ISBN: 978-628-95207-8-1. ISSN: 2414-6390. Digital Object Identifier: 10.18687/LACCEI2024.1.1.398

The Sky's the limit: - using CanSats for Immersive Engineering Education on the REEdI Project

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Abstract*– This paper describes the design and implementation of the CanSat Problem-Based Learning (c-PBL) project at Munster Technological University in Kerry, Ireland. c-PBL makes up part of the Rethinking Engineering Education in Ireland (REEdI) initiative, aimed at providing an immersive, agile and innovate approach in educating engineers of the future for Irelands Manufacturing sector. Modern engineering education is rapidly changing, as it evolves and adapts to the needs and demands of the industrial workplace, and nowhere is this more obvious than in the REEdI project. One of the key outputs of REEdI is a Bachelor of Engineering in Mechanical and Manufacturing Engineering (BEng MME). The c-PBL project, embedded within the MME programme is proving to be a highly successful addition in the realm of problem-based, immersive engineering education. Not only is the c-PBL project equipping student engineers with the technical knowledge required for modern engineering applications, it is also instilling essential teamwork and adaptability skills into the developing engineer's toolkits. By providing a dynamic and engaging pedagogical framework, this initiative has set a high standard for future endeavors in higher education and engineer development.

Keywords-- Immersive Engineering, Problem-Based Learning, Engineering Education, CanSat Technology for Teaching, Enhancing Undergraduate Education.

I. Introduction

In the modern educational landscape, there is an increasing need for Higher-Educational Institutes to produce graduates capable of meeting the needs of the growing and ever-changing industry. Universities, colleges and institutes of technology need to re-think the way that engineering is taught to students, empowering the students to meet the needs of the industrial sector. This changing industrial landscape derives from a variety of different factors, including the impact of students, society and science on industrial needs.

In Ireland, there is an increasing argument that current engineering education methods need to grow and develop, lest they become a barrier to economic growth. A recent report from Engineers Ireland, the representative body for engineering professionals in the country) shows that 91% of engineering companies and employers have identified skill shortages in current engineering graduates as a significant barrier to growth with the industry [1]. The skill shortages identify gaps in technical engineering skills, as well as shortcomings in the area of transversal skills - "soft" skills which are applicable to a wide range of situations and settings in the workplace e.g. organizational skills. The report found that industrial companies were struggling to fill roles in the mechanical and manufacturing engineering sectors, where a growth rate of 16.6% per annum is being reported.

The REEdI (Rethinking Engineering Education in Ireland) initiative looks to address this problem with the introduction of an agile and innovative undergraduate engineering programme in Ireland. The programme provides personalized, flexible and tailored educational options to diverse engineering students at the Munster Technical University (MTU), located in Tralee, Ireland. REEdI blends an innovative method of content delivery with immersive technology platforms to provide a transformative programme of innovative, self-directed learning for the next generation of Irish engineers.

The REEdI project framework has been developed around three central pillars: - 1) E-learning and immersive technologies (including AR/VR platforms), 2) project-centric learning and 3) performance planning and review/reflective practice. The framework has expanded on the ground-breaking model developed by Charles Sturt University, New South Wales, Australia [2], incorporating the use of immersive technologies and access to world-class Science Foundation Ireland (SFI) research centres in the REEdI framework.

Project-centric learning in the framework focuses on improving the student learning experience and empowering the student for the roles and requirements of their industrial placement and employment. One of the most effective ways this is realised is through the use of Problem-Based Learning (PBL) projects. In the Electric and Electronic Engineering 1 (EEE1) module, the c-PBL project chosen uses the CanSat development kit/platform in order to implement a novel group project for the students.

The project focuses on the development of a "CanSat", or "Can-Sized Satellite", system - a diminutive yet intricate mock-up of a satellite system ingeniously contained within the confines of a 330ml soft drink can. CanSat kits serve as a unique platform for advancing engineering education, allowing students to explore the intricacies of satellite systems, spanning power supply, sensors, communications, control systems, and more, within a compact, real-world context.

