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A Case Study in Using the Can-Sized Satellite Platforms for Interdisciplinary Problem-Based Learning in Aeronautical and Electronic Engineering

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Abstract**—**This work considers an interdisciplinary Problem-Based Learning (PBL) project developed by lecturers from the Aeronautical and Electronic and Computer Engineering departments at the University of Limerick. This "CANSAT" project utilises the CanSat can-sized satellite platform in order to allow students from aeronautical and electronic engineering to engage in a mixed format (online/face-to-face), interdisciplinary PBL assignment using a real-world platform and application. The project introduces students to the design, development, and construction of the CanSat system over the course of a single semester, enabling student(s) to apply their aeronautical and technical skills/capabilities to the realisation of a working CanSat system. In this case study, the CanSat kits are used to pivot the real-world, discipline-relevant PBL goal of designing, building, and testing the CanSat system with payload(s) from a traditional module-based setting to an online PBL setting. Feedback, impressions, benefits, and challenges identified through the semester are presented. Students found the project to be interesting and rewarding, with the interdisciplinary nature of the project appealing to them. Challenges and difficulties encountered are also addressed, with solutions developed between the students and facilitators to overcoming these discussed.

Keywords**—**Problem-Based Learning, Online PBL, Electronic Engineering, Aeronautical Engineering, Interdisciplinary Project, CanSat.

I. Introduction

PBL is a highly successful and widely recognised educational/instructional method used worldwide across a wide range of disciplines in higher educational institutes. It uses hands-on, active student investigation and emphasises the role of the teacher as facilitator to solve case studies/assignments based on problems or situations which the students are likely to encounter in their practice going forward [1]. PBL has been successfully implemented across a range of disciplines in higher education institutes including medicine, dentistry, health sciences, business, law, education, and engineering, including both aeronautical and electronics [2]-[6].

At the University of Limerick of Limerick, PBL is used across a range of different disciplines and courses, including aeronautical and electronic engineering cohorts. Within the ET4305 module in Electronics, to be discussed as part of this case study, for example, PBL would traditionally have featured as approximately 25% of the students' workload for the module, pre-COVID. In both disciplines, students would undertake academic modules covering theoretical and core content knowledge that integrate with psychomotor skills, practical laboratories and practice education (PBL-based and otherwise), where students apply the theory they have learned in a practical or laboratory environment.

While PBL is recognised as a valuable learning tool for students in both disciplines, it has tended to rely on a traditional learning environment/structure in order to realise this, requiring face-to-face contact time, tutorial group meetings and synchronous sessions. Due to the COVID-19 pandemic and its impact on higher education course delivery [7], [8], this approach is no longer feasible. More and more students in higher education are nowadays using blended learning, online courses and distance education in order to access courses remotely [9]. With the need to teach in such a space thrust upon us during the pandemic and the absence of face-to-face, lab-based sessions from the students' calendar, a different practical skills approach was needed. To address this, lecturers from the Aeronautical and Electronic and Computer Engineering have collaborated to develop the "CanSat" project as the interdisciplinary PBL project presented in this case study. For this project, the students had to assemble, program and debug a "can"-sized satellite system from a starter kit supplied to them. The completed system will be capable of delivering temperature and pressure readings remotely to a base station/laptop. As well as delivering practical skills and practice education to the students, this approach aims to increase student engagement and interaction, both with their classmates and across their respective disciplines.

The project maps to an online setting using collaboration and teamwork on the part of the students in realising the CanSat system; it introduces interdisciplinary aspects of aeronautics and electronics to each cohort and allows student(s) to apply the skills and technological capabilities they have developed to real-world problems and requirements across both disciplines/ fields.

The rest of this paper is organised as follows. The next section considers a brief review of online, problem-based and interdisciplinary learning in the literature. After this, the "Project Design & Implementation" section considers the design and implementation of the project in order to meet these

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online, PBL and interdisciplinary requirements. Student feedback and facilitator impressions of the project are then considered in the "Project Review" section. Finally, the "Conclusions" section summarises the main findings and concludes the paper.

II. Literature Review

This section describes some of the relevant research regarding online learning, PBL and interdisciplinary learning within the literature.

