Enhancing student learning through Project Based Learning (PBL) in a secondary school integrative STEM course

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CONTEXT

Parramatta Marist High, a Catholic systemic comprehensive boys school in Western Sydney, has utilised Project Based Learning (PBL) in all Key Learning Areas in Years 7-10 for almost a decade. Following the development of an *integrative Science, Technology, Engineering and Mathematics* (iSTEM) syllabus and its subsequent endorsement by the New South Wales Board of Studies, Teaching, and Educational Standards (BOSTES), it was deemed an opportune course to introduce and deliver utilising a fully PBL approach. The primary aim of the course's introduction in 2015 was to increase engagement and to help improve the communication skills of students as they progress into senior Science and Mathematics courses. Moreover, given constructivist based approaches to learning (like PBL) are growing in popularity within engineering faculties, this also became an opportunity to educate potential young engineers in a way they are likely to encounter at university.

PURPOSE

To illustrate how utilising a PBL approach in the delivery of the iSTEM course can enhance student learning.

APPROACH

To engage students, the NSW BOSTES endorsed course, iSTEM, was packaged into engaging authentic projects utilising the PBL pedagogy. The course was delivered as an elective course in Year 9. Students worked in groups to solve a variety of engineering-based problems in units centred on aerodynamics, coding, mechatronics, hydraulics and pneumatics. In groups, students were involved in the design, testing, fabrication and reporting processes. Emphasis was also placed on kinaesthetic learning with the school investing in a fabrication laboratory (FabLab) containing equipment such as a CNC mill, a laser cutter, vacuum former and 3D printers. Further emphasis was placed on engaging experts and the use of real-world scenarios. To gain some insights into the impact of iSTEM's implementation, students were surveyed and interviewed regarding their levels of engagement and their modes of learning at the midway point of the 2016 course. Teacher observations were also recorded regarding the suitability of iSTEM and PBL and student participation.

RESULTS

An analysis of student surveys, recorded interviews and teacher observations indicate students are engaged with the mode of learning and that the iSTEM course is well suited to a PBL approach. Some reported benefits of the PBL approach include peer-coaching within groups and development of the ability to grapple with and articulate more complex material to peers in more readily understandable terms. One area requiring attention is the development of Maths and Science resources to complement this approach to learning. Additionally, if the course were to be accommodated into year 10 in the future, there would need to be greater emphasis on material science and other content and skills that may complement the preliminary HSC courses.

CONCLUSIONS

The iSTEM course is very well suited to PBL but its effect can be maximised by utilising a fully PBL approach in its delivery. Student engagement and satisfaction with iSTEM is very high and there are perceived benefits to students in other related disciplines.

KEYWORDS

Project Based Learning, PBL, iSTEM, constructivism.

Introduction

There is growing interest in Science, Technology, Engineering and Mathematics (STEM) education worldwide. Rightly or wrongly, the state of STEM education within a country is often used to forecast the economic and intellectual fortunes of that particular nation-state. Similarly, in Australia, the Federal Government's recent 'National Innovation and Science Agenda' has raised the profile of STEM education nationally (Commonwealth of Australia, 2015). This follows a period of decline in Australian-based manufacturing, the repeatedly poor results of Australian students on international measures (like PISA) and the often-reported dearth of STEM-related graduates trickling out of universities (PwC, 2015). In a recent report from the Office of the Chief Scientist, *Australia's STEM Workforce: Science, Technology, Engineering and Mathematics* (2016), it was stated that "Australia's future will rely on science, technology, engineering and mathematics (STEM)—disciplines at the core of innovation" (Office of the Chief Scientist, 2016, p. 2). Moreover, recent research from the Australian Bureau of Statistics (ABS, 2014) highlighted that STEM jobs have grown at 1.5 times the rate of Non-STEM jobs and, according to a another recent report, *A Smart Move* (PwC, April, 2015), by shifting just 1 per cent of the workforce to STEM-related roles, around $57.4 billion will be added to the Australian gross domestic product (net present value over twenty years). Additionally, the PwC report, as well as many peak professional bodies that represent STEM-based professions or industries, expressed concern about the decline in interest and performance of students in the 'traditional' curricula and the socio-economic consequences for those they represent (Mills & Treagust, 2003). Hence, within this milieu, the following question has been frequently raised: *what is being done to engage and educate young people to meet these forecast deficits and challenges in the critical area of STEM?*

