DESIGNING CROSS-DISCIPLINARY PROGRAMMES TO DEVELOP THE ENTREPRENEURIAL SKILLS OF ENGINEERING DESIGN & BUSINESS STUDENTS

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ABSTRACT
It is desirable that current and future employees have a range of skills, be adaptable to challenges, collaborate with internal and external stakeholders, and are creative in finding new solutions to problems. To achieve this, developing the entrepreneurial skills of students is beneficial for future employers and the students themselves. This can be achieved by educating students on the factors which influence commercial success including technical feasibility, market desirability and commercial viability. An observation was made that engineering design students are typically highly skilled in developing creative & technically feasible solutions with the user in mind, and business students are highly skilled in developing commercially viable proposals. This paper details what happens when a cross-disciplinary educational intervention is conducted between engineering design and business students for mutual skills development. An 8-week pilot programme was designed at the University of Strathclyde where six teams of business students were paired with a student engineering design mentor to provide advice and guidance on the technical feasibility and viability of the commercial propositions being developed by the business students. The outcomes of the programme were in the technical and softs skills development for the engineering design students, the development of stronger commercial proposals supported by tangible assets for business students, and a greater appreciation of client/consultant negotiation and communication for both disciples of students. Recommendations are shared for those who are considering the development of similar programmes in the future.

Keywords: Entrepreneurship programme, engineering design students, business students, project-based learning, entrepreneurial skills development, tutorship

1 INTRODUCTION & LITERATURE REVIEW
Universities offer their students a safe environment to learn and practice entrepreneurial skills before entering real-world trade. Students may choose to attend university for personal reasons perhaps including knowledge building and skills development on particular topics which they choose to study. Within an educational environment there can be limited opportunities to design authentic experiences within the curriculum without specific interventions such as a placement within a company. However, specific lessons can be designed into the curriculum giving students an experience of and the knowledge to overcome challenges they may face after graduation. For students studying entrepreneurship related subjects or on a path towards it they need to build the skills to support their personal and professional development.

The question of 'how relevant entrepreneurship knowledge and experiences is to product designers' has been well addressed in literature [1]. Proposals have been made of innovative product design approaches to enhance innovation and entrepreneurship in design and engineering students [2], and others speak of the importance of combing market, design and innovation education together [3].

From a pedagogical perspective, bringing together design and business students for inter-disciplinary projects has learning benefits and develops transferable skills. Business students gain a better appreciation of user-centred design and have creativity skills enhanced. Design students gain a great appreciation of commercial elements such as finances and marketing [4]. When combined, all students

gain a more rounded appreciation of design and commercialisation, and how the two concepts are required for successful product development and launch.

At the University of Strathclyde an observation was made that further supports the work of Baelus [4]. Engineering design students are typically highly skilled in developing creative & technically feasible solutions with the user in mind, and business students are highly skilled in developing commercially viable proposals which consider financial and marketing aspects. This observation has led to a motivation to develop an educational intervention bringing both disciplines of students together.

The need for this work is supported by government initiatives in the UK including 'Developing the Young Workforce'. As our world evolves through Industry 4.0, there is a growing trend for the educational sector to develop graduates with transferable entrepreneurial skills going well beyond their subject of expertise [5] in order to better prepare students for the world of work [1]. This growing trend is being well documented in literature, with many academics acknowledging that 'a conventional academic degree alone is no longer sufficient' [5]. There is a growing desire for multi-skilled, adaptable, collaborative & entrepreneurially minded students as it is well understood that an entrepreneurial mind is crucial for future commercial exploitation of new opportunities [3].

State-of-the-art research in this area is currently investigating how to develop transferable skills, and acknowledge that in order to cultivate talent, the integration of entrepreneurship education and design education is key [3]. Progress is being made to address this issue through various work such as Spruce [5] discussing an initiative at Liverpool John Moores University called World or Work (WoW) and Mallins who cites a project looking to better connect students with industrial experience [6]. Sandy [7] also looks at a 2-month study providing students with a structured process for developing their ideas [7]. Two studies of particular interest in our work are by Baelus [4] and Tran [8], both of which look at the development of programmes that bring together business and engineering/design students and provide a strong foundation on which our work is based.

