INDUSTRY ENGAGEMENT PROJECTS FOR ENGINEERING UNDERGRADUATE STUDENTS DURING LOCKDOWN: WHAT WORKED AND WHAT FAILED?

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Abstract: There is recognised value in the role that authentic problem-based learning (aPBL) provides engineering undergraduate students in preparation for employability when done in collaboration with industry partners. Such practice falls within the construct of work-based or work-integrated learning. Motivations for industry agents to engage in these programmes include access to specialist facilities and resources for the purposes of prototype development, fabrication and testing as well as fulfilling future talent pipeline requirements, such as placement or graduate roles. The spirit of in-person collaboration between students and industry partners is an exciting and enriching part of experiential, work-based learning. During academic year 2020/21 at the height of movement restrictions, all registered MEng students in their third and fourth years (n=208) at Lancaster University undertook remote projects (n=42). These are group-based and last full-time for a fortnight.

This paper describes the 'what', the 'why' and the 'how' of this activity; it reflects on the shift from conducting such industry-based research and development projects in-person to wholly online endeavours, in pedagogical and practical terms. The paper utilises a range of feedback alongside the author's direct personal experience of leading this core module. It considers the recruitment of projects, the preparation of students, the nature of projects and scaffolding required. It critically reflects through a relatively holistic lens on the successes of such experiential learning and what features can be continued in the future. In so doing, it hopes to provide engineering educators with evidence informed approaches who utilise or are aspiring to conduct such work-based learning.

Keywords: experiential learning, authentic problem-based learning, aPBL, work-integrated learning, COVID-19.

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1. INTRODUCTION

1.1 Work-integrated learning (WIL)

Learning-by-doing is a fundamental component of modern education programmes, especially in science, technology, engineering and mathematics (STEM) courses where there is an expectation on students to demonstrate tactile skills. This is pertinent to highly vocational courses, including apprenticeships where knowledge, skills and behaviours have to be demonstrated to achieve the necessary qualification. There is an expectation on engineering graduates and ergo the universities that teach those students that they leave with practical, demonstrative skills as well as knowledge and competencies of a more theoretical basis. Experiential learning in this context provides students with valuable learning as part of undergraduate and postgraduate degrees, and is defined as:

> Learning is the process whereby knowledge is created through the transformation of experience. This definition emphasizes several critical aspects of the learning process as viewed from the experiential perspective. First is the emphasis on the process of adaptation and learning as opposed to content or outcomes. Second is that knowledge is a transformation process, being continuously created and recreated, not an independent entity to be acquired or transmitted. Third, learning transforms experience in both its objective and subjective forms. Finally, to understand learning, we must understand the nature of knowledge and vice versa.
>
> (Kolb, 1984, p. 38)

This widely accepted definition put forth by Kolb and informed by Piaget, Dewey and Lewin makes clear that experiential learning is a process and has both objective and subjective aspects. Gentry (1990) points to the following critical components that make up experiential learning: applied, participative, interactive, whole-person emphasis, contact with the environment, variability and uncertainty, structured exercise, student evaluation of the experience and feedback. Resonating closely with these features and within the domain of experiential learning resides problem-based learning (PBL) where “students, working in collaborative groups learn by resolving complex, realistic problems under the supervision of faculty” (Allen, Donham, & Bernhardt, 2011, p. 21).

The concept of ‘realistic’ can be interpreted differently across disciplines, for example in veterinary education it may be the presentation of animal symptoms and in engineering it could be a hypothetical problem or derivation of a problem that has happened, and one from which the instructor may have first-hand experience. Using problems and projects derived by industry partners that they are facing and that require discrete technical input is one way in which the concept of ‘realistic’ becomes ‘real’. Where this proximity to the real world is reduced and hence problems are real, this is referred to as authentic PBL or aPBL (Lambert & Ashwin, 2021).

1.2 COVID-19 and lockdowns

Movement restrictions imposed by governments through the earlier stages of the outbreak of COVID-19 and subsequent variants resulted in seismic shifts to the way in which experiential learning was conceived and conducted (Pelaez-Morales, 2020). Results show that instructors with effective communication skills, and teaching style, competent use of technology, flexible, friendly and supported attitude towards teaching, played a positive role in mitigating challenges caused by moving to remote to teaching (Ahmed & Opoku, 2021). Many teachers pivoted to this new way of learning rapidly with little time for preparation and now have the opportunity to reflect on what was effective, what was not and what can be taken forward in future strategies.