Interdisciplinary group PBL initiatives such as this project provide an inclusive learning environment that caters to students of diverse backgrounds and abilities. By bringing together individuals from various disciplines, these projects encourage collaboration and mutual learning. Students with different skill sets contribute unique perspectives, enriching the overall learning experience and fostering a sense of inclusivity. Moreover, such projects often require a range of tasks, from technical design to data analysis, allowing students to showcase and develop their strengths regardless of their academic background. The use of CanSats through the c-PBL project affords an innovative hybrid approach for the students, offering them an unprecedented opportunity to grasp the intricacies of the system, integrate with their peers at a group and personal level and develop the suite of electronic skills/abilities needed and improve their transversal/soft skills, all the while transcending the boundaries of traditional pedagogical methods.

The rest of the paper is structured as follows. Section II presents a literature review, considering immersive engineering education and the use of CanSats for education and outreach. Section III presents the CanSat kits themselves, describing their constituent components. Section IV discusses the integration of these kits into the REEdI EEE1 module and how they have been used to implement a novel and engaging real-world problem for the students taking the course. Section V concludes with a recap of the important points of the paper.

II. Literature Review

Immersive Engineering Education

Immersive technologies, such as Augmented Reality (AR) and Virtual Reality (VR), are more frequently being identified as key pedagogical tools in engineering education [3]. The technologies, particularly VR, are increasingly recognized not just as gaming tools but as valuable educational resources in engineering pedagogy. This shift is partly driven by the COVID-19 pandemic and the adoption of these technologies in the engineering and manufacturing industry [3]. Further to this, immersive technologies allow for equal opportunities for distance learners and support in promoting inquiry and exploration.

As outlined in the recent literature, integrating these emerging technologies into engineering curricula has the potential to transform how students learn and interact with their learning material [4-5]. These technologies enable interactive and authentic learning experiences, as unlike with traditional lecture-based methods, immersive learning allows students to be active participants, engaging with multimodal representations like text, audio, video, and 3D models. This approach has also been shown to motivate learners and improve engagement and interest in the subject matter area [3] [6] [7].

Furthermore, research indicates that immersive technologies significantly impact memory and learning retention in engineering programmes, as these technologies enable differentiated instruction, which is shown to enrich the learning experience of engineering students [8 - 10]. Furthermore, immersive technology used in engineering education offers cognitive and pedagogical benefits, such as improved technical subject understanding and academic performance [11]. Studies in various engineering domains, including mechanical, electrical, and software engineering, demonstrate the enhancement of technical and professional skills [12]. These technologies also reduce physical lab space requirements, health and safety issues, and provide benefits for distance learning students [9].

The REEdI project at MTU is actively embedding immersive technologies throughout their pioneering BEng in MME [13] [14]. Each Student Engineer on the REEdI BEng in MME has access to an Oculus Quest II VR Headset (HMD - Head Mounted Display), this is a tool that they use to build virtual manufacturing processes and environments, stimulating and promoting problem based learning. The Student Engineers also use the technology to enhance their/ people soft skills, using platforms such as BodySwaps[1]. Using this particular platform, student engineers can practice their presentation and interview skills in a safe and controlled environment. Student Engineers on the BEng in MME also have access to augmented reality HMDs in the form of the Microsoft HoloLens. Student Engineers, during their production manufacturing module, utilize this specific technology to digitize operating procedures and process flows, ultimately optimizing test manufacturing processes encountered during their engineering challenge assignments. Again, promoting problem based and challenge-based learning for engineering students, a pedagogical concept that is being taken one step further by scaling the technique to the c-PBL project in the EEE1 module.

The technologies and frameworks that the REEdI project are developing, leveraging and actively implementing are culminating in a new era of engineering education in Ireland.

Problem-Based Learning (PBL) through CanSats

Problem-Based Learning (PBL) is a widely used and highly regarded teaching paradigm across a range of disciplines [15 - 18]. It was originally introduced in McMaster University in the 1960s, developed to address shortcomings with applying traditional teaching models when used to prepare medical students for clinical practice situations [19 - 20]. Nowadays, PBL has grown far beyond this, promoting student-centred, multidisciplinary education and lifelong learning in professional practice across a range of disciplines and faculties [–20 - 21].

There are many reasons why PBL is a successful learning method. It fosters knowledge application, problem solving and teamwork on the part of the students through its very nature [22 - 23]. It is grounded in experiential, collaborative, contextual, and constructivist theories of learning, aiming to integrate different subjects and branches of knowledge [–24 - 25]. It appeals to educators as a pedagogical strategy - offering an instructional framework that supports active and group learning [25]. This is based on the belief that effective learning takes place when students both construct and co-construct ideas through social interactions and self-directed learning [26]. PBL helps students develop flexible knowledge for real-life scenarios, skills in problem-solving, self-directed learning, collaboration and an intrinsic motivation to learn on their own [24][27].