One possible solution is student-centred constructivist pedagogies like Project and Problem-Based Learning. Constructivist approaches to learning, like PBL, attempt to emulate the work environment encountered by professionals by increasing engagement and improving the thinking, practical and applied skills of students. These approaches can be considered as special ways of acquiring knowledge with certain demonstrable skills as by-products. There is a growing body of evidence that demonstrates the effectiveness and efficacy of these approaches (Schmidt, van Der Molen, te Winkel and Wijnen 2009) particularly in tertiary engineering settings - as demonstrated by Kolmos et.al. at the Aalborg Centre for Problem Based Learning in Engineering Science and Sustainability, Aalborg University, Denmark (Aalborg has held the UNESCO Chair in PBL in Engineering since 2007). It is therefore possible that the marriage of PBL to STEM education, specifically in a secondary (and even primary) educational setting has the potential to address the aforementioned issues of national importance. Critically, the recent development of a New South Wales Board of Studies, Teaching and Educational Standards (BOSTES) endorsed school-developed course, iSTEM, has offered secondary school students an opportunity to participate in an innovative and engaging course that is designed to be largely delivered utilising these student-centred approaches.

Background

Defining iSTEM

Whilst many people are aware of the constituent parts of the term 'STEM', how these component parts are truly integrated in practice, in a syllabus, course, class and/or project, is much harder to comprehend. In the mid-2000s, Mark Sanders, Emeritus Professor in Integrative STEM education at Virginia Tech, along with colleagues Jim LaPorte and John Wells, became aware of the extent to which STEM was a "hopelessly ambiguous phrase" (2015, p .1). As a consequence, they pioneered a "tight operational definition" (Sanders & Wells, 2015, p.1 web) to underpin their STEM education graduate program at Virginia Tech. The focus being on the 'integrative' implementation of STEM:

Integrative STEM Education refers to technological/engineering design-based learning approaches that intentionally integrate content and process of science and/or mathematics education with content and process of technology and/or engineering education. Integrative STEM education may be enhanced through further integration with other school subjects, such as language arts, social studies, art, etc. (Sanders & Wells, Program Website, 2010)

This ‘integrative’ approach to STEM education soon moved into primary and secondary education circles in Virginia as contained within in a 2007-8 report from the Career, Technical and Adult Education (CTAE) Advisory Committee to Virginia Department Advisory Council on Instruction in Arlington Public Schools. This report added emphasis on the integration and application of enterprise or ‘soft’ skills to meet “tomorrow’s demanding careers and complex societal issues” (CTAE Report, 2007-8, p. 4). Furthermore, an often-overlooked element in this wider debate is the importance of taking a truly interdisciplinary approach to STEM as articulated by both Sanders and Wells (2010) above and the CTAE in its report. Hence, various derivatives and the growing number of expanding acronyms associated with STEM, like ‘STEAM’ (incorporating ‘art’), are therefore redundant within this particular definition. The CTAE also highlighted in their report a growing awareness of *how* STEM should be taught:

Classroom activity and inquiry that encourages teamwork, problem solving, ingenuity, innovation, creativity, self-reliance, and autonomy in an entrepreneurial spirit will prepare students for today's world (CTAE Report, 2007-8, p.5)

From these beginnings in Virginia, an interdisciplinary and *integrative* approach to STEM or ‘iSTEM’ spread across the United States and is now being popularised worldwide. It is within this theoretical framework that the (BOSTES) endorsed course has been created and implemented.

iSTEM – A NSW BOSTES endorsed course (SDBEC)