At Lancaster University, the School of Engineering has five courses at integrated masters level (MEng): Mechanical, Engineering, Chemical Engineering, Mechatronic Engineering, Electronic and Electrical Engineering and Nuclear Engineering. As part of these programmes, all students undertake a core 15-credit, Level 7 module called Industry-linked group projects. In this, students undergo classroom-based preparation followed by two fortnight-long group-based (teams of five or six) industry-linked technical projects. One is completed at the end of the third year during Summer term (around the third and fourth week of June) and one is completed in Lent term of the fourth year (around the second and third week of March). Projects are recruited from industry networks, managed by the engagement team for the department and fulfil genuine needs from external collaborators. Projects vary considerably but a majority are technical research and development activities associated with new product development. In academic year 2020/21, across both fourth and third year cohorts, 208 students took part in 42 projects which for the first time were all conducted remotely.

2. METHODS AND RESULTS

2.1 Project content

In order to obtain metadata concerning the content of projects, project brief documents were grouped for those that took place during lockdown (n=42) and those that took place in the two years prior to COVID-19, during academic years 2017/18 and 2018/19. Within this group, two projects with the same organisation were removed, giving the same number of projects (n=42), to enable easier comparison. All briefs were stripped of extraneous information including external organisation background, contact details, titles and the brief, so that the remaining data was (i) project title and (ii) intended outputs. These documents were imported into computer assisted qualitative data analysis software (CAQDAS) ATLAS.ti. Table 1 shows the number of occurrences of the ten most common terms across each collection of briefs.

Term	2017/18 and 2018/19	Term	2020/21
Design	64	Design	51
System	25	Research	34
Materials	23	Recommendations	23
Recommendations	22	Development	21
Analysis	19	Materials	19
Development	18	System	19
Manufacturing	17	Product	17
Product	15	Requirements	16
Data	14	Understand	14
Mechanical	13	Analysis	13

Table 1: List of the most frequent terms used in project briefs pre-lockdown (2017/2018 and 2018/19) and during lockdowns (2020/21).

The term ‘design’ featured heavily and singularly as the most occurring term in both groups, which is unsurprising. The remaining most frequent terms provide some correlation with the following featuring in both groups of data sets: ‘system’, ‘materials’, ‘recommendations’, ‘analysis’, ‘development’, and ‘product’. Three terms that are new during lockdown briefs were: ‘research’, ‘requirements’, and ‘understand’. Three terms not featured during lockdown briefs but which were previously cited were: ‘manufacturing’, ‘data’ and ‘mechanical’. To help provide the reader with a fuller understanding of the types of projects that have been completed, Table 2 provides a list of titles from June 2021.

Evaluation of a magnetic split block system with generation/appraisal of alternative solutions
Simulation and analysis of a Unimog pick-up hitch and 3-point linkage
Manufacturing options analysis for a construction site safety product to prevent falls
Development of a scale-able contamination separation system
Design of housing and installation design for novel LED light fitting
Improvement of the housing design of a gateway unit for outdoor use in extreme weather conditions
Investigation of market applications for innovative technology for biogas upgrading to biomethane suitable for gas-grid injection
Investigation and technical appraisal of factors and solutions that contribute to fuel efficiency
Improve the efficiency of build support manufacture in additive manufacture of industrial components
Development of additive manufactured filters designed around new patent, design and CAD model
Material investigation for lightweight electronic housing for UAV and other applications
Optimisation of battery pack system using CFD techniques
Ultrasonic technology for enhanced liquid/solid separation: a study of feasibility, potential applications and next steps
Design and development of a snow quality measurement system
Feasibility study into smart lampposts, incorporating design and development
Re-design of a vaginal speculum for use in medical examinations
Developing solutions for dealing with whey as a bi-product in artisan cheesemaking
Overview of the European and worldwide research and education landscape in nuclear energy
Development and modelling of a novel modular hydro-energy device
Feasibility study for water blast and wastewater reclaim system for a casting site
Integration of electronic and electrical components into a subsea device
Using hollow glass microspheres in additive manufactured materials for subsea application
Investigation of non-halogenated flame retardants for use in textile products

Table 2: A list of titles from all participating projects in June 2021. Company names where relevant have been removed to preserve anonymity.