Online learning is one form of distance learning/distance education, where the education takes place over the internet [10]. In an online learning environment, both the educator/ teacher/lecturer and student have differing roles, responsibilities and engagement with the online learning environment. It is well documented that educator(s) fulfil a number of roles in online courses including pedagogical, instructional designer, facilitator, social, managerial and technical functions [11], [12]. The time and resources required to prepare online material should not be underestimated and can often exceed that required of traditional lecture-based courses [13], [14]. For example, from a pedagogical viewpoint, the online educator is required to understand student engagement and develop active learning in a digital environment, including the development of tailored material that engages and motivates the students to develop independent learning [15].

Online students are required to engage through intrinsic motivation with asynchronous and self-directed learning. Benefits for the student for engaging with technology include developing and enhancing core professional skills, such as in the acquisition of reflective practice skills [16], inter-disciplinary education [17] and fostering a sense of community [18]. However, there are a number of risks and concerns here – for example, students have reported that it can be hard to motivate towards, difficult to prioritise and tempting to leave e-learning activities until the last minute [19], [14].

Within this project, an online Problem-Based Learning (oPBL) approach is adopted. Traditional PBL is a widely used and highly regarded teaching paradigm across a range of disciplines [20]-[23]. PBL originated in McMaster University in the 1960s. It was originally developed to address issues with applying traditional teaching models to preparing medical students for clinical practice situations [24], [25] but has grown far beyond these beginnings and nowadays promotes student-centred, multidisciplinary education and lifelong learning in professional practice across a range of disciplines and faculties [26], [25].

There are many reasons why PBL and, by extension, oPBL are successful learning methods. They foster knowledge application, problem solving and teamwork on the part of the students through their very nature [27], [28]. They are grounded in experiential, collaborative, contextual, and constructivist theories of learning, and aim to integrate different subjects and branches of knowledge [29], [30]. They appeal to educators as a pedagogical strategy - offering an instructional framework that supports active and group learning [30]. 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 [31]. PBL/oPBL 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 [32], [30].

There are four basic characteristics identified across many of the different variants of PBL/oPBL in use nowadays: -using complex, real-world problems with multiple possible solutions, students working in groups to address the question of finding the best solution for them, students employing self-directed learning activities to achieve this and the teachers/lecturers acting as facilitators in the system [24]-[26]. There are iterative and reflective steps through which the students work collaboratively in small groups and independently [33], [26], [30]. The process of PBL has been described in works such as [34] and [35] using the following algorithm:

1. Addressing realistic problems;
2. Applying prior knowledge and experience;
3. Rehearsing a logical, analytical, scientific approach;
4. Identifying learning gaps and perceiving ignorance as a challenge;
5. Recognising that learning is never finite and needs to be shared;
6. Discussing the relative values of information sources and presenting to and questioning others;
7. Applying knowledge to the original and new problems;
8. Evaluation of the learning experience.

Within engineering, PBL has featured in many different articles in the literature. Mainstream electronics modules such as Analog Electronics [4], Digital Electronics [36], Power Electronics [37] and Environmental Electronics [38] 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.

In [39], the authors describe a PBL approach which employed the real-world problem of 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 ~3 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, [40] 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.

Within the aerospace engineering literature, PBL experiences have been reported at both undergraduate and postgraduate levels. 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 [5] 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. Reference [41] described 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 [42]. 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. These results indicate that the PBL methodology enhances students learning and improves not only their specific technical skills, but also transversal skills increasingly in demand in the engineering sector.

The project/problem used for this module is interdisciplinary in nature, catering to both the aeronautical and electronic student cohort. Interdisciplinary education (IPE) has been defined as occasions where multiple (two or more) professions learn with/from/about each other, in order to improve collaboration and the quality of service provided [59]. This differs from multidisciplinary education and learning, where students from different professions are taught together but there is no interaction between the professions [17]. There is a recent research focus on incorporating the PBL of collaborative learning as a pedagogical method to support IPE and foster improving attitudes towards other professional groups [43], [44]. Practical and logistical barriers to providing IPE described here include timetabling across multidisciplinary curricula, ensuring consistency and continuity of PBL groups and co-facilitation can be overcome by virtual learning environments. Another challenge discussed is the development of PBL scenarios which are suitable for all professions using the experience of staff teaching the different professional groups.

