# A CASE STUDY OF INTEGRATED MULTIDISCIPLINARY PROJECT-BASED LEARNING IN POLYTECHNIC EDUCATION

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## ABSTRACT

Project Based Learning (PBL) is an innovative pedagogical approach to applied learning that instils critical life skills into students, making them ready to face the challenges of the 21st century. Integrating multidisciplinary and team-based instruction into the PBL makes the approach even better because students can acquire teamwork, communication, and life-long learning skills and develop an appreciation for other disciplines. This paper describes a case study of the Integrated Multidisciplinary Project (IMP) programme conducted at Nanyang Polytechnic, Singapore in which students from different faculties such as engineering, business management, chemical and life sciences, health sciences, and interactive and digital media came together to work on real-life projects over a period of six months using an underlying methodology of Design Thinking. All twelve teams successfully developed working prototypes, presented their projects in public settings, demonstrated growing levels of diverse technical and life skills through the project and reflected on their learning journey in the end to identify their strengths and areas of improvement. All the students provided positive feedback on the impact that the IMP programme had on their personal and professional development. Finally, this paper also examines the challenges faced in the implementation of IMP and discusses the potential improvements to the programme.

## KEYWORDS

Integrated Multidisciplinary Project, Project Based Learning, Real-Life Projects, Design Thinking, 21st Century Skills, CDIO Standards: 3, 5, 7.

## INTRODUCTION

Nanyang Polytechnic (NYP) is a public institute of higher learning in Singapore offering pre-employment training and continuing education and training diploma programmes to post-secondary school students and adult learners respectively. The polytechnic comprises seven schools in faculties of engineering, business management, life sciences, health sciences, design, digital media and information technology. It prepares students for the workforce using a contextual and applied curriculum, developed and kept relevant in collaboration with the industry. A typical diploma course is a three-year programme with core foundational modules in the first year, specialised modules in the major of study in the second and third years, concluding with industry internship and capstone project. Project based modules are interspersed within the first two years but most are individual student projects aimed at deepening the knowledge and skills in a single discipline at a time. The capstone project, a dedicated twelve-week period, is also primarily an individual student project based on an authentic problem sourced from the industry (Nanyang Polytechnic, 2018).

Increasingly, polytechnic graduates face complex challenges in their professional careers that require attributes such as resilience, creativity and multidisciplinary skills. There is also a

global trend where employers place higher emphasis on 21$^{st}$ century skills than technical skills as necessary attributes from their workforce. (Reeve, 2016). Therefore, the curricula of higher learning must incorporate effective platforms, such as collaborative project based learning, for students to develop and demonstrate these attributes (Zhou, 2012). The Integrated Multidisciplinary Project (IMP), is a multidisciplinary project based learning (PBL) programme, that was conceived by Nanyang Polytechnic with the following five aims:

1. To engage, enable and empower students, through the medium of multidisciplinary projects, to undertake their own applied learning journeys.
2. To deepen and diversify student skills, not only in technical domains and project execution but also 21$^{st}$ century skills, such as collaboration, communication, critical thinking and problem solving.
3. To build students' resilience to persist and perform in challenging situations.
4. To enhance the students' presentation and public speaking skills.
5. To inspire and promote a culture of innovation whilst providing a risk-free environment.

## BACKGROUND

PBL is a student-driven and teacher-facilitated approach to applied learning. Students work on a project, relevant to their domain of study, to develop solutions to real-life problems. They are guided through the process of solution development using sound methodologies under the supervision of teachers, who play the role of facilitation rather than active coaching (Scarbrough, 2004). The domain knowledge required in the project is provided to the students in advance or just in time and is applied in the project thereby enabling effective knowledge retention. Problems that present themselves during the project are solved using sustained inquiry of the underlying subject thereby allowing the students to deepen their skillsets. Students are assessed more on the process of execution and inquiry and less on the actual project outcome. Allowing students to make their own choices and honouring their individual learning styles or preferences is key to success in the PBL. Students flourish under this approach to applied learning. They gain valuable skillsets that build a strong foundation for their future in the global economy (Bell, 2010).