This innovative course was developed by Regional Development Australia (RDA, Hunter Region) through their Advanced Manufacturing ‘ME Program’ in consultation with local industries and Maitland Grossmann High School. It was designed to deliver those components of STEM (which are often taught separately) in an integrative way and “aims to contextualise curriculum content using problem based learning activities” (Sleap, 2014). The curriculum has been designed for Stage 5 students (Years 9 and 10) and was first endorsed by BOSTES in 2014 and delivered by seven local schools in the same year; that number is expected to increase to over 70 schools by 2017 (Me Program website). The iSTEM syllabus offers Stage 5 students an interesting array of engaging topics: STEM Fundamentals, Motion, Aerodynamics, Mechatronics, Surveying, Statistics, CAD/CAM and Design for Space. In terms of the stated aims of the syllabus, the first objective is quite telling: “students will develop inquiry and project based learning skills appropriate to STEM practice” (iSTEM Syllabus, 2016, p 12). Importantly, to satisfy the requirements of the iSTEM course students “must undertake a range of inquiry- based (IBL) and project based (PBL) learning activities which occupy the majority of course time” in order to avoid “simple transmission of content” (iSTEM syllabus, 2016, p. 10).

The proper integration of ICT into the iSTEM course is also in line with the General Capabilities contained within the new Australian Curriculum (ACARA, 2012 edition) as well as commensurate with the latest research indicating that the inclusion of “digital technology and computing science in school curricula is one component of ensuring that Australian school students are educated in the technical ICT capabilities that will be required in the future workforce” (Deloitte Access Economics, 2015). This innovative syllabus has the potential to redress the manifold issues associated with STEM education in this country.

Context

Project Based Learning (PBL) and 'iSTEM' at Parramatta Marist High

At Parramatta Marist High, a comprehensive all-boys Catholic systemic school in Western Sydney, Project Based Learning has been utilised throughout the junior and middle school curriculum since 2008. Presently, subjects with related content and skills are already grouped together in a rotation and are often formed into integrated projects when learning outcomes and intentions align. Students are assessed individually (formative) and collectively in their groups (summative). Groups usually comprise 3 to 5 members of mixed ability and projects generally last anywhere from 3 – 10 weeks (except Mathematics which mostly uses a Problem-based approach and is accelerated from Year 9 onwards). For distinctions between 'Project' and 'Problem' based learning, please see Savery (2006). The school is also a member of the *New Tech Network*, a not-for-profit organisation with over 180 Project Based Learning schools across the United States. Students across Years 7 – 10 use the *New Tech Network's* purpose-built learning management system known as 'Echo'. This affords teachers access to all projects panned across the network as well as other professional development opportunities. In terms of academic achievement in standardised tests, Parramatta Marist is a high-performing school in the NSW Higher School Examinations and has remained in the Top 100 schools for the best part of a decade and was also ranked 6th in the state in the 2015 HSC for Mathematics (all 2 unit and extension courses combined) – a significant achievement for a non-selective school.

In Stage 5 (Years 9 and 10), *all* students undertake *Information and Software Technology* (IST), which is normally an elective course in other secondary settings. This course is also in a rotation with other similar courses as outlined above. Additionally, students elect to do another course that can be school-developed; at Parramatta Marist, iSTEM has occupied this very flexible position within the school curricula since its introduction in 2015.

In this setting, iSTEM, as an elective course, can therefore be school developed and refined to suit the needs of students and staff as well as being deployed to the fullest extent through the pedagogy it was intended to be delivered. On this point, it is important to note that iSTEM should reach its full potential and achieve maximum effect within a whole school environment where PBL has became the main mode of instruction and curriculum delivery - or, to borrow a colourful analogy from Larmer, Mergendoller and Boss (2015) - the 'main meal'; *not* a 'side dish' to be picked at along the way; *nor* a 'dessert' only served up at the end; *nor* a 'Buffet' to pick and choose the elements you want *nor* akin to an end of unit project following 'content dump' to be used as an assessment of learning at the end of the course (Larmer, Mergendoller & Boss, 2015). Furthermore, to support the iSTEM program and other Technical and Applied Studies (TAS) classes, the school has invested in Fabrication Laboratory or 'FabLab' containing sophisticated machinery such as a laser cutter, 3D printers, CNC Mill, vacuum former and small wind tunnel.

