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Bridging Design and Manufacturing: A Cross-Subject Project-Based Learning Approach in Core Engineering Subjects

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CONTEXT

Project-based learning models such as 2D/3D integration have proven effective in enhancing engineering students' engagement and learning (de Reviere et al. 2024). However, these models are often applied in elective or capstone settings. This study explores a novel application of project-based learning by integrating two core subjects in a Master of Engineering curriculum: Design and Manufacturing Practice (DMP) and Manufacturing Processes and Technology (MPT). The initiative simulates a real-world customer and supplier engineering relationship, where students must collaborate across subject boundaries to complete a shared objective. This structure aims to create a more coherent, realistic, and efficient educational experience.

GOAL

The study aims to examine how integrating a shared project across two core engineering subjects impacts curriculum coherence, student engagement, and real-world readiness. Specifically, it investigates whether simulating an industry-style client-supplier dynamic helps students develop a deeper understanding of both design and manufacturing processes. The project also seeks to improve teaching alignment across subjects and efficient resource usage on expensive project-based subjects.

METHODOLOGY

The focus topic was casting processes. Students in DMP were educated on designing components for manufacturing ease while remaining functional, while students in MPT were educated on investment casting as a process and fabricated the DMP student components. The work was conducted in partnership with the Victoria College of the Arts (VCA), where the MPT students performed the casting in the professional VCA foundry. Data is being collected via retrospective pre- and post-project surveys and focus group interviews to evaluate students' perceptions of learning, industry relevance, and collaborative experience. Staff reflections and course-level observations will also be analysed.

ANTICIPATED OUTCOMES

Preliminary observations suggest improved cross-subject continuity and student appreciation for authentic engineering tasks. Students reported greater motivation and understanding of the industrial context of design and manufacturing. We anticipate that survey and interview results will confirm that the integration fosters stronger learning outcomes and professional identity development. From the faculty's perspective, the project has shown promise in improving efficiency and fostering cross-discipline teaching collaboration.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

This project demonstrates that aligning core engineering subjects through a shared, real-world-inspired project can improve both student experience and curriculum management. The client-supplier simulation provides students with practical exposure to industry practices, enhancing their competence for professional roles. The findings may inform future integration strategies in engineering curricula across institutions.

KEYWORDS

Project-based learning; curriculum integration; engineering education

Introduction

Engineering courses aim to develop graduates who integrate disciplinary knowledge with design judgment, collaborate across technical boundaries, and operate credibly in authentic professional contexts. Syntheses in engineering education show that inductive approaches, including project-based learning (PBL), support these aims when project work and assessment are aligned with intended outcomes. Reported gains include stronger engagement, improved conceptual understanding, and enhanced teamwork (Edström & Kolmos, 2014; Prince, 2004; Prince & Felder, 2006).

A persistent challenge remains in mainstream implementation. Authentic project experiences are often concentrated in capstones or electives, while many core subjects, especially earlier in courses, retain traditional, siloed structures. Analyses attribute this to assessment alignment, resourcing, and staff readiness, which can make coordinated change difficult to sustain (Edström & Kolmos, 2014; Mills & Treagust, 2003). Large-scale reforms such as UCL's Integrated Engineering Programme show promising frameworks, yet relatively few empirical evaluations examine projects embedded inside pairs of core subjects and report how they function for students (Mitchell, Nyamapfene, Roach, & Tilley, 2021). If interdependent, authentic work occurs only at the end of a degree, opportunities for earlier identity formation, confidence building, and cross-subject coherence may be lost. Recent reviews also highlight renewed evidence for integrated PBL approaches in engineering programs (Sukackė et al., 2022).