[1] https://bodyswaps.co/

Within engineering, PBL has featured heavily in the literature. Mainstream electronics modules such as Analog Electronics [28 - 29], Digital Electronics [30], Power Electronics [31] and Environmental Electronics [32] have all successfully used PBL to improve course delivery and student engagement in India, USA and Ireland across a range of student cohorts from 1st year to 4th year undergraduate and post-graduate students.

Consider, for example, the authors in [33] describing a PBL approach for enabling wind turbines to cope with faults/problems in the power grid. The PBL assignment was part of the Electrical and Electronic Master's degree level course, dealing with wind energy power and conversion systems for electricity generation. Working in groups of ~three students, each group had 15 weeks in which to address the posed problem, with lecturers/instructors acting as facilitators across all the stages of the project. Meanwhile, [34] presents a PBL approach to teaching basic concepts of electronics to undergraduate students of business and information engineering. In laboratory sessions, students carry out a project using robotics tools, Arduino programming and several basic electronics concepts. In this way, students develop skills in electronic circuit design, problem solving and teamwork. The results indicate that learning the fundamentals of electronics through various robotic projects not only motivates students but also allows them to experience and discover the link between physics, technology and engineering.

PBL has been used in aerospace engineering to cater for problem identification in systems, solution development and with the design of complex systems. For example, PBL has been completely integrated in the curriculum in Aeronautics and Astronautics at MIT [35] with the aim of harmonising different engineering fundamentals into a multidisciplinary approach. The authors report that this approach to a design-oriented project often motivates students to better understand and appreciate the concepts of aerospace engineering and engineering sciences in general. [36] describes the use of PBL within the "Introduction to Aeronautics and Astronautics" module, implemented a PBL activity where the students were required to form design teams to assemble and test a model rocket to a specified set of constraints. This activity exposed students to a wide set of skills such as computer aided design, analytical methods, numerical simulation, experimental data acquisition and data analysis and relevant academic experience in one single project. Elsewhere, a PBL activity relating to the design, building and testing of a small satellite is described in [37]. The authors reported that the PBL methodology has definitely enhanced the student-lecturer interaction and it allowed the application of diverse strands of knowledge to the design of spacecraft systems, which has provided the students with skills that are not achievable with the traditional learning methodologies.

In this paper, c-PBL has been implemented using the CanSat (Can-sized Satellite) system as the real-world problem on which the c-PBL project is based. The CanSat competition [39] in Europe is an ESA (European Space Agency) initiative which has been running for 10+ years, that challenges students from all over Europe to build and launch a mini satellite which can fit into a soft drink/soda can [38 - 39]. CanSats offer a dynamic platform for interdisciplinary university projects, distinguishing themselves from traditional pedagogical methods through hands-on, collaborative learning experiences, similar to that describe [38]. Unlike conventional classroom settings, CanSats immerse students in real-world engineering challenges, fostering skills essential for professional success [39].

Compared to theoretical lectures or simulations, CanSat projects provide tangible, experiential learning opportunities [40]. Students engage in practical tasks, from designing and constructing the CanSat to analysing data retrieved from its flight. This hands-on approach not only deepens comprehension but also cultivates problem-solving abilities crucial in engineering disciplines [41].

National CanSat competition winners from countries such as the Netherlands [44], Ireland [45] and Portugal [43] proceed to compete in the European ESA competition, hosted at different venues across Europe every year. CanSats and CanSat competitions such as these are widely recognised as one of the main avenues for increasing engagement and uptake with space education courses at an international level [46]. Outside of the EU, CanSat competitions are regularly held in countries such as Korea [47] and Bolivia [48] for exactly this reason.

The CanSat platform has progressed beyond a development and engagement platform of late. It is now being used as an experimentation platform for in-the-field sampling and data collection at altitude. Moreover, CanSats promote interdisciplinary collaboration, mirroring the diverse skill sets required in professional settings [43]. Teams typically comprise students from various fields, such as engineering, physics, and computer science. By working together, participants gain insights into different perspectives and learn to integrate diverse expertise, mirroring real-world project dynamics.