2.2 Location of collaborators

Postcodes for collaborators from the 'pre-lockdown' and 'during lockdown' groups were collated and analysed with help from Google Maps. Unsurprisingly, there is a clustering effect in the Northwest of England in both cases as proximity is a contributing factor to collaboration for industry with top tier universities (Laursen, Reichstein, & Salter, 2011). During academic years 2017/18 and 2018/19, beyond the Northwest, there were four located in the South of England, one in the Northeast, one in the midlands, one in Scotland and one in Wales. There were no international collaborators. There appears to be two changed features during lockdowns: a tightening of the clustering effect to Lancaster, whilst simultaneously an expansion that includes four international partners, from France, the Netherlands, Republic of Ireland and Switzerland.

2.3 Management and co-ordination

This section describes first-hand reflections from the author's experience in convening the module. Significant resources, in the form of staff time are required to set up aPBL experiences particularly in the recruitment of suitable projects from committed external organisations (Wang et al., 2012). Despite the remote nature of these projects, recruitment was not a problem and in fact over-recruitment occurred during lockdowns, meaning there were excess projects submitted relevant to size of cohorts.

Scaffolding is an integral part of aPBL and during lockdowns, there was evidence that some students' lack of engagement was exacerbated because of the virtual way in which projects had to be delivered. Being physically 'absent' appeared to accentuate some students lack of contribution; this was isolated but highlighted, in some cases more scaffolding was required for some students. In most cases, student teams functioned well despite being virtual and generally, high levels of satisfaction were recorded. This was mirrored by industry feedback which almost always either met or exceeded expectations.

Scaffolding for external organisations that are part of student collaboration activities has received generally less attention, compared to scaffolding for students, as the latter tends to be a focus for HE teachers. Throughout lockdowns, the author took the opportunity to provide more scaffolding to the collaborating organisations. This included early guidance on expectations, detailed guidance once projects had been agreed and more direct communication in the run-up to students taking part. This appeared to be very effective at preparing external collaborators.

The remote working of student groups was supported by the use of MS Teams, wherein each group was provided with a private channel within a whole team for the module to share, collaborate and generally work together. Whilst some students did not use this, opting for spaces away from teacher's sight, in the whole most did use this and used it very effectively. Discussions, decisions, actions points could all be recorded in one place and working on documents simultaneously was done effectively by the students. Teams also used this space to hold regular meetings and the familiarity of the platform from the preceding year meant no additional training was required. MS Teams was considerably preferable to the institution's virtual learning environment, Moodle.

2.4 An aPBL case study

Veterans into Logistics CIC is an organisation based in Greater Manchester that aims to support ex-military personnel adjust to civilian life through mentoring, training and support. The company provide training on large goods vehicles (LGVs) for individuals to pursue a driving career after leaving the forces. A number of veterans who wish to re-train as LGV drivers have lost a leg. With modern automatic truck cabs, this is not a problem if it is the left leg. It is perfectly feasible and safe to drive as the right leg does all the work. If the trainee has a right leg missing or a prosthetic, this is not possible as there is insufficient feedback to the driver from a prosthetic leg to enable peddle operation. The overarching objective of this project was the design of a removable, adaptable system to enable safe and successful driving of LGVs by right-leg amputees.

A team of three mechanical and two mechatronic students undertook the project in March 2021 with an academic supervisor, carrying out conceptual and detailed design work, force calculations, CAD models, bill of materials and recommendations for progressing the work further. The team generated two final designs (Figure 3): one to be fitted into a cab and a second that aimed to be universal so that it could be placed and removed from cab-to-cab with ease.