This paper describes the design and evaluation of a programme to develop entrepreneurial skills in engineering design and business students through a cross-disciplinary Project Based Learning (PBL) educational intervention. The methodology for the design, delivery and evaluation of this programme is detailed in section 2. Results and discussion are presented in section 3 with a reflection on the limitations of the programme and recommendations for future development and advice for others who may be interested in implementing such programmes within their institutions. The conclusions in section 4 present a summary of the research and the findings.

2   METHODOLOGIES

In this section, the methodology for the design, delivery and evaluation of a cross-disciplinary to develop entrepreneurial skills in engineering design and business students is presented.

2.1 Design of the programme

To bring engineering design and business school students together an 8-week pilot programme was developed. The programme asked students to put into practice the skills and knowledge developed in order to create a convincing and consistent business proposition. Students were expected to identify a suitable business idea, use market research and prototyping for validation, and present two equally comparable, but different, strategies to grow their business. The programme formed part of the business student's Masters level project and was a self-directed and supervised class for the business students to research and validate their ideas. Incorporating the engineering design students was through a paid internship opportunity for those in their 3rd, 4th or 5th year of a Masters or Bachelor's degree in Design Engineering, or 1 year Post Graduate Design Engineering programme.

2.2 Delivery of the programme

The pilot programme ran throughout Jun & July 2021. Business students were asked to form teams based on their ideas and the skills they required. To better understand these teams, students were asked to complete a group formation form, detailing the team members, the skills they currently possess & gaps they may have, their commercial idea, and what they hope to achieve from the programme. To find suitable design engineering mentors a job advertisement was created by class coordinators and advertised to the engineering design students. At this stage, the engineering design students were not given information on the business student group formation forms. Interested engineering design students, were only asked to submit a CV detailing skills and expertise for consideration by the class

coordinators. Class coordinators of the programme then matched the skills stated on engineering design CVs to skill gaps stated on Business students group formation forms. This project was financially backed by the Hunter Centre for Entrepreneurship at the University of Strathclyde and engineering design mentors were paid an hourly rate to a maximum budget of 30 hours of support per group. Each business student group was supported by one engineering design mentor. Two engineering design mentors supported two projects each and two engineering design mentors supported one project each.

2.3 Evaluation of the programme

Upon conclusion of the pilot programme, feedback was collected from the participants to evaluate the experience. Engineering design mentors were consulted during an open forum focus group session. Two of the four mentors took part in this session. Further reflective interviews were then conducted via email with the engineering design mentors in January 2023. Three of the four mentors took part in these interviews.

Business students were not interviewed upon conclusion of the programme; however informal discussion was held following their graduation from the course. They were then formally interviewed in in January 2023. Three students took part in the formal interviews representing three of the six teams. Questions asked during the follow up interview were:

1. How did you find the experience of working with students from another discipline in general?
2. Were there any challenges?
3. Were there any highlights?
4. Did the experience of working with the students from another discipline enable you to develop your soft skills? If so, which skills were developed?
5. Did the experience of working with the students from another discipline enable you to develop your technical skills? If so, which skills were developed?
6. Reflecting on the experience of working with the students from another discipline, is there anything you would have done differently? Is there anything you would suggest is done differently if this programme were organised again in the future?
7. If you could rate the following aspects of the experience on a scale of 1-10 (10 being high), how would you rate them?
   a. Helpfulness in developing my soft skills,
   b. Helpfulness in developing my technical skills.

An additional question was asked of the business students being:
   c. Helpfulness in pursuing the idea further out with my studies.

3 RESULTS & DISCUSSION

3.1 Reflections of the Engineering design students'

The open forum discussion with the engineering design students suggested the programme was a success and different than that which they had experienced during their studies so far, describing the experience as "invaluable". An interesting detail was that in some cases, engineering design student mentors went above and beyond the allocated budget of 30 hours as they recognised the benefits of the skills development to their own personal development as a designer.

Covid-19 restrictions on face-to-face meetings were in place at the time of the programme and this was reported as a challenge for communication. It is unclear if this influenced the lack of project clarity communicated from the business students at the start of the project, or if this would be present under normal circumstances. Overall, students suggested their technical and soft skills had been greatly enhanced by the programme. The interviews which took place in January 2023, provided further insights.

