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MAPPING DESIGN BRIEFS AND RESULTS OVER A DECADE OF UNIVERSITY-INDUSTRY STUDENT PROJECTS

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ABSTRACT

This research focuses on navigating the complexity of a modern approach to product development in the educational context, revolving around how to best equip future product developers. The PdP (Product development Project) course at Aalto University has been running for 25 years and is considered a success in what concerns Industry-Academia cooperation. Many changes have occurred in industry, education, and students' profiles during the last decade. Collaborative projects became substantially more complex and showed a significant degree of trans disciplinarity. This paper analyses the wide repository of data related to the PdP course to classify characteristics of industry project briefs and the nature of multidisciplinary knowledge used during their development. The findings suggest industrial partners favour providing design briefs with relatively high degrees of novelty and uncertainty in the course. It was also found that breakthrough types of projects have resulted in the most balanced disciplinary contributions to the project outcomes, whereas derivative projects have leaned on mechanical engineering. More conceptual research and development projects emphasize design and business, and platform projects have varied widely. The project typology and profiles can be of help to educators, students, and industry representatives alike in scoping and planning university-industry project-based courses.

Keywords: Product development, design education, university-industry liaison, live projects

1 INTRODUCTION

Product development and design represent vibrant fields contributing to business and societal goals alike, with significant technological and paradigm advancements in the last decades. From an educational perspective, this fast-paced evolution provides students with the opportunity to expand their field of expertise to create meaningful and cohesive product solutions. The use of university-industry collaborative projects as a pedagogic model is well established, and much has been written about the use of industrial briefs within design and engineering courses in higher education [1]. These collaborations reinforce experiential learning within educational programmes and boost industry value creation [2], [3], as they generate mutually beneficial knowledge and promote technology innovation exchange between parties. The format of these collaborations, or *live projects,* is often described as "out of the studio setting, repositioned in the 'real-world'" and existing "between the two tectonic plates of learning in academia and in practice" [4].

Research from several countries has explored the nature of collaboration and the cooperative principles that emerge between industry and university [5],[6],[1],[2]. Generally, these studies have listed benefits for students' learning experiences where they can test in practice methods and tools that they learn through studies and explore real industrial contexts [6]. Research also points to industry advantages, where university partnerships raise companies' profile upon an innovative approach, providing the opportunity to test ideas with no immediate commercial applicability and keep in touch with a set of fresh-thinking individuals who are relatively unaware of industry limitations [1]. However, such collaboration also has its own challenges, with university-industry student projects blurring the borders regarding rights, responsibility, economy, and information flow [5]. Indeed, there are multiple types of uncertainties and novelties at play within these projects. For example, in terms of the target of development, product development projects can be classified in terms of the degree of change in the product and the degree of process change [7].

With the contemporary world being marked by vague boundaries between artefacts, structures, systems, and processes [8], industry-provided challenges often require addressing an entire system and not just a single part or component. As such, the target scope of university-industry student projects can vary in width, clarity and uncertainty. Furthermore, addressing such complexity through highly integrated product development practices emphasises the need to transform design engineering education from disciplinary to transdisciplinary [9].

However, we know relatively little about how these changing degrees of complexity, novelty and uncertainty influence student experiences and learning outcomes. As extant studies suggest, students new to design might struggle initially to accommodate high levels of uncertainty inherent in most design and development projects [10]. Some types of projects might be more conducive for university-industry collaboration in project-based courses than others. The current study investigates the evolution of the type of industry-provided design briefs offered during the past decade and how these different project types interact with student output to provide a better understanding of how to foster collaborative projects that contribute value to the industry, students and academia alike.

2 METHODOLOGIES

2.1 The course context

This study examines changes in project brief typologies within the PdP course at Aalto University (www.pdp.fi), spanning 12 academic years. The course has been organised since 1997 and sparked the creation of a global network of Design Factory development platforms [11]. From 1997 to 2021, 2895 master's level students participated in this multidisciplinary course. From 2018 to 2020, 46% of students were from mechanical engineering, 22% from design, 10% from business and 7% from electrical engineering and information technology. Students form multidisciplinary teams with varying compositions and partner up with students from partner universities. Each student team works on a unique design brief with a specific industry partner which contributes a 10,000€ team budget to be used for product development and prototyping expenses by the team. The final project prototypes are presented during an open gala. Since 1997, the PdP course has collaborated with 135 companies that vary in size, annual revenue, and activity sector.

