ŌTAUTAHI CHRISTCHURCH AOTEAROA NEW ZEALAND
35TH AUSTRALASIAN ASSOCIATION FOR ENGINEERING EDUCATION ANNUAL CONFERENCE
8-11 DEC 2024
THE ENGINEER AND THE WORLD

The Effectiveness of Applying Project-Based and Work-Integrated Learning Educational Strategies in Engineering Courses

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ABSTRACT

CONTEXT

Engineering educational institutions consistently emphasise incorporating practical learning skills in their curriculum to enhance students' professional knowledge as well as cognitive knowledge. One of the teaching strategies to accomplish this goal is project-based learning (PBL) which promotes opportunities for students to develop solutions for real-world problems. Compared to direct instruction in traditional education, PBL provides opportunities for better student engagement as they are developing a product. Another educational approach that is receiving high attention from curriculum developers in engineering education is Work-integrated learning (WIL). The intended outcome of WIL is to teach students current work environment skills in the field and increase graduates' employability.

PURPOSE OR GOAL

In this study, a teaching approach that includes both PBL and WIL was developed to investigate student experience. The model was reviewed to assess the inclusion of professional and cognitive skills in the learning outcomes, as well as the effectiveness of the educational model in improving the graduates' employability. We also evaluated the effectiveness of integrating real-world scenarios into educational programs through WIL and PBL methods and their impact on student learning success.

APPROACH OR METHODOLOGY/METHODS

To incorporate real-world projects and learning environments, a collaboration with industry is essential. Therefore, the projects were designed in partnership with external industry stakeholders through Innovation Central Perth (ICP) and academic staff from Curtin University. ICP invites student expressions of interest to participate in finding solutions for industry problems in the form of internships, work experience, and campus-based projects. Successful candidates work directly with external stakeholders and academic mentors to ensure both professional and theoretical learning are incorporated into the project work.

ACTUAL OR ANTICIPATED OUTCOMES

The study was conducted from 2021 to 2023. Throughout this two-year period, student learning success, measured through employability metrics, demonstrated a remarkable success rate of 90% employed. The program also shows a high level of satisfaction from companies involved, at 98%. Moreover, there was an increase in industry engagement with the university.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

In conclusion, the ICP project case studies supported the effectiveness of the engineering educational strategies that integrate PBL and WIL. It promotes professional skills, student engagement and autonomy in knowledge construction. The study shows that this educational model improved students' critical thinking, collaboration, teamwork, and problem-solving skills in an authentic learning environment. According to the findings, it also directly contributes to the employability of the graduates.

KEYWORDS

Work-integrated Learning, Project-based learning, Authentic learning environment

Introduction

The practical learning skill is an imperative part of the engineering education. The two teaching approaches that receive great attention from universities and educational institutions are Work Integrated Learning (WIL) and Project Based Learning (PBL). These methods provide work-ready skills to students and enhance their learning experience. In this study, Innovation Central Perth (ICP) was selected as an experimental environment to investigate the effectiveness of WIL and PBL implementation in engineering courses and evaluate the student experience via metrics such as employability.

While industry experience is essential in degree programs, students often face challenges in finding relevant WIL opportunities and securing industry connections. This is often due to a lack of contacts or skills needed to identify suitable projects. Innovation Central (IC) bridges this gap by partnering with universities to help students connect IC projects to the WIL and PBL course requirements. This is not possible without the collaboration with academics that ensures projects seamlessly align with university learning objectives. This structured approach enables students to fulfil their course WIL requirements and gain real-environment hands-on experience with industry.

ICP is one of six Innovation Centrals (ICs) in Australia (*Innovation Central*, 2022) and its collaboration with the global tech company Cisco, along with access to a broader network through the National Industry Innovation Network (NIIN), offers students greater opportunities to connect with various organizations and gain additional trusted advisors.