There are seven essential guidelines that are the gold standard for implementing PBL (Buck Institute of Education, 2015):

1. *Authenticity*: The projects are defined to solve a real-world problem. This ensures that the projects are not trivial, the learning outcomes are substantial, the requirements gathering phase is real and the project outcomes can be validated.
2. *Sustained Inquiry*: The project must have elements of problem solving that require a long period of critical thinking and analytical reasoning. This ensures that students deepen their knowledge and skills in the subjects associated with the project.
3. *Challenging Problem or Question*: The project must be challenging enough to allow the students to not only apply their own skills but also broaden and diversify their skills.
4. *Student Voice & Choice*: The students must be empowered to take charge of their learning journeys in PBL so that they take ownership of the projects and therefore commit themselves to extract maximum benefits from the project.
5. *Critique & Revision*: There must be regular opportunities for the students to obtain feedback on their projects from the supervisors and the end users so that they can learn to accept criticism, analyse the issues raised and apply their skills to resolve them.

6. *Public Product*: The students must have the opportunity to present their project to the public so that they can hone their presentation skills, learn to respond to different people with different views.
7. *Reflection*: The students must reflect on their PBL journey so that they can appreciate the importance of the process of project execution, learn from their actions and reactions to technical, personal and interpersonal issues and identify areas of improvement.

Multidisciplinary PBL is an enhanced version of the PBL in which a team of students work on a real-life project that involves the inquiry and application of multiple disciplines of study. By simulating real-life project environments, processes and expectations, but within the safe settings of the school, multidisciplinary PBL prepares students for the demands of the 21st century workplace, identified as early as the 1990s (Jahanian & Matthews, 1999). Each student not only applies and deepens his/her own domain skills in the project but also acquires the knowledge of other domains brought in by the other team members and the participating industry (Finnie et al., 2014). Students learn to work cooperatively in teams, thereby enhancing their collaboration and communication skills. They learn to appreciate the differences in disciplines, people, environments and expectations, and persist as a team towards successful completion of their projects. Students are assessed on the process and the project outcome, both as teams and as individuals (Stozhko et al., 2015). Several papers in literature have reported successful implementations of multidisciplinary student project programmes and how these programmes benefitted the students, the industry as well as the educational institutes themselves (Macklin et al., 2015, Behdinan et al., 2015 and King & Hermann, 2015).

**IMP METHODOLOGY**

The IMP was conceptualised to provide a multidisciplinary PBL platform to final year students from different diplomas to collaborate with each other in teams to work on real-life projects.

***IMP Model***

The IMP model is shown in Figure 1.  The IMP is integrated within the curriculum so that students are able to devote focussed time and attention to the programme and the organisation is able to dedicate resources for its implementation. Therefore, the existing capstone project module that is offered in the final year is chosen as the vehicle to offer the IMP. The IMP is graded and contributes to the GPA of the student and is aligned to the Conceive Design Implement Operate (CDIO) standards 3, 5 and 7 which are associated with 'Integrated Curriculum', 'Design-build experiences' and 'Integrated Learning Experiences' respectively (CDIO, n.d.). The CDIO Initiative focuses on educating students to be able to participate and, eventually, lead the conception, design, implementation and operation of systems, products, processes and projects. According to Lunev et al. (2013) and Takemata (2013), project activities within CDIO include problem clarification, idea generation, selection and substantiation and prototype development, evaluation and refinement, which are essential underpinnings of the IMP concept.

In line with the PBL guidelines, the projects in the IMP are authentic, aim to solve a challenging problem and have elements that require sustained inquiry from the students. Therefore, referencing from Singapore's Smart Nation Initiative (Smart Nation and Digital Government Office, 2017), four real-world themes, namely, 'Smart Healthcare', 'Smart Mobility', 'Smart Homes' and 'Sustainable Living' are chosen for the programme.
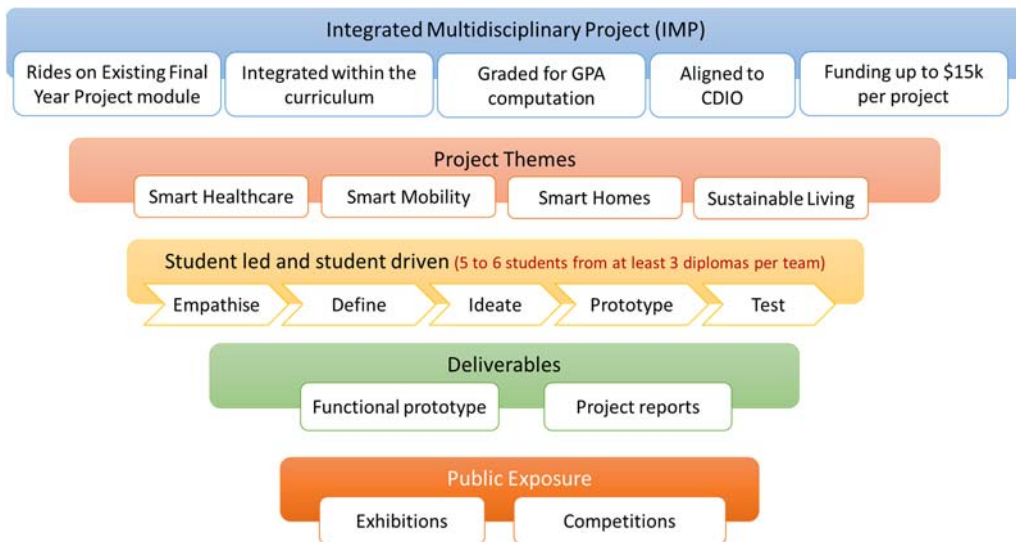
**Figure 1: The IMP Model**