Our theoretical rationale draws on four complementary lenses that explain why earlier cross-subject authenticity should matter. First, **Authentic/PBL** links knowledge to meaningful tasks and assessment, supporting engagement and transfer in engineering contexts (Edström & Kolmos, 2014; Prince, 2004). Second, **Professional identity and Communities of Practice (CoP)** emphasise participation in shared work and the social processes of becoming an engineer; identity constructs are linked to persistence and career intentions (Godwin, Potvin, Hazari, & Lock, 2016; Wenger, 1998). Third, **Self-efficacy** highlights that capability beliefs influence persistence and performance, and design experiences can strengthen those beliefs in engineering (Bandura, 1997; Carberry, Lee, & Ohland, 2010). Fourth, **Self-Determination Theory (SDT)** holds that environments supporting autonomy, competence, and relatedness foster intrinsic motivation, with engineering applications reporting corresponding benefits (Deci & Ryan, 2000; Trenshaw, Revelo, Earl, & Herman, 2016). Together, these lenses suggest that earlier authentic experiences spanning subjects can make roles legible, render competence visible, and invite collaboration, creating conditions likely to enhance identity, confidence, and engagement.

Guided by these lenses, we implemented a shared casting project across two core Master of Engineering subjects: Design and Manufacturing Practice (DMP) and Manufacturing Processes and Technology (MPT). The design binds upstream decisions to downstream realisation through a client–supplier simulation. DMP students created designs with manufacturability in mind, and MPT students fabricated those designs using investment casting in a professional foundry. This operationalisation aligns with the four lenses in complementary ways. Authentic, project-based work anchors a real interdependent task linked to the intended outcomes. Participation in a shared practice with industry-style roles supports professional identity and communities of practice. Clear responsibilities and authentic constraints support autonomy, competence, and relatedness. Opportunities for mastery are made visible when designs are realised as artefacts, reinforcing self-efficacy.

To evaluate outcomes consistent with this rationale, we used a mixed-methods survey administered at project completion. The closed-ended items targeted four constructs aligned to the lenses: authenticity and relevance; identity and communities of practice, including cross-disciplinary collaboration; self-efficacy; and SDT-based motivational affordances. The open-ended items elicited student perspectives on value, surprises, challenges, and advice. We analysed distributions and plotted stacked histograms for the closed-ended items, then thematically coded the open responses against the same categories to enable convergence across methods (Edström & Kolmos, 2014; Prince, 2004).

Given this context, the study addresses three questions:

1. How do students perceive the realism and value of a shared project that explicitly links design and manufacturing?

2. How does the project influence students' sense of professional identity and their confidence in working across disciplinary boundaries?
3. Which elements do students value most, and what challenges or surprises arise in a client–supplier simulation implemented across two core subjects?

By examining a coordinated, dual-subject project within the core curriculum and interpreting outcomes through these established theoretical frameworks, this study offers evidence on an under-documented form of integration and a practical pathway for strengthening curriculum coherence and professional readiness (Edström & Kolmos, 2014; Mitchell et al., 2021; Prince & Felder, 2006).

Methodology

Context and subjects

This study was situated in the Master of Engineering at The University of Melbourne and integrated two core subjects delivered in Semester 1: MCEN90054 DMP and MCEN90055 MPT. DMP is a project-based subject that develops design judgement with an emphasis on design-for-manufacture and the integration of design with downstream operations. MPT develops process knowledge across conventional and advanced technologies, explicitly including casting, supported by laboratory exercises. This pairing naturally supports a shared project that links upstream design decisions with downstream process realisation within the core curriculum.

Project design

A shared casting project was integrated across the two core subjects through an industry-style client–supplier simulation (Figure 1). Students in DMP acted as clients who produced component designs explicitly optimised for manufacturability. Students in MPT acted as suppliers who realised those designs by investment casting in the VCA foundry, making the linkage between upstream design decisions and downstream process realisation explicit within the core curriculum.

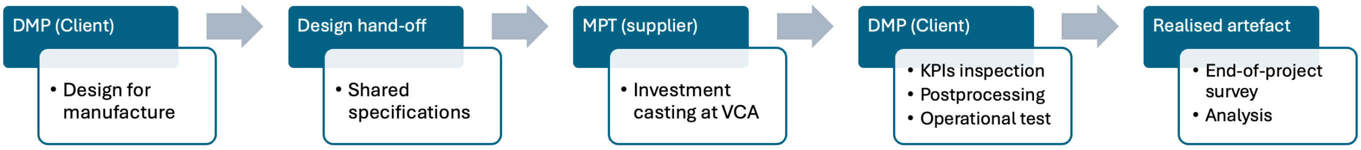

Figure 1. Cross-subject project design and data flow. DMP (client) prepares designs for manufacture → design hand-off with shared specifications → MPT (supplier) performs investment casting at VCA → parts return to DMP for KPI inspection, post-processing (e.g., fettling, drilling, tapping) and operational testing → realised artefacts inform the end-of-project survey and subsequent analysis.

