units but did not participate in the research element of the program.

Ethical Procedures

The research methods employed in this research were approved by Western Sydney University's Human Research Ethics Committee (approval numbers: H12808 and H13111) and the NSW Department of Education's State Educational Research Approval Process (approval numbers: 2018575 and 2019113). All prospective participants were provided with a plain language information sheet about the research. This research was conducted with participants who gave informed consent to participate.

Data Sources

Data informing this paper were drawn from interviews and focus groups from two professional learning programs. As such, two forms of triangulation were implemented in this study: data triangulation and methodological triangulation. Data triangulation is where data sources are compared and contrasted (Kervin, et al., 2006) and methodological triangulation involves the use of several data collection methods (Noble and Heale, 2019). In this study, the inclusion of data from two projects is a form of data triangulation, while the inclusion of interviews and focus groups is a methodological triangulation.

Interviews

Semi-structured interviews of approximately 30 min duration were conducted with the consenting teacher participants in each of the professional learning programs. Interviews were

selected as a way to garner in-depth information about the participants' experiences in the professional learning programs and related classroom practices. The semi-structured interviews were carried out on completion of the unit of work either during the final professional learning session or at school. Group interviews were conducted in circumstances where there was more than one program participant from an individual school. Where only one teacher at a school participated in the PD program, he or she took part in an individual interview. A total of five teacher interview transcripts were analysed for the purpose of this paper.

The following interview prompts were used to guide discussions:

- Can you talk about your general experience participating in the professional learning program?
- Based on your experiences designing, implementing and evaluating an inquiry-based unit of work, what are your current perceptions of teaching through an inquiry based approach?
- What are your perceptions about how an inquiry-based approach facilitates student access to the curriculum?
- Can you talk about the benefits of such an approach for your students?
- Can you talk about whether you believe the program assisted in the development of your skills in relation to inquiry-based learning?
- Were there any unanticipated benefits or outcomes to your participation in the program for you, your colleagues or your students?
- Can you talk about whether other teachers and/or stakeholders were involved in this project?
- Do you have any suggestions for future iterations of the program?

Focus Groups

Each participating teacher was invited to have students participate in a focus group discussion. Six focus group discussions are included in the data informing this paper. Students took part in a focus group discussion focused on their experiences participating in the unit of work designed by

TABLE 3 | Coding table for Framework for Engagement with STEM.

Element	Coding references				Representative quote
	Teacher		Student		
	Items coded	Schools	Items coded	Schools	
Pre-existing Knowledge (PK)	0		0		N/A
Continuous Interaction (CI)	5	1, 5	4	1,2,5	When we did do our groups and stuff, it helped a lot, because then we could share our ideas and what we had for presenting. (Student, Case 5)
Pedagogical Content Knowledge (PCK)	0		0		N/A
Teacher Awareness (TA)	2	3, 4	0		With an inquiry-based approach I'm not hearing that so much. There are opportunities for all of the students to engage on some level. I always see that inquiry-based learning, working in a group, means that you've got different skillsets, different interests, unique attributes that each student has and can offer and can contribute (Teacher, Case 4)
Constructive Feedback (CF)	2	1	1	1	I think for me, a lot of it was - because we were focusing on inquiry-based learning, so student questioning, so it's giving students feedback on the types of questions they're asking, in terms of what type of response that would then facilitate from people they're interviewing. (Teacher, Case 1)
Pedagogical Repertoires					
Substantive Conversation (SC)	0		0		N/A
Challenging Tasks (CT)	5	1, 3,4	7	1, 5	I teach some students who have the reading ability of Year 2 but yet they're in Year 9 or 10 and with inquiry-based learning they can do it at their own pace. They can take the project to wherever the pace and opportunities to achieve success they're at. It's interesting to see, even some of those lower abilities be really proud of their work, and they're doing work that's concurrent with other kids in their year level. (Teacher, Case 4)
Provision of Choice (PC)	2	1, 2	12	2, 4, 5	So we watched videos, like (student) said, and then we also chose what we wanted to make our station out of. So then we had to build it, which made us know what we were doing and we had to know what we were doing too. (Student, Case 2)
Student-Centred Technology (ST)	0		5	2, 4	I think I would like to use this type of learning again because it really motivates you to do well. With the promise of using a game like Minecraft at the end it motivates you to do well and listen and pay attention. I think that's very good. (Student, Case 2)
Relevant Tasks (RT)	23	1, 2, 4	18	1, 2, 4, 5	Rather than just learning it, we were now applying it; learning how to apply it to everyday life and to life in the future. It probably won't affect us in the immediate future, but in a few years, there - like, these are the kind of things that we're going to need to know and that - I think that would - really helped us. (Student, Case 5)
Variety of Tasks (VT)	0		3	1,5	We got to do things more ourselves than instead of the teacher teaching us what these things were, we would go out and find them ourselves and make our research and use our own ideas to do this work. (Student, Case 5)