In order to align with the PBL guideline on 'Student Voice & Choice', the IMP is designed to be 'Student Led and Student Driven'. Therefore, students form their own teams of five to six members, as long as there are representations from at least three different diplomas per team to ensure the multidisciplinary nature. Students also propose their own projects chosen from one of the four themes above. To ensure that the students understand the importance of being empathetic to the end users' needs and that they have higher chances of succeeding in their projects, all the teams are taught the 'Design Thinking' principles (Melles, Howard, & Thompson-Whiteside, 2012), which they can use to underpin their project execution.

All teams are required to deliver 'working' prototypes of their projects in 'Minimum Viable Configuration', which is at a level of completeness where the main objectives of the project are met and demonstrated. Each team is also required to submit a project report, documenting the project in enough detail for referencing by future cohorts. The teams is assessed based on the functionality of the prototypes and quality of their reports.

Finally, there are public exhibitions and competitions for the teams to pitch their projects to the public, obtain end user feedback and compete for awards. This fulfils the requirement of PBL guideline of having a 'Public Product'.

*IMP Implementation*

The IMP was implemented as a pilot study in 2017 by the School of Engineering (SEG) to evaluate its concept, processes and outcomes. The target was to recruit 5% of all final year students from all eleven diplomas in SEG and a maximum of six students from each of the other six schools (business management, life sciences, health sciences, design, digital media and information technology). A team of 19 supervisors and 50 domain experts were chosen from the teaching staff of SEG for supervising and guiding the IMP students.

*Staff Preparation*

The IMP is a deviation from the conventional project based supervision. While the intent is to promote student led, student owned projects, it is essential that the supervisors understand

their roles in the execution of the IMP while ensuring that each student from different domains has a role to contribute significantly. Therefore, the supervisors were trained in facilitation techniques and best practices in student team management for multidisciplinary projects. With the diverse skills required in each project and the varied composition of students in each team, additional staff with expertise from various technology specialist centres of the school were appointed as domain experts to support the supervisors in domain specific matters. Supervisors and domain experts work closely throughout the IMP programme.

*Student Selection*

Students were selected for the IMP programme on a voluntary basis without any criteria on past academic performances. Using roadshows, students were informed about the programme, its requirements and its benefits while also clearly explaining the other alternatives the students had in their final year such as individual capstone projects, overseas internships and local internships before they applied for the IMP. This way, the students were able to decide judiciously based their educational and career goals.

The IMP was implemented in 3 phases:

1. *Planning Phase*
   In this phase, the IMP students formed project teams, learned design-thinking principles and identified real-world problems within their chosen themes to pick their projects. The teams used the 3-month phase to research about their projects, scope them, internalise the design thinking methodology, and identify and purchase the components needed for their projects with guidance from their supervisors and domain experts.

2. *Execution Phase*
   The IMP teams had twelve weeks to execute their projects and produce a working prototype. In this period, the students worked full time as a team with each member assigned roles according to their individual disciplines. By cross-pollinating ideas and sharing of knowledge, students were exposed to disciplines that they normally would not have experienced if they had chosen to do individual capstone projects.

   The students were in complete control of their projects right from planning, scheduling and sourcing to execution and validation. Supervisors played the role of facilitators, guiding the teams in using the design thinking methodology, pointing them to sources of knowledge for self-help and course correcting only if required. The domain experts provided targeted assistance in specific technologies that the supervisor did not have expertise in on an on-demand basis. Any conflicts arising within teams were resolved either through negotiations among the students or interventions from the supervisors.