Students worked on a set of three functional components: Y motor holder, Y belt tensioner, and Y belt holder. Coordination points included a common specification, manufacturability constraints, a formal design hand-off, and feasibility checks prior to pouring. After casting, teams completed authentic post-processing: fettling and removal from the tree, surface finishing, drilling to specified diameters, and tapping where required. Figure 2 presents representative as-cast and post-processed artefacts that exemplify the range of student designs and the fidelity achievable with the selected process.

This arrangement served the study's four lenses in complementary ways: the project supplied authentic tasks and artefacts (Authentic/PBL), enacted roles and shared practice through the client and supplier model (Identity/CoP), supported autonomy-competence-relatedness via clear responsibilities and interdependence (SDT), and provided mastery cues as students saw their designs realised and finished (self-efficacy).

Participants and recruitment

All students enrolled in MCEN90054 DMP and MCEN90055 MPT were invited to complete an anonymous, voluntary post-project survey in the final week of semester. In total, 167 usable responses were received: N = 125 from DMP and N = 42 from MPT. The instrument included one item on cross-enrolment in the counterpart subject (Yes/No) to characterise cohort overlap. Since each dataset used unique anonymous identifiers and identifiers were not shared across subjects, responses could not be matched at the individual

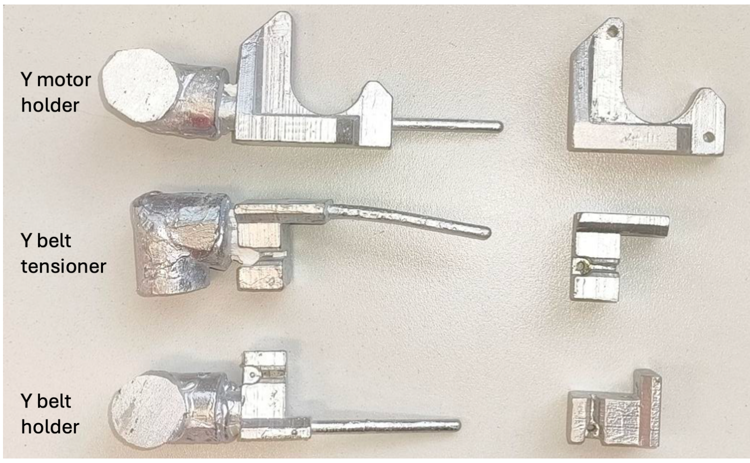

Figure 2. Representative cast artefacts (as-cast vs. post-processed). Left column: as-cast components produced by MPT via investment casting at VCA (from top to bottom, Y motor holder, Y belt tensioner, Y belt holder). Right column: corresponding post-processed parts after sprue/runner removal and fettling, drilling/tapping to specified diameters, and basic KPI/dimensional checks. The exemplars illustrate the upstream–downstream linkage from DMP design to MPT manufacture.

level. As a result, any cross-subject contrasts are reported descriptively and not as paired comparisons. Participation was voluntary and uncompensated.

Survey instrument

The instrument comprised closed questions rated using Likert scale (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree) and open questions. Closed-ended items targeted four constructs aligned to our theoretical lenses: (1) Authenticity and relevance, (2) Identity and communities of practice (including cross-disciplinary collaboration), (3) Self-efficacy, and (4) SDT-based motivational affordances (autonomy, competence, relatedness).

Q1 captures cross-enrolment and is not analysed within the constructs. The full construct-item mapping is shown in Table 1 below. Both cohorts used the same item stems and numbering.