their teacher. This allowed the researchers to gain a deeper insight into their perceptions of the inquiry-based learning and the associated infrastructure project. Each focus group consisted of five or six students selected by their teachers from those who had returned signed consent forms. The teachers were requested by the research team to choose (Table 2). The use of teachers as key informants for focus group selection provided the researchers with participants, many of whom were young children, who were comfortable and confident to speak to the researchers about their learning. Teachers have knowledge about the developmental

abilities of their students, which is an important consideration when conducting focus groups with children (Adler et al., 2019). Thus, consultation with teachers about student focus group participants is recommended to ensure the success of the focus group (Horowitz et al., 2003).

The focus group discussion prompts were as follows:

- You recently learned about the Parramatta Light Rail or Sydney Metro project. Can you talk about what you learned?
- Can you talk about the way that you learned?

TABLE 4 | Coding for additional themes.

Theme	Coding references				Representative quote
	Teacher		Student		
	Items coded	Schools	Items coded	Schools	
Industry Connecting with Schools	14	2, 3, 4	6	1, 2, 4	By getting professional people coming in and taking our work into consideration, I think it gets us motivated to create the project, and make a really well-made, or designed final product. (Student, Case 4)
Cognitive Engagement	6	1	3	1, 2	They were obviously having those conversations at home. The questions that - well, the question and answer session we would have at the end of each of the presentations, it was quite clear that they had gone off and spoken about designs, about materials et cetera, with people within their families who were experts, maybe had an engineering background. Thinking, I can go and talk to this person, because they know about this stuff. (Teacher, Case 1)
Operative Engagement	1	1	4	1, 5	It was really different from what we're used to, because usually we just sit as a class, do some questions, but whereas this is a better approach. It's, as (student) said, more interactive and we do think for ourselves, because we're not used to seeing boardroom meetings every day. I don't think either of - like, neither of us have actually been to one. (Student, Case 5)
Affective Engagement	2	1	2	1	Well, when we're doing enquiry-based learning, I guess, it's harder to do but you get more out of it, whereas the other learning, you just remember it to put it down on the assessment and then forget it straight after. (Student, Case 1)
Substantive Engagement	10	1, 2, 4	19	1, 2, 4, 5	I think the main benefit for my students was the level of engagement they got from the inquiry. I feel like they felt like a strong sense of ownership over the project. They got to design it and then make the design come to life and it was all their own ideas that they were seeing as they built their designs, so I feel like they really benefited from sort of owning that project from start to finish and feeling a sense of pride and I suppose that motivated their learning. (Teacher, Case 2)

- Was it different to the way you usually learn? How?
- Can you talk about whether you think learning in this way is effective?
- Would you like to use this way of learning again? Why or why not?
- Can you talk about the things your teacher did to help you in your learning?
- What impact do you think the Parramatta Light Rail or Sydney Metro project will have on your community and on your own lives?
- Do you have any feedback to your teacher about your learning or that way that you learned?