While traditional lectures may teach principles of aerodynamics, such a CanSat project allows students to apply these concepts practically. They must consider factors like air resistance and stability first-hand during construction and flight. Furthermore, analysing flight data enhances critical thinking and data interpretation skills, preparing students for complex engineering challenges beyond academia.

In essence, CanSats stand out as effective tools in engineering education, offering immersive, interdisciplinary experiences that bridge theoretical knowledge with practical application, ultimately shaping well-rounded, adaptable professionals ready to tackle real-world engineering problems.

III. CANSAT KITS

The CanSat kit used for these c-PBL projects is based on the one supplied by Science Foundation Ireland to participants in the CanSat Ireland National Competition. Fig. 1 shows the typical contents of the CanSat kit supplied.

Typical contents for the kit include the following:

- Arduino UNO Microcontroller: - used as the controller or microprocessor for the CanSat system. The Arduino Uno is programmed using the Arduino IDE (Integrated Development Environment) via a USB connection from a laptop/PC.
- AAU sensor PCB: - used for interfacing the Arduino Uno to the other components of the system, including the temperature and pressure sensors, the APC 220 RF communications module and the battery for the CanSat system.
- APC220 RF transceiver modules: - used for allowing the CanSat to wirelessly transmit data (in real time) back to the base-station (laptop) during flight. Two modules are supplied; one (transmitter) for the CanSat and one (receiver) for the base-station.
- Sensor Payload: - The CanSat system contains an (NTC) thermistor, a piezoelectric pressure sensor and sensor conditioning components for integration onto the AAU sensor PCB in the system.
- An electronics “breadboard” for prototyping electronic circuits for the CanSat.
- A 9V D-type battery connector for supplying power to the CanSat.
- Miscellaneous cables, wires and connectors for the CanSat.
- Fixtures & fittings for the container, parachute, etc.

IV. Incorporating CanSats into the Curriculum

The CanSat project is a cornerstone project of the REEdI Bachelor of Engineering course in Mechanical and Manufacturing Engineering, epitomising innovative pedagogy aimed at enriching student engagement. Offered as part of the Electrical and Electronic Engineering 1 module, the module aims to give the students an understanding of the fundamental concepts of electricity and electronic or electrical circuits. The CanSat kit emerges as an ideal conduit for fulfilling the module learning outcomes such as introducing the students to basic analog/digital theory, analysing basic electrical circuits and developing the necessary psychomotor skills and techniques. The CanSat kits provides an ideal platform for all this, while fostering captivating avenues for expansion and skill development.

Structured as a collaborative endeavour, the project enlists groups of 2-3 students and tasks them with construction, programming, testing, and flight of a can-sized satellite system, grounded in the CanSat kit framework. The central aim is to orchestrate the remote measurement of atmospheric temperature and pressure, with ensuing transmission of data to a ground-station/laptop for real-time analysis and display.

At the project's inception in week 2, students are acquainted with project specifics, deliverables, and ancillary information during an illuminating session. Subsequently, a comprehensive project document disseminated via the Learning Management Systems furnishes students with a roadmap encompassing project particulars, mission imperatives, online resources, and assessment modalities.

Fig. 1. CanSat Kit contents

Guided by a pedagogical ethos underpinned by hands-on learning and Problem-Based Learning (PBL) principles, the project’s mission imperatives serve as the fulcrum for engineering problem elucidation and scaffolded development of the student skillsets. Using the array of hardware components, programming resources, and supplemental literature relating to the kit empowers student groups to navigate the design, construction, and testing phases of their CanSat system.

The complete list of deliverables along with deadlines for the project is as shown in Table 1. In alignment with this scaffolded approach, project deliverables are delineated to encompass a sequence of succinct videos chronicling the project’s evolution over the semester. These videos serve as a dynamic conduit for ongoing assessment, affording students the opportunity to showcase developmental milestones, adherence to project objectives, mastery of system components, and command over pertinent programming applications.

The project culminates in a final, live test flight and subsequent project report. Each group orchestrates the flight of their CanSat, recording temperature and pressure differentials as the apparatus descends from a 50-meter altitude, cushioned by the student designed and built CanSat parachute system. Subsequently, the project report allows the student groups to delineate their solution strategies, expound upon satellite system components and functionalities, elucidate individual group member roles, and furnish reflective insights on the project dynamics and collaborative synergy engendered therein.