2.2 Data collection and analysis

To explore the types of projects suggested by the industry design briefs and how these connect to student output, the current study examined two archival data sets: (1) the 174 design briefs used in the course between 2009 to 2019; and (2) the 42 students project reports capturing the output of the course from three academic years during the studied period.

The course utilizes written design briefs, each representing an approximately 1-page long description of the project, distributed to the students at the very beginning of the course (and later expanded upon in meetings with the industry liaisons). These design brief documents were deductively classified into four degrees of novelty, building on the framework developed by Wheelwright and Clark [7] (Table 1). Figure 1 illustrates the different levels of methodological practices and degrees of novelty of the four types of projects. Each type of project was then mapped across different years of the course to examine whether the distribution of projects or degree of novelty had changed during the years by comparing descriptive statistics of the distribution.

After mapping the 174 design briefs, we then looked into the projects from three academic years in more detail: 2011-2012, 2015-2016 and 2020-2021, representing a total of 42 projects. We collected all of the student teams' final reports, which were submitted at the end of the course, and typically spanned 50-80 pages. Based on these reports, the content of the solution developed by the teams as well as the development process described within the reports were mapped into each five main disciplines in the course they represented: business, design, mechanical engineering, electrical engineering and information technology. Further, the degree of connection was assessed on a scale from 0 to 3, where 0 represented no connection and 3 a thorough connection in both solution content and reported process. Therefore, this analysis was divided into three levels where 1 represented minimal impact, 2 represented moderate impact, and 3 had a critical impact on the overall solution and product development process. These connections were then compared across the four design brief typologies as well as across the three years to examine which were salient and what were emphasised in different types of projects.

Table 1. Typology of Product Development Projects and PdP Requirements

Project Typology	Description based on Wheelwright and Clark [6]	PdP Team Requirement
Derivative projects:	Often range from cost-reduced versions of existing products and/or enhancements of current production process [7]. This typology can be divided into (1) Incremental Product Changes, (2) Incremental Process Changes, and (3) Incremental Product and Process Changes. In this typology of projects, a technical problem often exists.	Students should solve the problem by thinking about the product, process or both.
Platform Projects	Often entail more product and/or process changes than derivatives do, but they don't introduce untried new technologies. They typically deliver fundamental improvements on quality, performance and other range of dimensions over preceding generations [7]. Therefore, this category often includes product enhancement and technological integration. In other words, in this typology, a Product (1) or Technology (2) often exists.	Students should (1) solve the problem by improving the product for future needs or (2) by accommodating technology into a new product.
Breakthrough Projects:	Often, breakthrough projects establish core products and processes that differ fundamentally from previous generations by incorporating new technologies, materials, and manufacturing processes [7]. Due to the scope of this research, we expanded the extent of products from this typology to not only diverge from previous products but also create novel solutions so that this typology fits the PdP context. In other words, in this typology, a revolutionary Idea and concept often exist from Industry partners.	Students should find the technology required to implement the solution and go over the product development process.
Research and Development:	Often these are linked with the creation of the know-how and know-why of new technologies, materials and solutions that eventually translate into commercial development [7]. Therefore, the research scope tends to be wide and often unexplored. In other words, in this typology of projects, a general problem often exists.	Students should define the product and/or service that solves the problem and go over the product development process.