Data Analysis

The Framework for Engagement with STEM was used as an analytical tool and allowed for analysis across both sets of data. Interviews and focus groups were audio recorded and transcribed verbatim. NVivo was used to inductively code the data against the framework. This allowed the researchers to code data according to the elements within the framework as illustrated in **Table 3**. Deductive analysis was then conducted within each code to seek sub-themes (Saldana, 2016). Items that were linked to engagement but unable to be coded against the specific elements of the Framework for Engagement were coded against the themes of Substantive Engagement, Operative Engagement, Affective Engagement, Cognitive Engagement, and Industry Connecting with Schools, these additional themes were considered

indications of overall engagement or in the case of the Industry Connecting with Schools theme, provided a foundation for engagement to occur. Representative quotes from these additional themes are represented in **Table 4**.

Tables 3 and **Table 4** illustrate the significant alignment with the Framework for Engagement in STEM and the overall student engagement. While there were two elements from the Framework that were not coded within the analysis, there were instances where some data could easily have been coded against more than one element, demonstrating the interconnected nature of elements within and across pedagogical relationships and pedagogical repertoires. Similarly, as stated earlier, the additional themes were all strongly indicative of student engagement that was a direct influence of the opportunity of the program participants and students to interact with industry experts and a real-life, local context.

FINDINGS AND DISCUSSION

As indicated above, almost all elements of the Framework for Engagement with STEM attracted items coded from interview and focus group data. However, the spread of the items across the elements was quite uneven with a significantly higher number of items coded within the pedagogical repertoires section of the framework. We now present the data intertwined with our discussion. First, we will explore the findings relating directly to

the Framework for Engagement with STEM by exploring pedagogical relationships and pedagogical repertoires. We will then turn to the additional themes that emerged from the analysis.

Pedagogical Relationships

Pedagogical relationships form the foundations for student engagement to occur (Attard, 2014). It is not surprising there were fewer items coded against the elements of pedagogical relationships, given the interview and focus group prompts did not specifically set out to explore the teachers' practices in relation to establishing relationships. Rather, they were focused on exploring the results of the pedagogical repertoires implemented as a result of the professional learning program.

It appears the IBL approach was well suited to classrooms where positive pedagogical relationships exist. IBL also appears to promote the development of those relationships due to its flexible, collaborative and often open-ended nature (Melville, 2015). Most notably, the element with the greatest number of items coded (9), is Continuous Interaction (CI). The following quotes exemplify how those interactions played out:

It wasn't just you and your computer - it was you and your group, and whether friends or just acquaintances and stuff, it was just a way of actually talking, and, like everybody else, not getting the answers - you've got to discuss them, and it was just very different as well. (Teacher, Case 1)

I think I would have just liked it a bit if it was just us doing our own personal project, because with it being a group task, we get to share our ideas and depend on each other for certain parts of it. I think that really helped us with our communication skills with each other. (Student, Case 5)

Continuous Interactions occurred as a result of the student collaboration that occurred during IBL and through the interactions between teachers and their students. The positioning of the teacher as a facilitator within the various models of inquiry as opposed to a more traditional didactic teaching approach (Fichtman-Dana et al., 2011) appeared to be a significant contributor to students' engagement: "I think our teacher - because she was always there ready to help. She was constantly walking around and talking to people, making sure they were okay as a group" (Student, Case 2). Continuous interactions also appeared to promote students' independence within a supportive environment, giving them ownership of their work and promoting self-regulation, as evidenced in this quote:

We had to take our own initiative in doing this, it taught us a lot about responsibility, so, I did learn a lot about researching for myself and helping out my group. So, I think, with everything, the teacher not exactly telling us what to do and not giving us a guideline, helped us with group work and working collaboratively. (Student, Case 1).

The other elements of pedagogical relationships that were apparent to a lesser extent were the teachers' awareness of student needs and the provision of timely feedback while carefully

scaffolding student learning. The following quotes are representative of this sentiment:

If we didn't know what to do next, she would give us some questions, so, she wouldn't tell us what to do next but she would give us some questions, maybe that we had to think about to answer first and she said that - I remember, she told me specifically, that if you didn't know what to do next, you had to do some more research about it because you need to find more questions, you need to answer more questions to get to the next step. So, she was also just there to help set us back on the right path if we were ever be a bit confused. (Student, Case 1).