The partnership between ICP and Curtin University academics allows for the alignment of projects with course learning objectives and industry needs and, enables students to apply their theoretical knowledge to real-world challenges while highlighting the effectiveness of university teaching.

This program recognises that many students, particularly those without prior experience, find it challenging to connect theoretical knowledge with real-world applications. IC in general provides these students with opportunities to work on industry-relevant projects, allowing them to gain practical experience. This commitment to inclusivity also extends to international students, who often face additional challenges in the Australian job market. By providing WIL opportunities and PBL education, IC promotes diversity within its programs.

Teamwork is a fundamental aspect of the IC's programs, as students engage in projects within collaborative environments. This approach enhances communication, project management and teamwork skills while facilitating effective collaboration among individuals from diverse backgrounds and disciplines.

For instance, in the (Innovation Central Canberra) ICC student programs, more than 50% of Participants are international students, with one-third of those from the recent summer internship program securing employment with industry partners. Similarly, at Innovation Central Perth (ICP), 50 students completed their internships, and 90% of them found jobs as a result of their projects or directly with their industry partners.

The structured programs and ongoing support from IC, and the wider NIIN members, ensure that students not only gain valuable practical experience but also develop transferrable skills that will benefit them throughout their careers. These initiatives have resulted in positive outcomes for both industry and students, making graduates more employable, job-ready, and engaged in their chosen fields.

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The primary objectives of the ICP program at Curtin University is to achieve two key goals: bridging the gap between academia and industry and cultivate a deeper understanding of engineering principles. These goals align perfectly with the WIL and PBL methods explained in the next section.

Work Integrated Learning (WIL)

Work Integrated Learning (WIL) is an educational approach that encourages students to apply their academic knowledge in practical, real-world settings. The main purpose of including WIL in educational programs is to enhance employability amongst graduates (Sovilla & Varty, 2023).

Two primary factors motivated universities and higher education institutions to integrate vocational training into their academic courses. The first is the demand from industries for work-ready graduates. Experiencing the interaction with real-world scenarios provides better job opportunities for students (Sovilla & Varty, 2023).

The second motivation drive is the shift in modern learning theories and educational methods. Based on the most current learning theories the work-ready skills help students enrich their learning experience.

Constructivist learning theory states individuals construct knowledge based on their prior experiences, highlighting the significant impact of social environments on learning development.

These concepts are illustrated in Figure 1 as four focal characteristics of constructivism learning theory. The process begins with learners building their knowledge upon existing information, followed by the construction of their own meaning, which emphasizes autonomy in learning. This is further highlighted by the essential role of social interaction and authentic learning in the knowledge construction process(Bruning et al., 1999).

Figure 1: "Focal Characteristics of Constructivism"(Bruning et al., 1999)

Providing an environment for active learning is the main focus of pedagogical methodologies in constructivism theory. This epistemological stance also emphasizes the self-regulated instructions over the traditional guided direction promoting learner autonomy (Schunk, 2012).

Some examples of learning environments in constructivist theories are:

> **Discovery and inquiry learning**: This approach minimizes educator guidance, allowing learners to explore and uncover facts independently, building knowledge based on their prior experiences. It involves problem-solving and questioning activities designed by teachers to facilitate exploration.
>
> **Peer-assisted learning (PAL):** In this method, peers—typically students with more advanced knowledge—actively support their classmates in the learning process, fostering collaboration and deeper understanding.

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Discussion and debates: This method is employed when there are differing viewpoints on a subject. Through discussions and debates, learners gain a better understanding of opposing perspectives and develop essential skills such as communication and critical thinking (Glover, 2014).

Work-integrated learning aligns with all four key characteristics of constructivism.

Learners construct their own meanings: WIL methods include reflective practices where students are required to identify the part of the academic study that is related to the real-world problem and evaluate their learning this increases their social activities and creates outcomes.

Social Interaction Plays a Key Role: In the WIL environment, students participate in networking sessions and work closely with mentors, peers, academic staff, and industry professionals fostering valuable social interaction.