Specifically, the PBL problem given to the students centres on the CanSat competition kit. The CanSat competition 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 [45]. National CanSat competition winners from countries such as the Netherlands [46], Ireland [47] and Portugal [48] 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 [49]. Outside of the EU, CanSat competitions are regularly held in countries such as Korea [50] for exactly this reason.

The CanSat platform has progressed beyond a development and engagement platform of late and is now being used as an experimentation platform for in-the-field sampling and data collection at altitude. For example, [51] presents the design, data collection, analysis and results presentation for a set of atmospheric sampling experiments conducted using a CanSat mini-satellite.

III. Project Design & Implementation

The CanSat project involved two different cohort of students, ME6181, "Space Systems Design" from the Aeronautical Engineering course and ET4305, "Instrumentation and Control 1" from the Electronic and Computer Engineering course. ME6181 is a new module being delivered within Aeronautical Engineering at the University. ET4305 has been delivered for 6+ years to third-year students and traditionally features a PBL lab-based project for the students. With the need to teach online and the absence of lab-based sessions from the students calendar this semester, a different PBL project based on the CanSat kit was developed and expanded to cater for both aeronautical and electronic engineering students. Both modules were delivered over 12 weeks during the first semester of AY2020/2021. Within the project, students from these two modules have been asked to work together in mixed groups of ~4 students each in order to complete the project. In this section, details about the CanSat project design and implementation are presented.

Project Design

The CanSat project has been designed and developed around the concepts of hands-on, online learning, PBL and IPE, as discussed in the previous section. In particular, a set of online learning activities were created, utilising asynchronous learning resources such as group tutorial meetings and a series of videos dealing with the skills required for the project - essential topics such as the assembly, the programming and the testing of the CanSat module.

The CanSat project requires each group to build, program, test and complete a can-sized satellite system based on the CanSat kit. The primary objective of the CanSat mission is to remotely measure atmospheric temperature and pressure using the CanSat system and transmit the measured data to the ground-station/laptop for analysis/display. Students are required to build the CanSat system from the supplied components, including the on-board computer (an Arduino UNO microcontroller), temperature and pressure sensors, the radio communications module and a battery/power supply for the module.

Following the concept of PBL, the CanSat project has been developed around this specific mission requirement for the miniaturised satellite. The mission requirement summarises and introduces the students to the interdisciplinary engineering problem which they needed to solve. This has been supported/

scaffolded with details and descriptions of all the hardware components, programming resources and further reading material made available to each student group in order to design, build and test a viable CanSat system.

Deliverables for the project included the production of a series of four short videos (to be submitted online) detailing the project development across the semester, as well as a final project report for each group. The videos functioned as an online, continuous assessment strategy for the project facilitators, giving the students the opportunity to showcase the development of the project, fulfilment of the project objectives, the students' increasing knowledge of the system and individual components and familiarity with the programming application(s) involved. The project report is considered as the final submission for the project, with each group of students outlining their solution, describing in detail the components and functions of the satellite systems and detailing the duties assigned to each group member, as well as including a reflection on the project/group work.

Project Implementation

Starting in week 1, the two student cohorts were divided into their groups of ~4 students each. Each group was evenly composed of two students from the ME6181 (Aeronautics/ Space Systems Design) course and two students from the ET4305 (Electronics/Instrumentation and Control 1) course.

At the beginning of week 2, the project was presented to the students, with the project specification, deliverables and other relevant information presented in an online/virtual information session for the student groups. An accompanying project document distributed to the students through their respective module Learning Management System included all the information about the project, the requirements for the CanSat mission, links to the online available material and the assessment procedures/deliverables for the project. Students were asked to design, build, and test a CanSat capable of "remotely measuring atmospheric temperature and pressure, and transmitting the measured data to a ground-station". As a further requirement, students have been asked to design/equip the CanSat with a re-entry/landing system (that allows it to land safely on the ground and recover the hardware without any damage to the system) and to specify a secondary mission for the satellite.

By the end of week 2, the CanSat kit was distributed to each group. As the project required each group to work on a physical kit, a collection time/date was arranged with the student(s) and a representative from each group collected their groups CanSat kit from the UL campus in the first week(s) of the term. This kit is identical to the one supplied by Science Foundation Ireland to participants in the CanSat Ireland National Competition. Each hardware kit included the following components:

- An Arduino UNO Microcontroller;
- An AAU sensor PCB or "daughter" board for soldering the remaining CanSat components to;
- 2 x APC220 RF transceiver modules for communications;
- A thermistor, pressure sensor and sensor conditioning components;
- 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 parachute, etc.