iSTEM PBL Projects at Parramatta Marist High

In the initial project planning and programming phase, a backwards-design approach was adopted utilising Wiggins and McTighe's *Understanding By Design* (2005), and their mantra of 'beginning with the end in mind', as the basis. This offered planners an opportunity to 'reverse engineer' each unit to best ensure outcomes and objectives were met. As part of this process a 'matrix' was developed to understand how each element of STEM could be properly integrated within each unit. Subsequently, planners followed well-established school protocols in PBL design (and syllabus repackaging) and developed an iSTEM course program containing a series of projects containing the following critical elements:

- *Problem statement* or *driving question*

- Know and Need to Know List (used to identify prior knowledge and gaps within following reading of problem statement)
- Mapping of iterative skills to be introduced or and reinforced from project to project (e.g. CAD or portfolio)
- Authentic links to real world
- Individual or formative task
- Culminating group product or summative task
- A targeted *School Wide Learning Outcome* (based on the General capabilities of the Australian Curriculum) which is modelled, taught and assessed (e.g. teamwork)
- Activities, workshops, mini-lectures, online tutorials and other resources to scaffold the learning and 'benchmark' the process for students as well as to exploit some foreseeable 'teachable moments'
- Documenting the process through a portfolio

It ought to be noted that it is not always possible to create one project that touches upon every 'fundamental' within a unit within a syllabus and nor should this be attempted; however, through engagement and the process of learning engendered in a PBL environment, it becomes easier to 'lead' students to learning and highlight the interrelatedness of sub-domains within and across disciplines. It is possible to create authentic and engaging projects within existing mandatory school syllabi but it requires some creativity. Fortunately, the iSTEM course is flexible and as an elective (at this school at least) it can be even more targeted. A snapshot of four currently developed iSTEM PBL units are given below (All units last 10 weeks – the equivalent of one school term in NSW).

Engineering fundamentals project

As the name implies, this introductory unit in the syllabus aims to introduce students to the fundamentals of an integrative approach to STEM including investigation of principles (basic material science, material properties, fluid mechanics, electricity, magnetism and thermodynamics), fundamental mechanics, use of technology and problem solving. It is also designed to introduce students to the iterative design process and immediately engage students with the course. This is achieved by a task involving construction of a hydraulics kit to demonstrate basic principles and build teamwork skills. The project itself is centred on the problem statement: "Using the items contained within your 'goodies bag', invent something that you can pitch to the investors in *The Shark Tank*" - a reality show where inventors present their ideas and seek financial support from investors (the show being known variously as *Money Tiger* in Japan or *The Dragon's Den* in the UK). Contained within each group's 'goodies bag' were a simple invention kit (Makey-Makey) and other items like balsa, tubing, pins, glue, plastic syringes that students could use to invent. In this instance, all groups were constrained by the contents of the 'goodies bag' (as opposed to other constraints in later projects). Whilst ostensibly designed to demonstrate the basic principles of fluid mechanics (specifically hydraulics), this project touches upon a range of other fundamental principles of STEM outlined above. There are smaller tasks that students undertake as well as tutorials (online or direct instruction) to cover aspects like mathematical principles underlying the project – this is all done in aid of providing a solution to the problem offered. The soft skill assessed in this project was 'presentation skills'.

Mechatronics project

The focus of this project is on the 'design and development of solutions to problems associated with combined mechanical and electrical systems' (iSTEM syllabus, 2016). Moreover, it attempts to develop upon the knowledge and skills from the introductory project with increasing sophistication. The following driving question underpins the project: *How can we utilise mechatronics to support people who, through a physical disability, struggle with day-to-day tasks?* A subsequent problem statement establishes the practical challenge facing student groups:

We at 'Enabling the Future Mechatronics Pty. Ltd.' are looking for future engineers to help design, construct and launch a device that will help people who have lost a hand or arm. The winning design will be one that shows a) creativity b) functionality c) aesthetic appeal and d) follows the design process.

Throughout this project, students engage more deeply with principles of mechanical and electrical systems through specifically designed tasks (e.g. Lego Mindstorms) which builds knowledge and skills which can be applied to *their* solution to the problem; and, more broadly, increases their understanding of how mechatronic engineering can address social and health problems as indicated in the driving question. Consequently, the soft skill assessed in this project was 'personal and social capabilities'. Students are also afforded time for self directed design activities. In this project, students are introduced to basic CAD (Sketchup), more sophisticated coding through the prototyping platform Arduino as well as the use of algorithms. It is in this project that material science is also introduced. As seen in figure 1, the prototype and refined design of an artificial hand design has been printed on a 3D printer. In Figure 2, students are attaching circuitry to their design of mechatronic hand.