Authentic learning tasks are crucial for meaningful learning: work-integrated learning creates a balance between academic learning and practical real-world work experience. It provides an environment where students engage in real-world activities, enhancing their understanding through hands-on experience.

Learning depends on existing understanding: To solve real-world problems, students utilize their problem-solving skills. WIL promotes this by challenging students to develop solutions to practical scenarios, encouraging them to apply their academic knowledge and draw on their existing understanding.

Another modern learning theory supporting the implementation of WIL and PBL is Connectivism which is also known as the learning theory for the digital age. It emphasises the role of networks and technology in the learning process. Based on connectivism theory, knowledge is distributed across a network and resides in nodes. Nodes can be people, organizations, databases, or other knowledge sources. Connectivism states that learning is the ability to navigate these nodes(Siemens, 2004)

WIL programs often utilize digital platforms and tools to connect students with industry professionals, resources, and peer networks. This aligns with the connectivist view that learning occurs through navigating and connecting information sources.

The collaborative environment created by WIL is also a good example of the educational methods supported by the connectivism learning theory.

Project Based Learning (PBL)

Another effective educational approach backed by industry and contemporary learning theories is Project-Based Learning (PBL). It is an instructional teaching method that engages students in learning through the completion of meaningful projects (Krajcik & Blumenfeld, 2006). Students will complete complex real-world project/s over the study period as individuals or teamwork. PBL promotes active learning, critical thinking, and problem-solving skills as students research, plan, and create solutions or products related to the project topic (Salleh & Yusof, 2017). These are many elements of the constructivism approach.

PBL enhances student engagement as they are working on real-world, relevant, and challenging projects. While working on the project, students explore and apply knowledge enhancing their understanding of the subject. Similar to WIL, PBL also helps students enhance their educational experiences and prepares them for the work environment (Sanger & Ziyatdinova, 2014).

While students are completing the project, they are using digital tools to connect the information, experts, peers, and any other knowledge node. This is aligned with the connectivism learning theory.

While both WIL and PBL are educational approaches to integrate practical knowledge in academic courses, they have a slightly different focus. WIL primarily aims at real-world work

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experiences while PBL main attention is on academic projects. Collaboration with the industry partner is more significant for WIL compared to PBL.

Experimental Model ICP

Established in 2015, Innovation Central Perth (ICP) has been an integral part of Curtin University's framework. ICP is committed to institutionalizing industry engagement through a pioneering approach that leverages Curtin University's student talent to initiate and expand industry research opportunities.

Prior to this initiative, collaborations between the School of Electrical Engineering, Computing and Mathematical Sciences (EECMS) and industry partners were typically conducted on an individual academic basis, resulting in isolated projects that often lacked cohesive direction and support for ongoing relationship development.

In a strategic move in March 2021, the initiative was rebranded as 'Innovation Central Perth 2.0' (ICP 2.0) and transitioned from the Research Office to EECMS. This pivotal shift, marking a departure from its prior operational model, emphasized a more profound engagement with industry and a new fiscal strategy requiring industry contributions for services.

The ICP 2.0 model significantly enhances this landscape by providing robust administrative support for industry projects. This strategic support enables academic staff to cultivate industry engagement skills more effectively by relieving them of administrative duties, thereby allowing them to concentrate on their areas of technical expertise. This approach not only streamlines project management but also fosters a sustainable framework for deepening industry-academic partnerships. To achieve this goal, the model seen in (Figure 2) is utilised which provides a workflow of applying technology to digitise a business and create datasets that can be analysed and provide opportunities for optimisation and automation in the area. Additionally, academics who are supervising the projects, scope the solutions such that rapid prototyping can be done by mostly undergraduate students. ICP exemplifies the superior quality of Curtin University's educational programs. Through engaging current students who are keen to apply the knowledge gained from their coursework to real-world industry issues, ICP demonstrates the practical impact and relevance of the university's teaching methods.