In week 3, the groups had time to go through the online resources, familiarise themselves with the kit components, and prepare their first project deliverable, due by the end of week 4. In general, the deliverables have been scheduled in order to give the students 2+ weeks between deliverable to work on that section of their project, before the next deadline was due. The complete list of deliverables along with deadlines for the project is shown in Table I.

TABLE I
LIST OF 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.

For the first deliverable, each group was asked to submit a short video showing the CanSat Arduino controller working with the temperature sensor (thermistor). Specifications for the video, supporting technical "how-tos" and other scaffolded learning material was provided for the students in advance of this, to prepare the students for producing a collaborative video online. The video was to illustrate the Arduino UNO controller measuring the temperature by reading the voltage back from the temperature sensor/thermistor. This required an Arduino program to be written/used to read the data and the thermistor/ resistor hardware used with the Arduino to measure the temperature.

The second video deliverable was due in week 6 and was very similar to the preceding one, with one major difference – this time, users were asked to interface the Arduino with the pressure sensor. For this deliverable, each group was asked to show the CanSat Arduino working with the pressure sensor on a breadboard, illustrating the Arduino measuring pressure by reading the data back from the sensor.

In week 8, deliverable 3 was due - groups were asked to produce a video demoing the radio transceivers working with the Arduino (transmitter) and a laptop/computer (receiver/base station) in order to transmit sensor data (temperature or pressure from one of the previous deliverables) from the CanSat Arduino back to the PC.

Finally, for week 12 of semester, groups were asked to finalise their CanSat construction and to demonstrate their CanSat system working independently to record temp/pressure data, transmit this data back to the laptop/base station in real time and log the data at the base station for processing later.

The final deliverable for the project was the project report (one per group). The project report comprised the following sections:

- Introduction: includes a brief introduction to the project, including figures/diagrams; the requirements as per the project specification given at the start of the project, as well as the function and duties carried out by each member of the group.
- System Overview: (briefly) describes each of the major components of the CanSat system, summarising the design and building process which leads to the final, assembled CanSat. Included a short description of all the components, their functions and all the assembly phases for the project.
- Pre-flight Tests: a description/details of all the instrumentation and software tests carried out during the development of the project. Included the three deliverables for the project, i.e., the thermistor test, the pressure sensor test and the radio transceiver/communications test.
- Flight Test: presented the completed CanSat system, fully assembled and enclosed in its 330 ml drinks can. Described the final assembly of the system, the testing of the completed unit and any corrections/fixes required in order to realise a complete, working system. Also included details of the demonstration of the CanSat carried out in Week 12 of the semester.
- Secondary Mission: as part of the CanSat mission, the satellite can incorporate a secondary sensor/system onto the sensor board of the CanSat to extend the measurement capabilities of the system. Students were asked to specify a secondary mission for the CanSat which added some aeronautical, astronomical or environmental advantage/ benefit to its mission by extending its payload. This involved specifying a sensor/transducer which the CanSat system can use, showing how it would be interfaced to the Arduino UNO and any other hardware required (via a circuit diagram, for example). Groups were asked to describe the parameters/criteria used to choose this particular sensor for the mission and comment on how this will extend/enhance the mission of the CanSat through extending its sensor payload.
- Group Work Reflection: a reflective piece which asked the students to reflect on how their group worked together, discuss logistics, successes and challenges associated with the project and discuss how online collaborations were used to realise the completion of the project.

Finally, the assessment/grading of the project was as shown in Table II.

TABLE II
CANSAT PROJECT GRADING SCHEME

Deliverable	Mark/Percentage
Temp Sensor Demo Video	10%
Pressure Sensor Demo Video	10%
Radio Tx Demo Video	10%
CanSat Demo	20%
Group Report	50%

IV. IMPRESSIONS & FEEDBACK

To evaluate the effectiveness of the project, a range of qualitative feedback was collected, including student evaluation scoring, student feedback and facilitator observation and comment(s). Qualitative research was deemed to be more appropriate for the small samples, offering a complete description and analysis of a research subject, without limiting the scope of the research and the nature of participant's responses [52], [59].