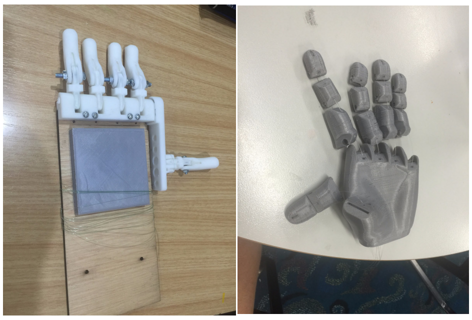

Figure 1: Prototyping and refined design produced on 3D printer

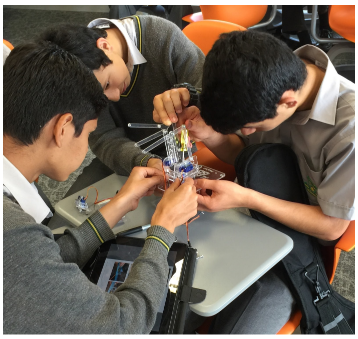

Figure 2: Students assembling mechatronic hand

Aerodynamics project

The focus of this project is on the 'engineering concepts related to aerodynamics' (iSTEM syllabus, 2016). The project is underpinned by the driving question, *how could a drone be used to save a human life in a natural disaster?* In practical terms, students design, fabricate, assemble and test a quadcopter to demonstrate the feasibility of its use in emergency situations and relate the potential benefits and drawbacks. Whilst each group has the same motors and control systems they must learn to assemble these, consider the materials, design and dimensions of the airframe as well as the weight distribution (e.g. the placement of the batteries). Again, following an iterative design process, students again use CAD systems to design and prototype their airframe, first in cardboard cut on the laser cutter (Figure 3), before fabricating in their preferred material (wood, plastic, metal or a combination thereof) and assembling. Students learn the principles of aerodynamics - like Bernoulli's principle, Newtonian physics, trigonometry and even differential thrust – firstly by using a programmable Parrot drone to negotiate a triangular course (the distance and interior angles supplied) and secondly, by flying their own quadcopter!

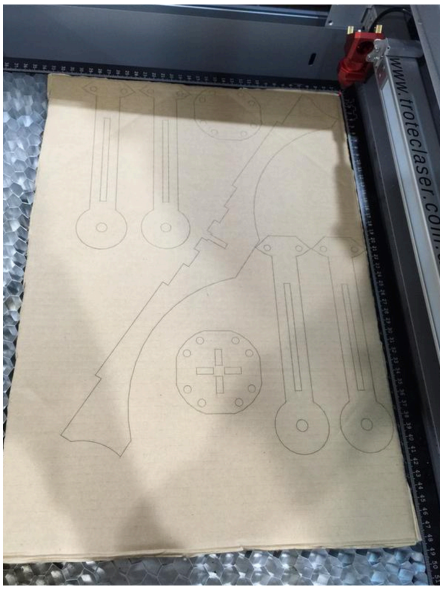

Figure 3: Prototyping and testing CAD design using cardboard in laser cutter.

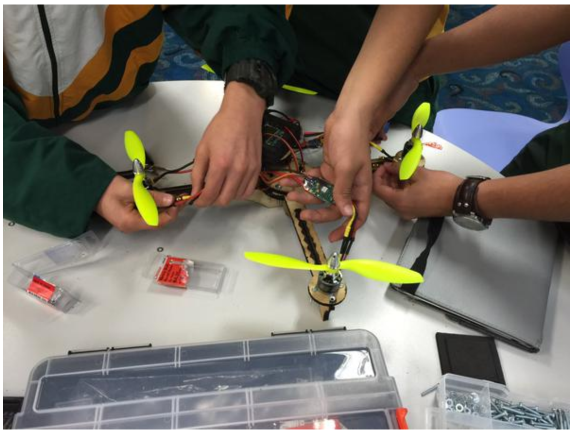

Figure 4: Students assembling drone on their design airframe (cut on the laser cutter).