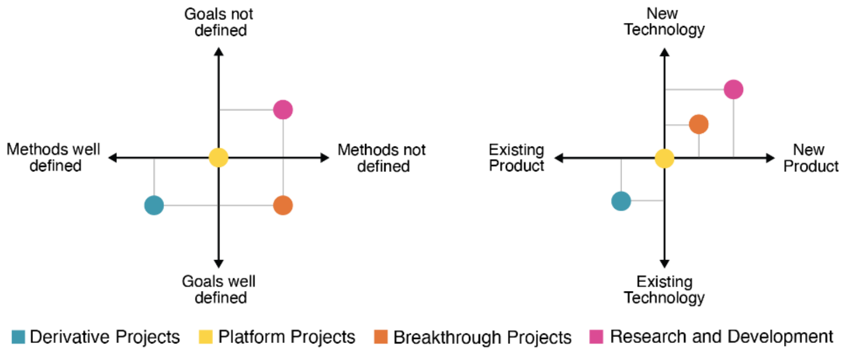

Figure 1. Project typologies – level of methodological practices and level of novelty

The emerging project typologies, across the 42 studies, each represent a unique disciplinary composition, based on the students within the team (Table 2). The multidisciplinary nature noted here is limited to the academic background of the participating students and does not take into account any knowledge or skills acquired outside of academia, which students may contribute.

Table 2. Disciplinary composition of project teams based on students' field of study

Type of Project Brief	Year																	
	2020-2021						2015-2016						2011-2012					
	Fields of Study (%)						Fields of Study (%)						Fields of Study (%)					
	BUS	IT	ELEC	ENG	DES	OT	BUS	IT	ELEC	ENG	DES	OT	BUS	IT	ELEC	ENG	DES	OT
Derivative	0	8	8	76	8	0	12,5	25	0	50	0	12,5	10	0	10	70	10	0
Platform	25	0	0	75	0	0	6	6	9	70	6	3	13	13	0	47	27	0
Breakthrough	9	12	9	49	21	0	7	18	4	56	15	0	7	4	12	54	10	12
R&D	17	0	17	49	17	0	13	15	11	42	15	4	10	17	5	40	23	5

DES Design **ENG** Mechanical Engineering **ELEC** Electrical Engineering **IT** Information Technology **BUS** Business **OT** Other

3 FINDINGS

3.1 The evolving typology of PdP product development projects

Examining the distribution of projects in different types (Figure 2), the analysis revealed the prominence of two industry project-brief typologies: Breakthrough (illustrated in orange) and Research and Development (presented in pink)[1]. These types both represented 35% each of all projects.

[1]During the process it was noted that 4% (n=7 industry briefs) could not be located (indicated in grey, in Figure 3).

However, examining change over time, a decrease in Research and Development Projects was noted from 2014 to 2021. Breakthrough Projects proved to be consistently prominent during the period observed. Similarly, Derivative Projects remained rare in the course throughout the study period (at an average of 6%). Platform Projects, in turn, fluctuated considerably, ranging from 0% (2010-11) to 50% (2019-20). Mapping how the industry project brief categories have shifted over time may allow the prediction of the project types that the students might encounter, and thus improve planning and course management. The mapping also showcases the nature of the collaboration between Industry and Academia, contributing to a better understanding of both industry's evolving and the requirements of project teams. Figure 3 illustrates the results of the analysis of three academic years in order to provide a longitudinal perspective through the lens of three sets of PdP project samples (total number of projects included n=42)[2]. These were a 2020 – 2021 sample (illustrated in the radial matrix as blue), a 2015-2016 sample (illustrated in orange) and a 2011-2012 sample (illustrated in pink). An average line was drawn representing the distribution of disciplines over the three sample sets analysed.

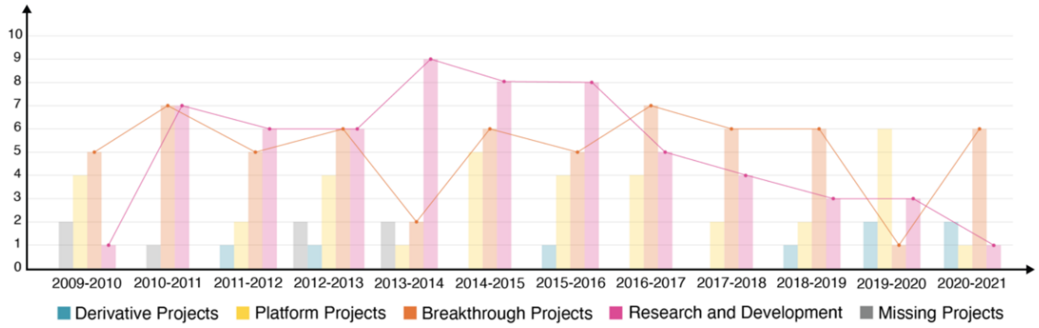

Figure 2. Distribution of project design briefs into the four types of projects between 2009 and 2021