Student evaluation scoring was collected from module evaluation form(s) which the students completed as part of each module. Student feedback was gathered through student reflection(s) on the project at the end of the semester. Teacher/ facilitator feedback and comments were gathered directly from the teacher(s) involved in the modules.

Overall, students were happy with the project, found it to be interesting and rewarding as applied to their respective discipline.

> "The project went well with our group, we finished every deliverable for the due date, and everything worked well in the organisation and in the realisation of the CanSat. We are glad to have work on this project on this semester and adapt ourselves to an online version of the CanSat project."

The CanSat platform provided the ideal intersection between aeronautical and sensor/instrumentation technologies in electronics for the students to apply the theory and knowledge they were exposed to in the module(s):

> "Overall, the project was interesting. As an international student, it is very interesting to study a theme and to be able to apply the knowledge."

> "The experience gained from working on a project [was the most beneficial part] … it was very different from previous assignments."

The use of a real-world and "authentic" problem such as construction of the CanSat meant that the project appealed to the multiple skills-based disciplines involved (aeronautical and electronics), providing the students with transferable skills and knowledge [53], [54]. This interdisciplinary nature of the project allowed students to liaise with different disciplines and apply their existing knowledge in new and novel applications:

> "I also found it very beneficial to work with students in the ET4305 module as we were able to pool our knowledge together to overcome any technical difficulties we experienced."

> "The most rewarding part of the project in our eyes was writing the Arduino code, uploading it to the Arduino and subsequently seeing appropriate values of pressure and temperature being read out on the laptop. This verified our work was correct and motivated us to successfully achieve the subsequent deliverables."

Online PBL projects such as the CanSat project maintain the benefits of traditional PBL while adding some additional advantages through its online/virtual nature [55]. For instance, moving the project online helped cater for a diverse cohort of students, as well as supporting "anytime, anyplace" collaborations.

> "Our team was spread out over Limerick City, Co. Clare, France and Zimbabwe."

Most project groups were arbitrarily assigned, comprising four team members, two from the aeronautical and two from the electronics module. Team members did not know 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 through the use of online communication tools such as meeting channels in MS Teams, WhatsApp groups, etc. Most teams found that instant messaging apps/tools allowed the team(s) to interact and communicate in order to achieve the goal(s) of the project:

> "We did not have many meetings during the semester because it was easier for everyone to talk via message, without any constraints of time."

There were also several potential challenges with the implementation of such a project highlighted in the student feedback, mirroring findings in the literature [56]-[58]. Nearly all students agreed that the online setting was not ideal for the project, as it was not as efficient or beneficial as a weekly laboratory session would have been:

> "If the semester were not online and we were able to see each other in labs, we would have worked differently. Having face to face meetings and work as a group at every lab session would have been more efficient."
>
> "The biggest challenge we faced as a team was trying to balance the workload between us all."
>
> "Due to the corona virus the pandemic made team work together in person impossible which the experience of group work was hampered by this."
>
> "Troubleshooting is something that can be difficult when not done in person."
>
> "Undertaking a group report while we were unable to meet in person proved to be challenging."

Limitations in terms of final, test flight(s) for the system also meant that no end-of-term flight could be organised for the group(s) to see their CanSat(s) working in real time as the culmination of their hard work and effort for the semester:

> "Not being able to complete a real, live test of the CanSat was disappointing. However, the knowledge gained will outweigh this disappointment long into the future."
>
> "The Flight test had if happened would have been a nice opportunity to meet in person and see the finished product."

V. Conclusions

This paper has presented the case study of the "CanSat" project – using the CanSat platform as a project in third-level, higher-education electronics and aeronautical engineering courses as an online, interdisciplinary PBL project. The project has aimed to increase student engagement, motivation and retention through the use of the CanSat platform and an online PBL format for the students.

The project pivoted a real-world, topical, relevant and beneficial problem from a traditional to an online PBL setting. Students designed, built, programmed and debugged CanSats according to their working groups in line with the project requirements and deliverables. This allowed the scope of the project to be widened to an interdisciplinary cohort of electronic and aeronautical engineers working together to realise their goals.

Feedback, impressions, benefits and challenges associated with the project are considered, from both a student and facilitator viewpoint. While the data collection and analysis for the case study are necessarily limited, feedback from all participants is largely positive. The project has proven successful beyond the expectations of the organisers and it is planned to continue implementing it in online or traditional PBL format for subsequent iterations of the project in the future.