   Once the prototypes were developed, the students conducted functional tests to verify the working of the prototypes and introduced their prototypes to the end users for trials in order to validate their projects. Some teams with business students produced business plans to take the product to market whereas teams with students from digital media produced marketing campaigns through websites, blogs and advertisement videos.

3. *Exhibition Phase*
   In this phase, students worked outside their curriculum hours to participate in both internal and external competitions and elevator pitch sessions at public places such as libraries and displayed their projects in public exhibitions. This phase introduced the students to public

speaking, gave them opportunities to enhance their presentations, taught them how to use elevator pitches to convince stakeholders about the promise of their projects and provided the teams with valuable feedback from members of the public comprising people from different age groups, cultures and backgrounds that enriched their learning.

*Student Assessment*

The IMP students were assessed both as teams and as individuals. The assessment components, for teams, were the project outcome (prototype, report and presentations) and teamwork (team dynamics, cross learning among members). The assessment components, for individuals, were professional attributes, personal soft skills and contribution of technical or domain competencies in the project.

Two assessments were conducted, one in the mid- term and one at the end in seminar styled events in which each team presented their project to an audience comprising the panel of assessors, supervisors, domain experts and other IMP teams. This way, teams could learn from each other and have the opportunity to provide peer feedback. During the assessments, the panel graded only the presentation and project outcome components whereas the supervisor assessed the teams continually through the twelve weeks on the soft skills and technical or domain competencies components. The supervisor's assessment contributed 75% of the total grade whereas the assessor panel's assessment contributed 25% (Figure 2).

| | First Assessment | | | Second Assessment | | | | | Overall Score |
|---|---|---|---|---|---|---|---|---|---|
| | Attribute (Individual) | Technical (Individual) | Presentation (Group) | Attribute (Individual) | Technical (Individual) | Documentation (Individual) | Teamwork Performance (Group) | Presentation (Group) | |
| | 10% of Overall | 10% of Overall | 10% of Overall | 10% of Overall | 20% of Overall | 10% of Overall | 15% of Overall | 15% of Overall | 100% |
| Marks | /10 | /10 | /10 | /10 | /20 | /10 | /15 | /15 | |
| Staff Signature | | Supervisor | Panel | | | | Supervisor | Panel | Supervisor |

**Supervisor: 75%     Panel: 25%**

**Figure 2: IMP Student Assessment Form**

**FEEDBACK AND REFLECTIONS ABOUT THE IMP**

This section presents the feedback obtained from the students, supervisors and the IMP programme committee.

***Students' views on their learning experiences***

All the teams provided their feedback on the IMP via testimonials. Individual students also provided their feedback via email to the supervisors and the committee. Students recognised teamwork, collaboration, peer learning, conflict management, and project planning and management as their major learning outcomes from the IMP. Excerpts from the testimonials are as follows:

*"Throughout the entire IMP, we learnt that teamwork is very important and time management is very crucial. Rather than giving up on challenges, facing them together made us a better team."*

*"This has been a very enriching and interactive experience for all of us. We were able to use knowledge from our different courses to complete the project. We learnt new skills that we do not specialize in our individual courses."*

*"During the course of the project, we have had plenty of conflicts. Nevertheless, our desire to see our unique project succeed and delve into something beyond our individual capabilities helped us forge strong relationships with one another."*

*"What we benefited most is that we worked together as a team, overcoming challenges that none of us expected in the beginning. We learnt different skills from each other. The experience of dealing with matters such as project planning, purchasing, execution and problem solving were pretty challenging but equally satisfying."*

The students also provided feedback on improving the IMP programme ranging from a more structured approach for consultation with domain experts to incorporating peer assessments into the formal assessment system.

### Feedback from Supervisors

According to the supervisors, IMP provided a rich and dynamic learning environment for the students. They observed that the motivation among the students was intrinsic and they had to do very little to motivate them through the project. They noted that since the students had voluntarily opted for the IMP, they were committed to the programme and often stretched beyond their capacities to ensure that their projects succeeded. From the supervisors' perspective, collaborating with each other, managing interpersonal and professional relationships, doing formal presentations, managing projects, accepting and delegating responsibilities, and using creativity to solve problems were major learning points for the students. The second major learning outcome was cross learning and application of skills that naturally resulted in broadening the competencies of the students.