I think our teacher - because she was always there ready to help. She was constantly walking around and talking to people, making sure they were okay as a group. (Student, Case 2).

The data analysis has highlighted the reciprocal nature of positive pedagogical relationships and engaging pedagogical repertoires. The repertoires employed via an IBL approach were built on existing relationships that allowed the teachers to design IBL units of work at appropriate levels of inquiry as described by Fichtman-Dana et al., 2011. This suited the specific needs of their learners aligning with IBL literature (Darling-Hammond et al., 2020), yet, conversely, provided opportunities to strengthen those relationships. For example, the teacher in Case 1 designed a unit that was considered a guided inquiry, promoting high student agency. The teacher in Case 5 designed a unit that was considered a controlled inquiry due to the need to address specific curriculum outcomes and school programming requirements. The elements of the resulting effective pedagogical repertoires emerging from the data will now be explored.

Pedagogical Repertoires

The most outstanding element of pedagogical repertoires that emerged from the data was the provision of learning tasks that were relevant to the participating students. A total of 41 items were coded against relevant tasks (RT), comprising 54.6% of the total items coded against pedagogical repertoires. Importantly, the benefits of using local transport projects as the stimulus for inquiry was perceived as a highlight for both teachers and their students.

Several sub-themes emerged within RT. These included *contextualised learning*, *application of skills*, and *community connections*.

The contextualization of learning through the use of local contexts was viewed by teachers and students to be highly engaging. This was evident through quotes such as the following:

I already had some limited skills but by having the opportunity to do a local project that is real, it's authentic, I think that's the secret ingredient for it to be successful. Because I can do other projects that are a bit pie in the sky or of not a real relevance to the students, but by having it local it's meaningful and it then inspires me to maybe work that big harder because I can see that it can be so successful. It motivates me because it connects with the students. (Teacher, Case 4).

Rather than just learning it, we were now applying it; learning how to apply it to everyday life and to life in the future. It probably won't affect us in the immediate future, but in a few years, there -

like, these are the kind of things that we're going to need to know and that - I think that would - really helped us. (Student, Case 5).

Several of the students commented on the realistic or real-life elements of the work and the fact that the transport projects would have an impact on their present and future lives, with comments such as this from primary students: "I think that it will have an effect on my life because then we don't - I don't need to dress go to my ballet class. So then because it just arrives 4 minutes - every 4 minutes." (Student, Case 2). Although this quote doesn't explicitly link to learning, it does imply that the student is making a link between what was happening in the classroom to her life outside school. This next quote from a secondary student illustrates a deeper connection between the context and learning:

What I found out was that, for the light rail project, there's actually a lot for them to have to get approved. There's not just the environment, they have to improve the air quality, the amount of noise they're making, the impact they're having around the community, and I thought that was very interesting. (Student, Case 4).

These results reflect findings from Boda and Brown (2020), providing opportunities to emphasise the relevance of STEM for students from diverse backgrounds. They also indicate levels of cognitive engagement, that is, students were reflecting on their learning and making important links to their lives and to prior learning. The opportunities afforded by IBL to apply previously learned skills featured in the student focus groups and teacher interviews, as exemplified by this student: "We got to apply the skills that we've been practicing in class and in homework to a real-life situation and learn a few things as well" (Student, Case 4). Similarly, the following quote represents the sentiments of the teachers:

I found that kids are better able to reach curriculum goals in a sense that they understand concepts more thoroughly because they have implemented them in a real scenario whereas, they might already be able to do those skills in a test, but they've got a better depth of knowledge about things in the curriculum because of the way that they've learnt them. (Teacher, Case 2).