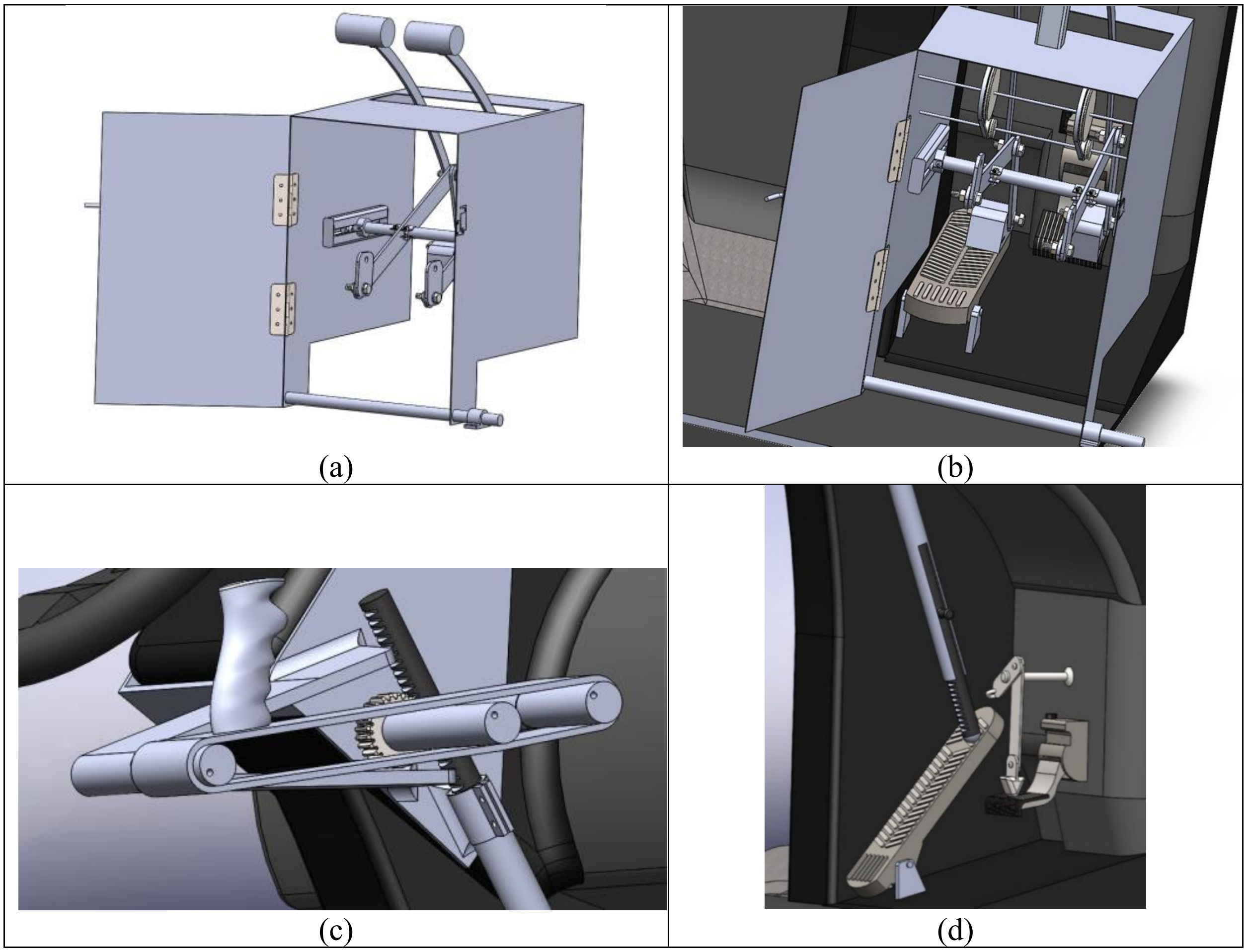

Figure 3: (a) and (b) showing the universal design and (c) and (d) showing the fixed design, each using a combination of reverse linkage mechanisms to control brake and accelerator pedals.

Students who worked on the project provided the following collective feedback:

> *"Veterans into Logistics were a friendly company to work with and we all enjoyed collaborating as a team. Learning about their ethos was an honour and a privilege and we are glad we had the opportunity to work on such an exciting project with them. The experience of getting to know the clients and how we could work to best deliver them a product was really great and has definitely added value to our degrees that we can carry forward into our future work. We hope that this product will benefit veterans in the future and make a positive impact people's lives. It was a challenging but gratifying experience."*

Janice Gurney, National Company Secretary for Veterans into Logistics CIC provided the following feedback:

> *"Working with engineering students who were very engaging and wanted to know about Veterans and also Veterans into Logistics, especially those who have served their country,*

> *now facing life changing challenges. These Students not only wanted to rise to the challenge but to deliver a concept on paper, all this whilst in a pandemic of covid 19. This is not only humbling but truly inspirational for the students."*

3. DISCUSSION

Over the several years prior to COVID-19 as a Department, we had experienced a healthy level of demand (often beyond supply) for these projects. One of the largest concerns for the author was if this appetite would erode as businesses focussed on other parts of their operations following economic impacts from the pandemic. Another chief concern was whether the lack of access to facilities for testing and prototyping would have contributed to external organisations not engaging with these projects. However, engagement levels remained high, showing that organisations continued to place importance on the role of research, development and innovation, despite resources and projects being remote. Most organisations we work with tend to be small-to-medium-sized enterprises (SMEs) and most of those tend to be small and micro-enterprises and so resourcing for R&D activities is likely a contributing factor for this demand.