As for improvements, the supervisors suggested that the projects could be defined and scoped by the school instead of the students themselves because often the project scopes creeped and put the projects in danger of not completing. The supervisors had to intervene in some instances, sometimes against the team's wishes, to ensure that the teams completed their projects in time. Though the teams were initially disappointed, in the end they appreciated the intervention. The supervisors also agreed with the students' suggestion that the consultation process with the domain experts could be more structured to avoid delays.

### Reflections from the Programme Committee

The IMP was introduced by the polytechnic to reinforce its efforts to develop all-rounded graduates equipped with 21st century skills. By deepening discipline-specific skills, gaining skills from other disciplines and applying close articulation between theory and practice, the students honed their technical proficiencies. The use of design thinking methodology that stressed the importance of empathising with peoples' needs made the students aware of the socio-economic aspects of projects rather than just the technical ones. Because of the challenging and authentic nature of the projects, students had to solve problems using their combined ingenuity and resourcefulness. Finally, the students were exposed to a wide range of authentic professional situations such as forming teams, grappling with leadership, responsibilities and conflict management issues, communicating through meetings, writings

and presentations, and setting and managing their own goals. The committee, having engaged with all stakeholders, also noted a few areas of improvement:

1. Improving the consultation process with domain experts to ensure effective coordination among staff and students without affecting the projects.
2. Providing active guidance in assignment of individual roles and responsibilities to students in a team rather than leaving it entirely to them.
3. Increasing differentiation of grades within the team, introducing peer assessments and increasing the frequency of student feedback.
4. Including more students from the design and information technology disciplines to have more diversity of skills and knowledge in the programme.

The committee also observed areas of concern during the pilot study which were similar to those identified by Berglund et al. (2007) in their multidisciplinary project based learning programme:

1. *Project Scope Creep*: As students work on their projects and get excited about the solutioning possibilities, they tend to keep adding features and functions to their prototypes thereby risking successful completion of the minimum viable product in time.
2. *Visible cooperation problems in groups*: Observed in cases where there have been differing opinions on solutions, differing personalities, disagreements on distribution of workload between team members and members not being able to meet their set targets.
3. *Non-visible cooperation problems*: This happens when the team does not acknowledge problems that exist within the team and cover up for them to not let the team look bad.
4. *Supervisory cooperation problems*: Contrasting styles of supervisors and domain experts that the same team of students interact with can create a mismatch of expectations among students.
5. *Supervisor-centred (proactive) vs. Student-centred (reactive) supervision*: This is a difficult calibration because the supervision approach must be carefully tuned to the characteristics of the team as well as personal traits of individual team members.
6. *Students stick to what they have in common*: observed in some teams as the members get to know each other well and find their "common denominators" after which they become reluctant to look for new ways of working. They take the safe route that all team members can relate to even though better solutions could be found.
7. *Student Assessment*: Students may not get regular formal feedback on their performance, given that there are only two assessments (mid-term and final) and that they find it difficult to document their concerns during the project.

## CONCLUSION

The pilot study of the IMP was successfully conducted at Nanyang Polytechnic. The students involved acknowledged the benefits and learning outcomes of the programme. Supervisors observed the positive transformation of the students with respect to collaboration, communication and presentation skills, professional skills, and an increased intrinsic motivation for learning. Overall, the general experience is that students were much more committed, involved and driven than is normally the case in individual capstone projects.

Putting together a high performance team of teaching staff and educating them in PBL philosophy to provide effective and targeted supervision to the students is key to implementing

programmes such as the IMP. Another key requirement is to provide empowerment to students to form their own teams, propose their own projects and take charge of project execution. It is important that the students are clear that the learning outcome is more about the process of executing and managing their projects rather than the actual prototype or solution. The pilot study also revealed areas of improvements, both from the perspective of the students and the supervisors. The programme is resource intensive, needing a team of 69 academic staff to work with the students for a period of one year from planning to execution to exhibition phases. The IMP role is in addition to the staff's regular teaching and non-teaching roles, requiring active prioritisation at the staff and department levels.

The benefits of multidisciplinary PBL far outweigh the demands of running such a programme. The results reported in this paper have given the polytechnic the confidence to establish the IMP as a mainstream programme in the curriculum that is pervasive across all schools of the polytechnic.

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