Question 1. Challenges highlighted mainly focussed on Covid-19 restrictions making communication more challenging. Time management was also highlighted as a key challenge. As the engineering design students also were not with the business student daily, this resulted in project direction and project clarity challenges. Engineering design students also reported that the business students lack of understanding of the design process meant time had to be spent educating the business students. The short time frame for the project was also another challenge.

A key highlight for the engineering design students was seeing work they created being used well after the programme had finished in the start-up's that were created from the programme i.e., logo and

branding. The students also had a much better understanding of what it would be like being a freelance designer & could see how their soft skills were developed. In addition, the programme also provided network expansion opportunities, and it was noted that some of the students still stay in touch with each other.

Question 2. The key soft skills that were highlighted as being developed were time management, communication, adaptability, ability to manage criticism, and confidence.

Question 3. The main technical skills development was in those that were new to the student and/or had not been taught on their respective courses i.e., wire framing and UI/UX design skills.

Question 4. On reflection, the students themselves said they should have tried to maintain more regular communication/meetings throughout the project duration with their groups, and they should have tried to establish better clarity from the project onset on expected project deliverables and outcomes.

Suggestions for improving the project included providing engineering design students with a broader range of projects to work on and a more formal 'royalty' agreement between engineering design and business students. In addition, running the programme over a longer timeframe and providing more paid hours to support the business student if requested.

Question 5. Asked for a quantitative answer with the average response to the 'Helpfulness in soft skills development' being 7.7/10 (individual responses were 8, 8, 7) and in response to 'Helpfulness in technical skills development' being 6.7/10 (individual responses were 7, 7, 6). Responses were very similar and positive for both questions.

3.2 Reflections of the Business Students'

It was reported through communication with the students upon their graduation, that of the six business student teams supported, four went on to engage with external support services for developing their ideas further after they graduated. From this, two registered businesses, and two continued to explore the ideas at idea stage out with their university studies. Three business students responded to our interview request in January 2023, their responses are now discussed.

Question 1. The main challenges focussed on educating the engineering design student on the market in which the business students wished for them to work. This is not unexpected, as the engineering design student is completely new to the project area, in comparison to the business student who already knew the area well from having developed the proposal. Covid 19 was also noted as being a challenge due to the implications this placed on face-to-face meetings and communication, however this is not a unique challenge to this project, and similarly was noted as a challenge by the design engineering students. The key highlights for the business students that was noted was in the high-quality outputs & attitude & self-motivation of the engineering design students ('diligent and charismatic'). This suggests effective selection of the engineering design students with a skill set that added value to the business students.

Question 2. Two of the students answered there that were no soft skills developed, however one student responded that they felt their communication and people management skills were enhanced.

Question 3. No technical skills development was noted. However, a comment was made by one student that this was seen in their view as positive, as it allowed them to focus on commercial and business aspects of their business, which was their area of interest, rather than trying to learn new technical skills.

Question 4. There was limited reflection from the business students on what they could have done differently, however they did note more face-to-face communication would have enhanced the experience. They also did suggest that the programme could be improved by better alignment/pairing of engineering design students in terms of their interest in the project area, and perhaps consider providing the business students with a team of engineering design students rather than just an individual. Again, this feedback is similar to that of the design engineering students, who suggested it would be good to work on a broad range of projects.

Question 5. It was stated by all business students that the design student was not a factor in pursing the project beyond the programme, however a good relationship was still maintained between both students.

Question 6. Asked for a quantitative answer with the average response to the 'Helpfulness in developing soft skills' being 4.7/10 (individual responses were 2, 4, 8), in response to 'Helpfulness in developing technical skills' being 1/10 (individual responses were 1, 1, N/A), and in response to 'Helpfulness in pursing the idea further' being 2/10 (individual responses were 2, 2, N/A). Responses were very similar and negative for these questions.

Comparing the experiences of both students there are clear differences. For the engineering design mentors the experience was positive and these students were able to reflect on the positive skills

development they experienced. On the other hand, the business students did not have a positive experience related to their skills development. It is unclear why this is the case but perhaps there is a difference in the reflection skills of the students or the emphasis they put on the importance of building these skills. This is something we wish to investigate in the future.