References

[1] Neville, A.J. and Norman, G.R., 2007. PBL in the undergraduate MD program at McMaster University: three iterations in three decades. Academic Medicine, 82(4), pp.370-374.

[2] Ahlfeldt, S., Mehta, S. and Sellnow, T., 2005. Measurement and analysis of student engagement in university classes where varying levels of PBL methods of instruction are in use. Higher Education Research & Development, 24(1), pp.5-20.

[3] Etchepareborda, P., Bierzychudek, M.E., Carducci, L., Veiras, F.E., Zacchigna, F.G., Corbellini, E., Marra, S.G., Iglesias, M., Teggia, M.M., Alvarez-Hamelin, J.I. and Veiga, R.A., 2018, March. A project-based learning method applied to an introductory course in electronics engineering. In 2018 IEEE World Engineering Education Conference (EDUNINE) (pp. 1-4). IEEE.

[4] Mantri, A., Dutt, S., Gupta, J.P. and Chitkara, M., 2008. Design and evaluation of a PBL-based course in analog electronics. IEEE Transactions on Education, 51(4), pp.432-438.

[5] Brodeur, D.R., Young, P.W. and Blair, K.B., 2002, June. Problem-based learning in aerospace engineering education. In Proceedings of the 2002 American society for engineering education annual conference and exposition, Montreal, Canada (pp. 16-19).

[6] Benedito, J.P., Perez-Alvarez, J. and Calzada, M.C., 2015. PBL in the teaching of design in aeronautical engineering: Application and evolution of a consolidated methodology. The International journal of engineering education, 31(1), pp.199-208.

[7] Burgess, S. and Sievertsen, H.H., 2020. Schools, skills, and learning: The impact of COVID-19 on education.

[8] Hodges, C., Moore, S., Lockee, B., Trust, T. and Bond, A. (2020) 'The difference between emergency remote teaching and online learning', Educause Review, 27.

[9] Dziuban, C., Graham, C.R., Moskal, P.D., Norberg, A. and Sicilia, N., 2018. Blended learning: the new normal and emerging technologies. International journal of educational technology in Higher education, 15(1), pp.1-16.

[10] Anderson, T., 2004. Towards a theory of online learning. Theory and practice of online learning, 2, pp.109-119.

[11] Baran, E., Correia, A.-P. and Thompson, A. (2011) 'Transforming online teaching practice: Critical analysis of the literature on the roles and competencies of online teachers', Distance Education, 32(3), 421-439.

[12] Evans, S., Knight, T., Walker, A. and Sutherland-Smith, W. (2020) 'Facilitators' teaching and social presence in online asynchronous interprofessional education discussion', Journal of interprofessional care, 34(4), 435-443.

[13] O'Donoghue, G., McMahon, S., Doody, C., Smith, K. and Cusack, T. (2011) 'Problem-based learning in professional entry-level therapy education: A review of controlled evaluation studies', Interdisciplinary Journal of Problem-Based Learning, 5(1), 54-73.

[14] Serrano, D.R., Dea-Ayuela, M.A., Gonzalez-Burgos, E., Serrano-Gil, A. and Lalatsa, A. (2019) 'Technology-enhanced learning in higher education: How to enhance student engagement through blended learning', European Journal of Education, 54(2), 273-286.

[15] de Jong, N., Savin-Baden, M., Cunningham, A.M. and Verstegen, D.M. (2014) 'Blended learning in health education: three case studies', Perspectives on medical education, 3(4), 278-288.

[16] O'Reilly, S. and Milner, J., 2020. Impact of technology-based reflective practice tools on student skill development. International Journal of Technology and Human Interaction (IJTHI), 16(1), pp.77-93.

[17] Van den Beemt, A., MacLeod, M., Van der Veen, J., Van de Ven, A., van Baalen, S., Klaassen, R. and Boon, M., 2020. Interdisciplinary engineering education: A review of vision, teaching, and support. Journal of engineering education, 109(3), pp.508-555.

[18] Liu, X., Magjuka, R.J., Bonk, C.J. and Lee, S.H., 2007. Does sense of community matter? An examination of participants' perceptions of building learning communities in online courses. Quarterly Review of Distance Education, 8(1), p.9.