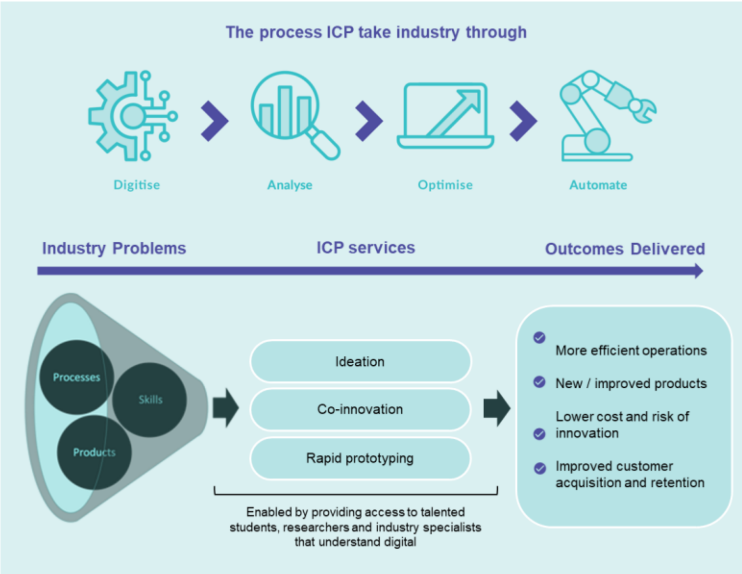

Figure 2- ICP industry engagement process

This application of learning extends to Higher Degree by Research (HDR) students as well, who utilize their research skills to address industry challenges effectively. Further attesting to its

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success, ICP was honoured with the "*Excellence in Industry Engagement 2023*" award by Engagement Australia, the peak alliance of Australian and New Zealand universities committed to advancing the engagement agenda in higher education. This recognition highlights ICP's role as a leader in fostering meaningful university-industry collaborations, contributing significantly to the field of academic engagement.

ICP Projects

ICP offers a range of projects that incorporate both WIL and PBL, addressing various aspects of industry and educational needs. Some of the evidence and achievements are listed below:

1. Evidence of the response to industry demand.

All projects at ICP are demand-driven, with industry partners presenting specific challenges or requirements to which Curtin students, as interns, respond by delivering tailored outcomes. For instance, one notable project involved developing a hybrid premises and cloud-based remote operation platform prototype for the defence sector. This initial collaboration not only demonstrated ICP's capacity for innovative solutions but also paved the way for subsequent, more extensive cooperation with Curtin University in applying for a Defence Science Centre (DSC) grant. Another significant engagement began with a team of Curtin undergraduate data science students addressing ad-hoc challenges at Mineral Resources Limited. This project has since evolved into continuous involvement that includes physical projects with Curtin's Motorsport Team and the Mechanical Engineering Department, thereby expanding the scope and depth of academic-industry collaboration.

2. Evidence-based outcomes of the industry engagement.

In addition to being honoured with the 'Excellence in Industry Engagement 2023' award by Engagement Australia, Innovation Central Perth (ICP) achieved notable recognition as a finalist in the 2022 WA Premier's Science Awards for the Chevron Science Engagement Initiative of the Year. These prestigious accolades, together with the escalating adoption of the ICP model by various industry sectors, underscore the substantial value that ICP contributes to the industry. This acknowledgment highlights ICP's efficacy in bridging academic research with practical industry applications, thereby enhancing the impact of Curtin University's collaborative engagements within the scientific and business communities.

3. The impact the engagement has had on the industry, including the direct value of the research on the end user (whether social, economic, or environmental).