TABLE I. LIST OF CANSAT PROJECT DELIVERABLES

Week #	Deliverable
4	1-2 minute video demoing the Arduino working with the resistor/thermistor on a breadboard illustrating the Arduino reading the voltage back from the temperature sensor.
6	1-2 minute video demoing the Arduino working with the pressure sensor, again on a breadboard, in order to read atmospheric pressure.
8	1-2 minute video demoing the radio transceivers working with the Arduino and a laptop/computer in order to transmit sensor data (temperature or pressure from one of the previous deliverables) from the CanSat Arduino back to the PC.
12	CanSat construction completed and demonstration of the CanSat working with real-world demonstration via drone or other applicable method(s).
12	Final Group Project Report for the project due.

To ensure the inclusion and accessibility of all students in the CanSat project, several strategies were implemented. First and foremost, clear communication of project goals, roles, and expectations is essential to provide a level playing field for all participants. Additionally, creating diverse teams that balanced expertise and skill levels helped promote peer learning and support. Moreover, offering flexibility in the project deliverables allowed the students to contribute in ways that align with their abilities and interests. Providing access to resources, mentorship, and support networks further ensured that each student had the opportunity to engage meaningfully in the project.

Overall, fostering an inclusive and supportive learning environment is key to maximizing the benefits of interdisciplinary group PBL projects like the CanSat initiative.

V. DISCUSSION AND CONCLUSION

Implementing the CanSat project has proven to be extremely successful as an engaging developmental platform for students on the Immersive Engineering REEdI program. While it does come with a steep implementation overhead in the first year, students are very happy with the resulting project. They are finding it to be interesting and rewarding as a platform for developing their electrical and electronic skillset, as well as improving their group and problem-solving skills.

The CanSat platform has proven to be a good choice of real-world problem for the PBL implementation, as it provides the ideal intersection between engineering and sensor/instrumentation technologies in electronics for the students to apply the theory and knowledge they were exposed to in the module(s). The use of such a real-world and “authentic” problem (the construction of the CanSat) means that the project appeals to the multiple skills-based disciplines involved, providing the students with transferable skills and knowledge [49 - 50].

The group-based nature of the project allows students to liaise with their peers, both in and out of the classroom and lab setting on the project. Furthermore, it allows them to apply their existing knowledge in new and novel applications. Another benefit experienced by the students is the sense of developing and bonding as a team over the project. Most project groups were arbitrarily assigned, with team members not knowing each other very well (if at all) at the start of the project, which necessitated that they interact, develop a team ethos and manage the project requirements and workload using face-to-face meetings and/or online communication tools such as meeting channels in MS Teams, WhatsApp groups, etc. For more information and feedback on CanSat-based PBL projects, please refer to [51].

In conclusion, the interdisciplinary Problem-Based Learning (c-PBL) implementation of the CanSat project, undertaken as part of the REEdI Immersive Engineering Degree course at Munster Technological University Tralee has contributed to the development of innovative pedagogical methods. Using such transformative and highly successful “real-world” platform for the PBL project has yielded significant benefits for both educators and students, provided a platform that effortlessly bridges the gap between students and their learning.

The CanSat project allows a shift from the traditional module-based approach to a more interactive, hands-on learning environment that enables students to develop exponentially. Most notable in this regard is the engagement with real-world problems, transcending the confines of traditional laboratory and teaching methods. The CanSat kits, encapsulating the complexity of satellite systems within a compact can-sized form, have emerged as a powerful tool for fostering holistic engineering education going forward. The CanSat project underscore the adaptability and effectiveness of the c-PBL approach when applied in an immersive engineering context and we look forward to expanding and developing the size and scope of the project in future iterations.

In the ever-evolving landscape of engineering and technology, where boundaries blur and innovation thrives at the intersection of these boundaries, the CanSat project serves as a valuable blueprint. It highlights how educational departments and institutions can break free from conventional paradigms and offer students an immersive, transformative experience that prepares them for the challenges of the 21st century. As we look to the future, projects like this will shape the next generation of engineers and problem solvers. These projects will enable them to push the boundaries of what is possible, in their pursuit of knowledge and innovation.

ACKNOWLEDGMENT

This work was funded by the Higher Education Authority in Ireland under the Human Capital Initiative Pillar 3 Fund.

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