[19] Donnelly, R. (2010) 'Harmonizing technology with interaction in blended problem-based learning', Computers & education, 54(2), 350-359.

[20] Bijsmans, P. and Schakel, A.H., 2018. The impact of attendance on first-year study success in problem-based learning. Higher Education, 76(5), pp.865-881.

[21] Farmer, J.L. and Wilkinson, L., 2018. Engineering success: Using problem-based learning to develop critical thinking and communication skills in a Chemical Engineering classroom. Proceedings of the Canadian Engineering Education Association (CEEA).

[22] Greening, T., 1998. Scaffolding for success in problem-based learning. Medical Education Online, 3(1), p.4297.

[23] McParland, M., Noble, L.M. and Livingston, G., 2004. The effectiveness of problem-based learning compared to traditional teaching in undergraduate psychiatry. Medical education, 38(8), pp.859-867.

[24] Hmelo-Silver, C.E. and Barrows, H.S. (2015) 'Problem-based learning: Goals for learning and strategies for facilitating', Essential readings in problem-based learning: Exploring and extending the legacy of Howard S. Barrows, 69-84.

[25] Thorndahl, K.L. and Stentoft, D. (2020) 'Thinking Critically About Critical Thinking and Problem-Based Learning in Higher Education: A Scoping Review', Interdisciplinary Journal of Problem-Based Learning, 14(1).

[26] Boud, D. and Feletti, G. (2013) 'Initiating problem-based learning at Harvard Medical School' in The Challenge of Problem-Based Learning Routledge, 81-88.

[27] Perrenet, J.C., Bouhuijs, P.A. and Smits, J.G., 2000. The suitability of problem-based learning for engineering education: theory and practice. Teaching in higher education, 5(3), pp.345-358.

[28] Evensen, D.H. and Hmelo-Silver, C.E., 2000. Problem-based learning: A research perspective on learning interactions.

[29] Savin-Baden, M. and Major, C.H. (2004). Foundations of problem-based learning, McGraw-hill education (UK).

[30] Yew, E.H. and Goh, K. (2016) 'Problem-based learning: An overview of its process and impact on learning', Health Professions Education, 2(2), 75-79.

[31] Palincsar, A.S. (1998) 'Social constructivist perspectives on teaching and learning', Annual review of psychology, 49(1), 345-375.

[32] Hmelo-Silver, C.E. and Eberbach, C., 2012. Learning theories and problem-based learning. In Problem-based learning in clinical education (pp. 3-17). Springer, Dordrecht.

[33] Barrows, H.S. (1985) How to design a problem-based curriculum for the preclinical years, Springer Publishing Company New York.

[34] Schmidt, H.G. (1983) 'Problem-based learning: Rationale and description', Medical education, 17(1), 11-16.

[35] Walton, H.J. and Matthews, M. (1989) 'Essentials of problem-based learning', Medical education, 23(6), 542-558.

[36] Kiray, V., Demir, S. and Zhaparov, M., 2013, August. Improving digital electronics education with FPGA technology, PBL and micro learning methods. In Proceedings of 2013 IEEE International Conference on Teaching, Assessment and Learning for Engineering (TALE) (pp. 445-448). IEEE.

[37] Lamar, D.G., Miaja, P.F., Arias, M., Rodríguez, A., Rodríguez, M. and Sebastián, J., 2010, April. A project-based learning approach to teaching power electronics: Difficulties in the application of project-based learning in a subject of switching-mode power supplies. In IEEE EDUCON 2010 Conference (pp. 717-722). IEEE.

[38] Fitzpatrick, C., 2008, May. A problem based learning (PBL) module on electronics & the environment. In 2008 IEEE International Symposium on Electronics and the Environment (pp. 1-6). IEEE.

[39] Santos-Martin, D., Alonso-Martinez, J., Carrasco, J.E.G. and Arnaltes, S., 2011. Problem-based learning in wind energy using virtual and real setups. IEEE Transactions on Education, 55(1), pp.126-134.

[40] Luna, A. and Chong, M., 2020, July. A PBL approach for teaching Electronics Fundamentals by Developing Robotics Projects. In 2020 XIV Technologies Applied to Electronics Teaching Conference (TAEE) (pp. 1-7). IEEE.

[41] Jayaram, S., Boyer, L., George, J., Ravindra, K. and Mitchell, K., 2010. Project-based introduction to aerospace engineering course: A model rocket. Acta Astronautica, 66(9-10), pp.1525-1533.