Hydrodynamics project

The focus of this project is on the engineering concepts related to hydrodynamics. In a slight divergence from the iSTEM syllabus, this project is underpinned by the driving question, *how can you optimise boat design for racing on water?* In this project, a local engineer with experience in boat-building introduced students to concepts related to hydrodynamics (e.g. hull design, hull construction, hull speed, bow waves) and challenged students to design, fabricate, test, re-design and then race their boats against other groups (Figure 5). This project also aimed to increase proficiency in CAD by introducing students to Autodesk Inventa (Figure 6). Each group designed their hull, milled a prototype out of polystyrene (using the CNC machine) before using a vacuum former to cover their hull in plastic. Each hull design is tested in a purpose built test tank. In a twist, a second challenge affords students an opportunity to design their own propeller, which is fabricated using a 3D printer, and attached to their standard solar powered motor – leading to a repeat in the design process. Whilst each project is still evolving and being refined, it is clear that the iterative design process and an integrative approach to STEM are both key focal points of this course.

Figure 5: Local engineer and self-taught boat builder, Mr Ian Jane, talking about hull design, materials used in hull construction and calculating hull speed.

Figure 6: Students using Autodesk Inventa to explore and design hulls for their boat.

Measuring student engagement and understanding

Objectives

The objective of this paper was to illustrate how utilising a PBL approach in the delivery of the iSTEM course can enhance student learning as well as measuring student engagement and their perceptions of the suitability of PBL to iSTEM and its effect on their learning.

Method

All Year 9 iSTEM students (n=58) were surveyed, interviewed and observed in class for levels of engagement. Teacher observations were also recorded. The survey consisted of four questions utilising a 5-point Likert scale ranging from *strongly disagree* to *strongly agree*. Students were also asked to respond to five open-ended questions and provided with an opportunity to give feedback. The sample feedback from students to these five open-ended questions is displayed in tables 2 – 7 (below) with the four most ‘typical’ responses elicited from students given in each. Lastly, students were also selected at random and asked about their experiences in iSTEM.

Results and Discussion

Students were asked to rate their levels of engagement, the suitability of PBL and iSTEM, and the effect of iSTEM on their skills and learning. The average ratings are contained in Table 1.

Table 1: average ratings from 58 Year 9 iSTEM students

Questions:	**Average Rating (/5)**
Do you find the subject iSTEM engaging?	4.6
Do you think iSTEM is suited to PBL?	4.6
Do you think taking iSTEM has helped in your other subjects?	4.3
Do you think iSTEM has helped you develop your skills?	4.5

Overwhelmingly, students believed iSTEM is engaging, suitable to PBL and helpful to their wider learning and skill development. Tables 2 and 3 offer insights into what aspects students found most engaging and least engaging concerning iSTEM.

Table 2 – Most 'typical' responses elicited from 58 iSTEM students

Question: What elements of iSTEM do you find MOST engaging?	
Student 1	The design and construction phase of projects
Student 2	I believe the control over our solution is the most engaging part of this subject.
Student 3	The element of iSTEM that I find most engaging our the way that the team is able to complete the project and not have the teachers tell us what we need to be done, but let us decide what we need to do and complete.
Student 4	Learning new things and doing things that I didn't think I could

Table 3 - Most 'typical' responses elicited from 58 iSTEM students

Question: What elements of iSTEM do you find LEAST engaging?	
Student 1	I find the research phase the least engaging even though it's important
Student 2	Writing out portfolios and presentations and keeping a log of stuff
Student 3	The theory I find is the least engaging
Student 4	I don't find any part of iSTEM not engaging.

Despite some aspects lacking engagement for students, this has not greatly affected their overall and very positive rating (4.6/5). For students in their third year of a PBL-oriented education, they rated the suitability of PBL and iSTEM very highly (4.6/5). This is noteworthy given their level of experience in this pedagogical model across all subjects in years 7 to 9. Table 4 illustrates the elements of iSTEM these students felt were most compatible with a PBL approach.