3.3 Recommendations for future development

There are lessons learned in the approach to this pilot project which now provide recommendations for future work.

1. In this pilot, the commercial ideas the business student groups would be working on were not disclosed until the engineering design student was allocated to the group. A specific job advert for each business student group, would perhaps allow better matching of engineering design skills with skill gaps stated by the business student groups and allow for better alignment of engineering design student to project areas of interest.

2. Engineering design students were not interviewed for the internship, and were selected only based on skills stated on their CV. It is recommended that an interview process or 'speed dating' activity for engineering design student recruitment would provide better skills/project interest matching and also ensure engineering design students selected continue to be motivated by the skills development opportunity.

3. No design development process education had been given to the business students prior to this project.

4. Groups were not consulted or asked how much time they thought they would require. All groups were provided equal hours (30 hours total), however during the project some did not use all the hours available, and some asked for additional hours. In terms of engineering design students, some also went above and beyond allocated hours (which was therefore unpaid).

5. This pilot was run during Covid-19 pandemic restrictions, therefore most interaction between the engineering design and business students occurred online.

To overcome these limitations recommendations have been created.

To overcome limitation 1. it is recommended that specific job adverts should be created for each business student group detailing the project proposed & providing further details on the market they will be targeting.

To overcome limitation 2. it is recommended that engineering design students should be invited for interviews or a 'speed dating' event with the business students.

To overcome limitation 3. it is recommended that design development overview workshop with business student's prior the programme commencing to ensure a good appreciation of the design development process and provide a more realistic appreciation of what can be achieved in the given timeframe when working with the engineering design students.

To overcome limitation 4. it is recommended that ask the business students to propose how much support & time they would need from an engineering design student.

To overcome limitation 5. it is recommended that encourage face to face meetings and communication between engineering design students and business students. It is recommended that students are encouraged to meet at least once per week.

In addition, two further recommendations were created which do not relate to a specific limitation identified these are: to provide design engineering students with at least two projects to work on in order to allow them to develop skills in different areas or consider running the programme with engineering design students working as a collective group managing and working on all business student projects, and to situate the design engineering students as full-time group members, with remuneration in terms of class credit rather than payment. Although, the skills development opportunity is seen as being most beneficial to the engineering design students, and less so for the business students, it was still seen as a positive experience for the business students in providing them with valuable, high quality, tangible assets that allowed them to develop their ideas further. The business students were also able to more fully focus on developing stronger commercial propositions, as their time was not wasted trying to learn new technical skills. On reflection, the programme was primarily beneficial in developing the soft and technical skills of design engineering students and providing business students with an appreciation of the design process and in allowing them to focus on developing strong commercial propositions supported with tangible business assets to develop their businesses further.

4 CONCLUSIONS

An entrepreneurial mind-set is crucial for industry, where there is a growing desire for multi-skilled, adaptable, collaborative & entrepreneurially minded students [3]. In the presence of Industry 4.0, the educational sector must be developing graduates with transferable skills that go beyond their subject of expertise, as the conventional academic degree is no longer enough [5].

This paper looked to address this growing need for more entrepreneurially minded students and to explore the educational benefits to the students of bringing together cross-disciplines to work on solving real world problems. To achieve this groups of business students were paired with an engineering design student to function as a mentor in product development. Upon completion of the course both sets of students were interviewed to evaluate the success of the programme. The outcomes of this evaluation are a set of recommendations for future development of the programme supporting student satisfaction and coordination of the educational experience.

It was identified that mentors and business student groups could be better aligned based on personal interest or through interviews. Business students should be given education on design process for an appreciation of the design process. The contribution of the mentor to the product development was not equal for all who contributed which could be formalised. And it is recommended that more face-to-face meetings are encouraged & facilitated. Also, it was identified that the design students could contribute to more groups at one time, and they may be situated within the team in exchange for class credits rather than as a paid mentor.

Further investigation is required to determine why the business students did not share the same reflection of the value of the experience as the design engineering students received from the process and if the programme design can be changed to better support the commercial propositions of the business students.

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