Evidence of students' engagement due to the relevance of the IBL context is provided from teachers who spoke about their students extending their conversations to family and community members. Their apparent excitement and curiosity and the student-centred nature of IBL was evident in the following:

They were obviously having those conversations at home. The questions that - well, the question and answer session we would have at the end of each of the presentations, it was quite clear that they had gone off and spoken about designs, about materials et cetera, with people within their families who were experts, maybe had an engineering background. (Teacher, Case 1).

Further to this, students from several cases engaged more broadly with their communities as an integral part of their IBL. For example, students from Case 1 interviewed their local mayor about the planned Sydney Metro line. Other students interviewed elderly members of their community to explore issues relating to safety and accessibility and students from Case 5 conducted surveys with community members living along the Parramatta Light Rail line. These interactions providing the opportunity for

students to see the relevance of their learning. This was particularly evident for students in Case 5, where one commented: "I felt like it was almost like an older, like a grown-up approach to learning, because you wouldn't do a survey to find actual data and present it". Another student in the same group added this comment: "We've never done data, actually surveying people ourselves, creating a survey and usually in math class, we—no offence—we kind of find it—literally zone out a little". This comment reflects a long-standing issue in mathematics education and perhaps more broadly throughout the STEM curriculum, where students fail to see the connection between their learning within the classroom and their current and future lives beyond, resulting in disengagement (Boaler, 2000; Attard et al., 2020).

Other aspects of pedagogical repertoires that attracted coding were provision of choice (PC), challenging tasks (CT), student-centred technology (ST) and variety of tasks (VT). Although there were variations in the models of IBL, elements of student choice were embedded within each unit of work, leading to the provision of variety within tasks. These elements appear to have been influential on student engagement, with making comments that indicate ownership over learning. The following quotes typify this sentiment:

So we get into our own groups and find our own research and make our own things and we did also - obviously we all got help if we needed help, but it was more independent than what we usually do. (Student, Case 5).

We actually get to explore and do our own research, and find research that interests us, rather than just learning whatever's on the curriculum (Student Case 4).

It was also really interesting, and we got to search up online for stuff and search it up on our own—based on our own questions, rather than set questions people have given us (Student Case 1).

Finally, the provision of challenging tasks (CT) attracted coding of 12 items across the student and teacher data, indicating the nature of IBL combined with the STEM-based nature of the contexts appears to have promoted student engagement. The students indicated that although the work was challenging, they felt the learning was worthwhile:

I think it was very effective, because it challenged us in a way that - yes, because I was a bit surprised when we got the task. So I think it was effective in challenging everyone to step further beyond what we've learned (Student, Case 5).

Similarly, the teachers spoke about the ways in which IBL promoted the development of challenging tasks, as articulated in this quote:

I think one thing about inquiry-based learning is you can really make it metacognitive. Why are we doing inquiry-based learning? So, part of the introduction to this course was students thinking about what a successful student looks like within the inquiry-based learning framework. They had to set themselves goals, so SMART goals, and actually then work towards improving their own skills or attitudes towards learning, to become a successful student within the inquiry-based learning model (Teacher, Case 1).

Interestingly, students who made specific mention of the challenges embedded with the IBL units also used words such

as “effective” and “engaging”, indicating an overall engagement with their learning. In other words, a combination of operative, affective and cognitive engagement. We now turn to data that specifically illustrates each of these dimensions of engagement.

Substantive Engagement

As mentioned earlier, many of the coded items could have been coded against multiple elements of the Framework. Similarly, those items could also have been coded against the dimensions of cognitive, operative, and affective engagement. Although the decision was made to avoid multiple coding, there were items within the data that did not explicitly address elements of the Framework yet implied engagement at cognitive, operative and affective levels as a result of the elements within the Framework. These items provide further evidence that the use of IBL in conjunction with local contexts. Of note, there was strong evidence of cognitive engagement in several comments from teachers, such as this:

Their ability to research and collate this information, their ability to collaborate and assign tasks and roles to each other, I think has been quite extraordinary for such a young group of people. I haven't - I was quite surprised that they were able to work in the way that they have worked, in this - on this project. I think it shows a high level of engagement and a certain amount of maturity there. Certainly, a high level of engagement. That's so, so important.