Figure 3 stresses 3 prominent patterns: (1) Derivative Projects, described as technical product/process enhancement in the previous sections, often lean towards the right side of the pentagon. This highlights a critical impact on Engineering in this typology of project briefs and a growing trend in the electronics field. (2) Likewise, on Research and Development Projects, there is an apparent propensity on the left side of the pentagon where business and design are at the core of the accent. This reflects the unexplored nature of this typology. The students are required to conduct extensive research to understand the challenge and how to create a product service that answers the actual problem (3). Additionally, Breakthrough Projects have delineated a clear trend to become the 'perfect pentagon Transdisciplinary shape', which seems to cover all disciplines over the years on a consistent scale. Furthermore, both information technologies and electronics have become increasingly critical over the last decade. This analysis highlights the persistence of technological progress as a clear impact of project-based learning. Future product developers should be comfortable embracing interdisciplinarity and coping with the fast-paced integration of new technological innovations into their systemic product solutions.

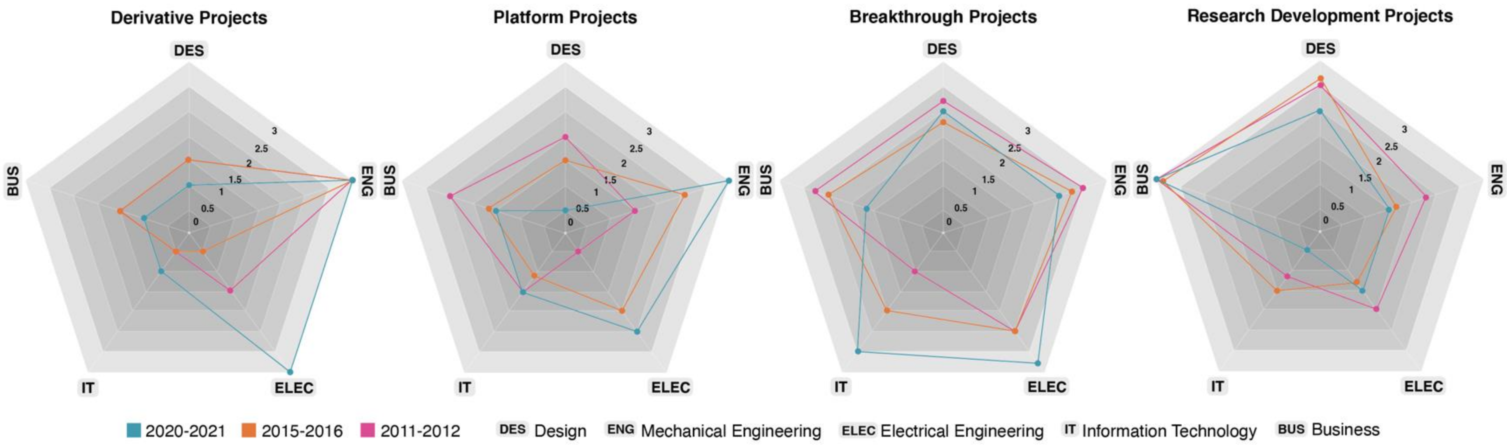

Figure 3. Radial discipline matrix based on project typologies over a decade of PdP

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[2]Derivative projects (2020-2021; 2011-2012) and Research and Development Projects (2020 – 2021) constitute only one project each and thus represent a limited sample.

3.2 Derivative projects

Over the 3 sets of years analysed, Derivative projects constituted a limited sample, with 1 project in 2011-2012, 1 in 2015-2016 and 2 in 2020-2021. All of these 4 project outcomes leaned towards the right side of the radial pentagon, emphasising the rooted presence of mechanical engineering in this typology. Design, business and information technology have played consistently relatively minor roles, whereas electrical engineering has varied. For example, one of the projects focused on improving an existing pole fuse switch disconnector to make it more appealing, cost-effective, modular and competitive on the market. This was mainly an engineering project combining electrical engineering, mechanical engineering and design.