[42] Rodríguez, J., Laverón-Simavilla, A., del Cura, J.M., Ezquerro, J.M., Lapuerta, V. and Cordero-Gracia, M., 2015. Project Based Learning experiences in the space engineering education at Technical University of Madrid. Advances in Space Research, 56(7), pp.1319-1330.

[43] Elangovan, S., Venugopalan, S.R., Srinivasan, S., Karimbux, N.Y., Weistroffer, P. and Allareddy, V., 2016. Integration of basic-clinical sciences, PBL, CBL, and IPE in US dental schools' curricula and a proposed integrated curriculum model for the future. Journal of dental education, 80(3), pp.281-290.

[44] Thompson, C. (2010) 'Do interprofessional education and problem-based learning work together?', The Clinical Teacher, 7(3), 197-201.

[45] Wang, T. and Grande, J., 2011, October. The first European CanSat competition for high school students. In 20th Symposium on European Rocket and Balloon Programmes and Related Research (Vol. 700, pp. 285-290).

[46] Eerkens, R.H.P., Van Breukelen, E., Verhoeven, C.J.M., Vollebregt, S. and Fitié, A., 2008. The Dutch CanSat competition: How 350 secondary school pupils compete to build the most innovative 'satellite' in a soda can. In 59th International Astronautical Congress: IAC 2008, 29 September-3 October 2008, Glasgow, Scotland.

[47] Walsh, M., 2015. A review of STEM promotional initiatives and activities in Ireland. In Conference Proceedings. New Perspectives in Science Education (p. 179). libreriauniversitaria. it Edizioni.

[48] Contente, J., Galvão, C. (2022) 'STEM Education and Problem-Solving in Space Science: A Case Study with CanSat', Education Sciences, 12(4), 251, available: http://dx.doi.org/10.3390/educsci12040251.

[49] Berthoud, L., Glester, A., Akram, S., Rees, O., Ardelean, I.C., Smith, K., Bannister, N., Fedun, V., Verth, G., Jones, M. and Kingston, J., 2020. Spicing up your space education with CanSats rockets and hackathons...-the Space Universities Network Recipe Book.

[50] Won, S.H., Jun, H.Y., Kim, S.H. and Lee, S.R., 2012. Very Small Satellite Program for Expending the Space Technology Base: CanSat Competition. Journal of the Korean Society for Aeronautical & Space Sciences, 40(7), pp.636-645.

[51] Ostaszewski, M., Dzierzek, K. and Magnuszewski, Ł., 2018, May. Analysis of data collected while CanSat mission. In 2018 19th International Carpathian Control Conference (ICCC) (pp. 1-4). IEEE.

[52] Collis, J. and Hussey, R., 2013. Business research: A practical guide for undergraduate and postgraduate students. Macmillan International Higher Education.

[53] Donnelly, R. and Fitzmaurice, M., 2005. Collaborative project-based learning and problem-based learning in higher education: A consideration of tutor and student roles in learner-focused strategies. Emerging issues in the practice of university learning and teaching, pp.87-98.

[54] Jurewitsch, B., 2012. A meta-analytic and qualitative review of online versus face-to-face problem-based learning. Journal of Distance Education (Online), 26(2), p.1.

[55] Donnelly, R. and Portimojärvi, T., 2009. Shifting perceptions within online problem-based learning. In Encyclopedia of Distance Learning, Second Edition (pp. 1865-1875). IGI Global.

[56] Luck, P. and Norton, B., 2004. Problem Based Management Learning-Better Online?. European Journal of Open, Distance and E-Learning, 7(2).

[57] Brodie, L., 2009. Virtual teamwork and PBL-barriers to participation and learning. In Proceedings of the Research in Engineering Education Symposium (REES 2009) (pp. 1-9). University of Melbourne.

[58] Gürsul, F. and Keser, H., 2009. The effects of online and face to face problem based learning environments in mathematics education on student's academic achievement. Procedia-Social and Behavioral Sciences, 1(1), pp.2817-2824.

[59] Prasad, K.N., Research methodology notes – data collection, Dynamic Tutorials and Services. Available at: https://www.dynamictutorialsandservices.org/2017/05/research-methodology-notes-data.html (Accessed October 26, 2022).