It appears that the student-centred nature of IBL and the opportunity to work collaboratively, combined with the complexities embedded within the context of transport construction supported all three dimensions of engagement.

When teachers implement teaching and learning activities that promote high affective, operative, and cognitive engagement, substantive engagement occurs. This leads to students valuing and enjoying school STEM related learning and seeing connections between the STEM concepts and practices they learn at school and their own lives (Fair Go Team NSW Department of Education and Training 2006; Munns and Martins, 2005). There were 29 items coded against the theme of substantive engagement, 19 of which came from student focus group discussions. Within their discussions, the students spoke about their overall perceptions of learning through an IBL approach, citing the opportunity to work flexibly and collaboratively, along with the resulting sense of agency as engaging features. Other comments related to students feeling a sense of control over their learning. Conversely, teachers spoke about the challenge of letting go of control to empower their students, recognising that some teachers may not be comfortable with this. The following comment from a teacher in Case 1, highlights both the disadvantages and advantages of such a student-centred approach:

I don't think it's an easy thing to - for everybody to take on board, the idea that in a way you're not in control of what's happening in your classroom. But, in place of the control comes the trust and the responsibility that you're putting on the shoulders of those young people, which as I say, I think are invaluable skills for them to have. To know that - and I think they do realise this, that, wow, our teacher is trusting us. Our

teacher is giving us that responsibility. That our teacher is interested in what we have to say, and not only what we have to say, how we go about finding out what it is that we've got to say (Teacher, Case 1).

Other evidence that students were substantively engaged in their learning came from comments that made specific mention of either the Sydney Metro or Parramatta Light Rail projects. For example, there were several comments about the tunnelling that occurred underneath Sydney Harbour. Other students made specific comments about the complexities involved in planning such significant infrastructures. Some comments indicated aspirations for STEM-related careers while others felt the STEM practices as described by Lowrie et al. (2018) that resulted from the IBL units would prepare them for the future.

Industry Connecting With Schools

The final theme emerging from the data focused on the perceived benefits of working with industry experts within the IBL units. During the implementation of the units several of the case studies incorporated interactions with experts from the Sydney Metro and Parramatta Light Rail projects. These interactions were facilitated by the representatives from Transport for NSW who worked collaboratively with university academics to support the teachers in all aspects of the professional learning program. These industry connections appear to have had a significant influence on the work of students and their teachers, and arguably provided a strong foundation for engagement to occur. A total of 20 items were coded against this theme, with 14 items coded against teacher interview data.

Students' comments regarding industry engagement indicate that the work felt important because outsiders were involved. This focus group excerpt from Case 4 exemplifies this sentiment:

Student: For the light rail project, it felt more important than the other ones, so we had to take it more seriously.

Facilitator: Yeah, and what made it feel more important?

Student: Because usually we don't have a lot of people coming in. It's either parents, but this one is more like professionals and things.

Facilitator: Okay, so it was because the people that came in.

Student: Also, it was a lot more important than the other ones because it was about the future, about the future that we have ahead of us, so it was important that we took it a little bit more seriously than all the other projects.

Student: Also, it felt more important because they said they would take our recommendations into practice, I guess.

Notably, teachers found that the interactions with experts improved their knowledge and enhanced the assistance they were able to provide to their students. However, teachers indicated that while the interactions were valuable, further ongoing connections with industry experts would be beneficial. Although there were many digital resources provided, the teachers felt the personal visits to school were of the most benefit to students. Reasons cited were linked to the opportunities for the experts to provide students with feedback on their work, answer questions, and perhaps most importantly, to inspire students' aspirations to follow STEM-based career paths.