In addition to collaborations with major enterprises, ICP has played a pivotal role in nurturing start-ups to develop impactful innovations. Notably, a project facilitated by ICP with the local start-up Assuro was honoured at the 2022 Curtinnovation Awards. This project revolutionized the financial sector by creating digital bank guarantees. Furthermore, 2022 marked ICP's inaugural project on another Curtin campus, funded by the City of Kalgoorlie-Boulder, which researched the potential use of local wastewater for electrolysis. This project sparked considerable interest from the industry in the Kalgoorlie region, recognizing Curtin's role in driving impactful developments in the Goldfields. Encouraged by this success, the Department of Jobs, Tourism, Science and Innovation has provided funding to support ICP's expansion to Kalgoorlie, further extending its influence and enabling regional innovation.

4. The commercial value of the industry engagement if relevant

Innovation Central Perth (ICP) efficiently allocates its revenue to benefit academics, students, and other essential aspects of project delivery, including investments in infrastructure that enhance deeper engagements with industry. This strategic allocation underscores ICP's pivotal role in advancing the faculty's research and innovation goals, specifically aimed at building and diversifying research income. Furthermore, ICP has successfully spearheaded several projects leading to product commercialization. Notable among these are the collaboration with

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RAC/WaterCorp on a water leak detection system, and a partnership with Horizon Power to develop an IoT solution for monitoring electrical infrastructure. These initiatives are directly aligned with the faculty's objective to develop and expand commercialization opportunities, demonstrating ICP's integral role in transforming academic research into practical, market-ready solutions

The ICP projects offered to Curtin University students consist of complex industry challenges that require a high level of critical thinking and problem-solving skills. For instance, the development of a hybrid premises and cloud-based remote operation platform prototype for the defense sector was an interdisciplinary project that encouraged students to approach the issue from various perspectives and understand how different fields intersect. These types of projects also foster teamwork and collaboration. An example is the project provided by Mineral Resources Limited, where students from various disciplines, including data science and mechanical engineering, worked together to find solutions.

The ICP program also provides networking opportunities with a variety of companies, ranging from startups like Assuro to larger organizations such as Defense, WaterCorp, RAC, and Horizon Power. This experience exposes students to projects of different sizes and complexities, each with varying allocated resources.

Outcomes and Conclusion

After two years of running the ICP program, which utilized Work Integrated Learning (WIL) and Problem-Based Learning (PBL) methodologies, the following outcomes were observed:

- **Student Success**: The program achieved an impressive 90% employment rate for graduates immediately after they completed the program.
- **Industry-Based Projects**: All projects were grounded in real-world environments, providing students with valuable practical experience. Over 100 engineering and data science students participated in this program supported by more than 150 industry partners.
- **Academic Involvement**: Academics played an integral role in all projects, ensuring high-quality guidance and support. The academic staff involvement plays a crucial role in helping students transfer their theoretical knowledge into practical skills.
- **Diverse Offerings**: A variety of projects were available across different disciplines, catering to a wide range of student interests and career paths. Projects spanned diverse sectors including Mining & Resources (35%), Health (25%), Defence (10%), Manufacturing (15%), and the Public Sector (15%). Figure 3 shows the summary of project diversity within two years of ICP 2.0 operation.

Figure 3- ICP projects

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- **Industry Endorsement**: The program received strong endorsement from industry partners, with a satisfaction rate of 98%. Additionally, the number of industry partners involved in the program increased significantly. This not only aids in continuing relationships with existing partners but also facilitates the recruitment of new industry partners through networking events and positive word-of-mouth referrals making the ICP a sustainable model. This program has catalysed approximately $2.5M in cash and in-kind industry contributions to the centre as well as $1M worth of equipment contributed by Cisco.

These outcomes highlight the effectiveness of the ICP program in enhancing student employability and fostering strong industry connections.

The ICP model developed at Curtin has been replicated Australia-wide to create a network of facilities, industry specialisations and services.

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Acknowledgements

The authors would like to acknowledge Erin Stacey, Director of Innovation Central Canberra and James Stewart, Program Manager, Cisco, National Industry Innovation Network & University Partnerships for their support in reviewing case studies in this paper.

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