Table 4 - Most 'typical' responses elicited from 58 iSTEM students

Question: What elements of iSTEM do you think are suited to PBL? Why?	
Student 1	To build an object we get put into groups to work together, collaborate, share ideas and everyone gets a job to do.
Student 2	Different design ideas from group members allow the team to come up with the best design.
Student 3	Teamwork, problem based learning, communication, leadership and organisation.
Student 4	You are able to work in teams like a design team would in the real world for an engineering product. Everyone has a role to play in order to meet the deadline.

Similarly highly rated by students was their recognition of the help this integrative STEM course has offered them in their other subjects (4.3/5). Table 5 offers a sample indicative of the responses offered by students; unsurprisingly, iSTEM has proven most helpful in related or component courses.

Table 5 - Most 'typical' responses elicited from 58 iSTEM students

Question: In what ways has iSTEM helped you in other subjects? (Please refer to the subjects by name in your response).	
Student 1	iSTEM has specifically helped me in Information, Software and Technology (IST) because I had a very basic imagination in designing and having another subject to assist me in design has helped me in IST.
Student 2	In science we are learning about the Newton laws and as I have already learnt it in iSTEM it gave me a boost.
Student 3	It has helped me in maths.
Student 4	Newton's Laws of Motion have helped us in science and has helped us get ahead.

Students also rated highly the skill development that the iSTEM course has afforded them (4.5/5). Typically, as shown in Table 6, responses were centred on skills such as time and group management and organisation as well as creative and problem solving.

Table 6 - Most 'typical' responses elicited from 58 iSTEM students

Question: What skills do you feel are maximised in iSTEM?	
Student 1	I believe that time management skills and group skills are maximised in ISTEM
Student 2	Engineering, improving, designing, and thinking outside the box.
Student 3	Management, leadership roles and organisation
Student 4	My creative skills have definitely improved. My creativity has gone to a new level and I can conjure good ideas more easily and faster.

Lastly, students were asked to comment freely on iSTEM or the use of PBL in the course. The results shown in Table 7 are overwhelmingly positive regarding the course and the deployment of PBL.

Table 7 - Most 'typical' responses elicited from 58 iSTEM students

Question: Please feel free to make other comments about iSTEM or the use of PBL in iSTEM.	
Student 1	iSTEM is one of the best courses I have ever taken.
Student 2	iSTEM is a great for teamwork and technical thinking
Student 3	I get a lot of help from my groupmates (sic) which makes learning easier especially for the harder stuff
Student 4	iSTEM is probably one of the most engaging electives out of all, it successfully integrates PBL in an extensive manner whilst allowing us to express our knowledge.

This snapshot of student perceptions of iSTEM is echoed by teacher and researcher observations of the students within class or 'Fabrication Laboratory'.

Conclusions and Recommendations

It is quite evident from student feedback, teacher observations and project development that iSTEM is, even in its infancy at the school, an engaging course that is most suited to and best delivered fully within the framework of Project/Problem Based Learning approach – as intended by the developers of the syllabus. Clearly, this very limited 'snapshot' into iSTEM projects and student perceptions is a starting point for greater exploration and has offered as many next steps and recommendations as conclusions. Some of those next steps include a greater focus on the development of appropriate Maths and Science resources for each project; greater emphasis on material science; consideration given to staffing challenges should the course be expanded into Year 10; establishing clearer links with HSC preliminary course syllabi; greater industry engagement and the establishment of tertiary links and, lastly, an increasing focus on growing authentic links with professionals in the field, for example, linking with nearby Westmead Hospital Amputee Service (the largest in NSW) for the mechatronic project.

Limitations

Whilst the self-reported high levels of student engagement and perceived enhancement of learning is promising, it is worth noting than an oft repeated limitation of studies into pedagogies which diverge from the norm include the notion that students (and teachers) *know* they are part of an innovation and may adapt their behaviour accordingly (Norman & Schmidt, 2000). Additionally, the difficulty in obtaining a similar 'control' group in other PBL or 'traditional' school environments can limit studies into the effectiveness of PBL at times (Norman & Schmidt, 2000). However, there is still merit in these small-scale studies as a starting point for more detailed investigations in the future.

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