CONCLUSION

Data gathered from participating teachers and their students in two separate studies provide strong evidence that in these two programs the implementation of inquiry-based learning, combined with an industry-based partnership appeared to promote student engagement in the STEM disciplines. However, there are some limitations to this study and its findings. As indicated in *Methods*, data informing this paper is drawn from two overarching studies investigating the impact and influence of the PL programs. A strong theme that emerged from original analysis of the data sets was that of student engagement, and a more fine-grained analysis was then conducted for this paper. While there may be limitations due to having only two data sources from each study, triangulation across the two studies did occur, leading to this current exploration. Future research that includes classroom observation and quantitative data from a larger number of students would allow for more generalizable findings. A further limitation is the potential sampling bias that may have occurred by asking teachers to identify students to participate in the focus group interviews. While this was necessary to ensure that focus group participants were children who felt comfortable to share their experiences with the researchers, future classroom observation studies could be employed to confirm these findings.

It is important to note that the student engagement occurred as a result of two sustained programs of professional learning and in partnership with university academics and industry representatives. Arguably the combined support provided by the University and the industry partners enhanced the outcomes of the IBL units of work. It is not possible to predict if the same outcomes would be achieved independently of the professional learning program and the school/industry/university partnerships. In addition, the research did not explore the impact of the program on student learning outcomes, which is the ultimate goal of teacher professional learning programs.

The Framework for Engagement with Mathematics (Attard, 2014) was adapted as a Framework for Engagement with STEM based on the hypothesis that that the elements described within the framework would also influence engagement with other STEM-related content and arguments from literature stating that engagement in STEM subjects is enhanced by elements articulated within the framework (Ainley and Ainley 2011; Watt et al., 2012). This study provided evidence the two elements (pedagogical relationships and repertoires) and many of the sub-elements within them (Table 1) continue to be essential within the individual and combined STEM disciplines because of the way they interact with each other, resulting in substantive engagement (*Substantive Engagement*). The study also confirmed that the framework can be applied across STEM disciplines to highlight the specific ways in which IBL and contextualised learning through engaging pedagogical repertoires can enhance student engagement. The use of the framework also illustrated the reciprocal nature of pedagogical relationship and repertoires. Teachers used their existing pedagogical relationships to design units of work that responded to student needs and interests, and in turn, the student-centred nature of IBL coupled with the used of local contexts strengthened those relationships. The use of a

framework that specifically identifies the elements of pedagogical relationships and repertoires that influence student engagement provided a nuanced understanding of the influence of the school, university and industry partnership in combination using a contextualised IBL approach. The adapted framework has shown to be a useful analytical tool and can potentially assist teachers of STEM to understand the complex nature of engagement and plan for substantively engaging teaching and learning activities and tasks.

Findings indicate the professional learning programs influenced teachers' understandings of the design and implementation of inquiry-based pedagogical approaches within the STEM disciplines. This resulted in significant shifts away from existing practices that resulted in perceived changes to student engagement within operative, cognitive and affective domains. The findings also indicate the use of real-life infrastructure projects situated within the students' local areas appeared to improve students' engagement in STEM education because they directly impacted their lives and the lives of those around them. The perceived increases in student engagement appeared to influence the students' ability to apply prior learning within a relevant and interesting context. Increased student agency was also perceived as a significant benefit of the program as a result of using a localised context. In addition, the IBL that occurred as a result of the professional learning program incorporated skills such as critical thinking, problem solving and collaboration, which are identified as important STEM practices (Lowrie, Leonard and Fitzgerald, 2018).

Findings from this study may have implications for teacher professional learning and STEM education using inquiry-based pedagogies, along with the use of school-industry partnerships across primary and secondary education. While the emphasis in existing literature relating to school-industry partnerships focuses on increasing career aspirations and enhancing school-to-work transitions, this study contributes to what we know about the potential for industry partnerships to foster student engagement and learning at both primary and secondary levels. Further study into the potential of such partnerships across all levels of schooling would be of benefit as would further use of frameworks such as the Framework for Engagement with STEM to assist in promoting and identifying student engagement.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because data use is only approved for use by the authors of this paper. Requests to access the datasets should be directed to CA.c.attard@westernsydney.edu.au.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Western Sydney University Human Research Ethics Committee NSW Department of Education State Educational Research Approval Process. Written informed consent to

participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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