In terms of project content, it was initially surprising to see a reduction in the term 'design' although this could be explained by recognising that design is a collective, collaborative endeavour, more difficult to accomplish efficiently online. compared to physical presence in a room with whiteboards, flip-charts and PCs with CAD. Inclusion during lockdown of terms such as 'research', 'requirements' and 'understand' indicate a broader set of content, in which concepts, problems and ideas were more widely investigated. This indicates that projects were potentially wider in scope and with less-focussed aims, reflecting an unknown of how the students may perform or what would be reasonable expectations. Inclusion of terms pre-lockdown such as 'manufacturing', 'data' and 'mechanical' suggest more fabrication and testing activities.

Given the influence of external organisaitons to impact the quality of aPBL experiences for students, the author recognises that more could be done to scaffold those industry partners. Whilst we can be confident that they are experts in their own fields, we cannot necessarily be certain that their expectations are aligned with university staff, students or learning outcomes. Providing appropriate scaffolding to external organisations will be a continuing feature of aPBL undergraduate engineering projects run from Lancaster, with the aim of helping to set expectations and identifying common features of success.

Having students not just communicate virtually but collaborate virtually through active participation pre-pandemic was a challenging endeavour, with low levels of use as reported by Gidion and Grosch (2012) in Schuster, Groß, Vossen, Richert, and Jeschke (2016). The pandemic forced students to communicate and collaborate virtually. Our own experiences show that students achieved this by engaging in regular dialogue with each other, making decisions by consensus, evaluating design concepts, assigning roles to each other, making logistical arrangements, communicating with staff and working on shared documents simultaneously. Importantly, this has continued post-pandemic and so has become a positive legacy of virtual collaboration during lockdowns, which now during periods of in-person collaboration is still extensively and successfully used. The virtual nature of collaboration during the pandemic demonstrated that our geographical reach goes beyond the UK and in so doing, exposes students to internationalisation of their learning.

4. CONCLUSION

Experiential learning during COVID-19 lockdowns presented teaching staff with numerate challenges, whilst simultaneously the opportunity to reflect on the 'what' the 'why' and the 'how', attempted here for undergraduate Engineering students engaged in aPBL at one UK institution. We found a natural shift from prototyping and testing (requiring facilities) to more design, simulation and modelling, but still constituting and contributing to innovation development within collaborating organisations. As we move out of lockdowns, access to facilities has been a welcome return so that prototyping and testing can once again be carried out. We found aspects which could be improved and have seized the opportunity to continue the positive legacies of remote working. Clear manifestos to do this for the author are in the appropriate preparation and scaffolding of industry collaborators, recognising their value in the learning process. In addition, the continued use of digital platforms to support experiential learning as well as continued engagement of aPBL collaborators both within and beyond our locale.

5. REFERENCES

Ahmed, V., & Opoku, A. (2021). Technology supported learning and pedagogy in times of crisis: the case of COVID-19 pandemic. *Education and Information Technologies*, 1-41.

Allen, D. E., Donham, R. S., & Bernhardt, S. A. (2011). Problem-based learning. *New directions for teaching and learning, 2011*(128), 21-29.

Gentry, J. W. (1990). What is experiential learning. *Guide to business gaming and experiential learning, 9*, 20.

Gidion, G., & Grosch, M. (2012). Welche Medien nutzen die Studierenden tatsächlich? Ergebnisse einer Untersuchung zu den Mediennutzungsgewohnheiten von Studierenden. *Forschung und Lehre, 6*(12), 450-451.

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*: FT press.

Lambert, C., & Ashwin, P. (2021). Using Student Feedback to Reflect on Authentic PBL (aPBL) in Undergraduate Engineering Education. *J Probl Based Learn, 8*(1), 4-12. doi:10.24313/jpbl.2020.00311

Laursen, K., Reichstein, T., & Salter, A. (2011). Exploring the effect of geographical proximity and university quality on university–industry collaboration in the United Kingdom. *Regional studies, 45*(4), 507-523.

Pelaez-Morales, C. (2020). Experiential learning in the COVID-19 era: Challenges and opportunities for ESOL teacher educators. *Teaching/Writing: The Journal of Writing Teacher Education, 9*(1), 12.

Schuster, K., Groß, K., Vossen, R., Richert, A., & Jeschke, S. (2016). Preparing for industry 4.0–collaborative virtual learning environments in engineering education. In *Engineering Education 4.0* (pp. 477-487): Springer.

Wang, Y., Yu, Y., Wiedmann, H., Xie, N., Xie, C., Jiang, W., & Feng, X. (2012). Project based learning in mechatronics education in close collaboration with industrial: methodologies, examples and experiences. *Mechatronics, 22*(6), 862-869.