3.3 Platform projects

A total of 7 projects represented Platform projects in the 3 focal years - 2 in 2011-2012, 4 in 2015-2016 and 1 in 2020-2021. This type of project had less consistent disciplinary emphases over time, varying in all five dimensions across years and within the same years. The phenomena might be linked with the nature of the typology of projects, since those can vary from improving an existing product using a new technology to designing a non-existent product application based on an existing technology. This inconsistency in the disciplinary pattern is also noticed in the collection of projects in each year. One example was a project that combined air purifying and supply air technology and created a supply air diffuser that increases the quality of the indoor climate of schools and other premises with high demands on air quality. It combined chemical technology with electronics and mechanics after a business evaluation.

3.4 Breakthrough projects

A total of 16 projects represented Breakthrough projects in the three focal years - 5 in 2011-2012, 5 in 2015-2016 and 6 in 2020-2021. In these projects, a fairly systematic emphasis on Design and Mechanical Engineering could be seen, as well as a clear contribution of Business and Electrical Engineering. Furthermore, the role of Information Technology grew over time. One example of such a project was a system to improve health conditions of workers in construction sites which used prototypes of a particle, temperature and humidity sensor, called a “dust sensor”, connected to a web platform and an app to enable dashboarding and reporting in real-time. This project was supported by a large set of disciplines including engineering, electronics and information technologies encompassed by a strong design component, from device to service design.

3.5 R&D projects

A total of 15 projects represented Research and Development projects in the three focal years - 6 in 2011-2012, 8 in 2015-2016 and 1 in 2020-2021. Design and business were systematically prominent dimensions in these projects, whereas mechanical engineering played a smaller role than in the other three project types. Information technology and electronics also represented more moderate contributions than in Breakthrough projects. As expected, this project type is focused on new technologies. These could be broad, such as projects related to sanitation in Africa, or narrow like two projects in information technologies interconnection of home devices trackers for small appliances or a project focused on the automation of container displacement in harbours. Large organizations often proposed these projects and were clearly researching technologies not existent at their launching date.

4 DISCUSSIONS: IMPLICATIONS FOR COLLABORATION

Mapping the industry-provided project briefs used within the long-standing PdP course at Aalto University highlights the variety of projects tackled in industry-university collaborations and how those might impact interdisciplinarity. The findings reflect a noticeable shift in the typologies of students' project briefs during the period reviewed. Research and Development challenges have decreased in the last seven years, which has impacted the number of projects in which student teams both frame the problem space and conceptualise suitable solutions. The prevalence of Breakthrough projects, however, have remained consistent. In this project type, students actively engage in seeking appropriate technologies and in conceptualising a suitable product or service.

The depth of exploration required by Breakthrough projects allows student teams to engage in meaningful creative problem solving which leverages the transdisciplinary fields of knowledge represented in the teams. Indeed, the analysis shows that Breakthrough projects were the only type where all five disciplinary domains were systematically leveraged across projects. One possibility is that the high degree of novelty and uncertainty require a further degree of integration across disciplines, and the collaborative project style interaction can then support student learning and skills development [12], [13]. While additional research is needed on both the prevalence of different types of design briefs in other contexts as well as on the reasons for the observed distributions, the results highlight how different types of design briefs seem to either attract students of different profiles or facilitate their ability to utilise these disciplines to different degrees. Similarly, within the current study, electrical engineering and information technology represented a growing presence in the product development process of both Breakthrough Projects and projects overall. This suggests that a lack in these skills could place teams at a disadvantage. However, the degree to which this growing emphasis depends on the design briefs, their industry application areas and the changing student composition of the course requires further research.

5 CONCLUSIONS

The study suggests that capturing the varying degree of novelty and uncertainty within the initial design briefs, as well as the distinct disciplinary profiles of the project outcomes attached to each type of design brief, can reveal different types of patterns in project-based courses. While further research is required to examine whether other multidisciplinary product development courses have seen similar shifts in foci and how different disciplines contribute to different project types, this study provides a typology and starting point for educators to examine project-based course practices and a scaffold for discussing design briefs with industry liaisons and students.

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