Table 1. Construct-item mapping used in the survey

Construct (lens)	Closed ended items (Q#)	Open ended prompts (Q#)
Authenticity and relevance (Authentic/PBL)	Q2 “I saw a meaningful connection between the design and manufacturing components of this project.” Q5 “I can see how this type of project-based collaboration is relevant to my future engineering career.” Q6 “My contributions were aligned with industry-like responsibilities.” Q7 “The project felt realistic and achievable.”	Q11 Has this project changed your perspective on engineering practice?
Identity and communities of practice (Professional identity/CoP)	Q3 “The shared project helped me better understand how different engineering disciplines collaborate in practice.” Q4 “The experience changed how I think about the role of engineers in real-world settings.” Q10 “This subject made me reflect more deeply on what it means to be an engineer.”	Q12 Did anything surprise or challenge your expectations of engineering work?
Self-efficacy	Q9 “I felt more confident in my ability to work with engineers from different technical backgrounds after this experience.”	Q14 What advice would you give to future students working on a similar cross-subject project?
SDT-based motivation (autonomy, competence, relatedness)	Q8 “The project motivated me to engage more deeply.”	Q13 Would more shared projects help you prepare for professional roles? Why/why not?

Data handling

All submitted responses were included. For closed-ended items, analyses used pairwise deletion at the item level and no imputation was performed. Open-ended non-responses were retained as blanks. Because the two datasets cannot be linked at the individual level, no matching was attempted across subjects.

Analysis methods

Quantitative

Likert responses were coded 1–5 in ascending agreement from “Strongly Disagree” to “Strongly Agree”. For each item we reported distributions, mean, standard deviation, median, % positive (Agree + Strongly Agree), and % negative (Disagree + Strongly Disagree). We visualised item distributions as stacked 5-bin histograms, grouped by the four theoretical categories and shown separately for each subject. Given the unpaired cohorts and unequal *N*s, cross-subject differences are interpreted descriptively, not inferentially.

Reliability

The Cronbach’s alpha (α) is estimated for multi-item constructs: Authenticity and relevance (Q2, Q5, Q6 and Q7) and Identity and communities of practice (Q3, Q4 and Q10). Single-item indicators (Self-efficacy and SDT-based motivation) are reported at the item level.

Qualitative

Open-ended responses were analysed using a two-cycle approach. First, descriptive coding captured students’ meanings in their own words. Second, theory-led coding aligned excerpts to the four constructs. Representative quotations are presented to illustrate prevalent ideas and include mixed/critical cases where they clarify boundaries. Coding agreement was addressed through collaborative review and negotiated consensus within the teaching team.

Ethics

The study was conducted under research ethics protocol 29248 secured by the Faculty’s Teaching and Learning Laboratory.

Results

A total of $N = 167$ survey responses were received (MCEN90054 DMP = 125 and MCEN90055 MPT = 42). Among those who answered the optional cross-enrolment item, 33.6% of responding DMP students reported being co-enrolled in MPT, and 76.3% of responding MPT students reported co-enrolment in DMP. Because identifiers were unique to each dataset, responses could not be linked across subjects; contrasts are therefore descriptive.

Across items, distributions were right-skewed, with medians of 4 (Agree) for every Likert item in both cohorts. Items aligned to authenticity and relevance (as shown in Figure 3) drew the strongest endorsement. In DMP, positive responses were 92.7% for a meaningful design and manufacturing connection (Q2: 4.33 ± 0.70), 90.3% for career relevance (Q5: 4.25 ± 0.75), 75.4% for industry-like responsibilities (Q6: 3.89 ± 0.90), and 84.4% for realism/achievability (Q7: 4.13 ± 0.75); negatives on these items were low (≤10%). In MPT, the pattern was similarly strong or stronger: 95.2% (Q2: 4.50 ± 0.50), 92.9% (Q5: 4.36 ± 0.75), 83.3% (Q6: 4.21 ± 0.62), and 85.7% (Q7: 4.33 ± 0.85).

Items linked to professional identity and communities of practice (as shown in Figure 4) were also positive overall, with sharper concentration at “Agree/Strongly agree” in MPT. In DMP, positive responses were 73.2% for understanding cross-disciplinary collaboration (Q3: 3.83 ± 0.95), 61.3% for rethinking the role of engineers (Q4: 3.69 ± 0.92), and 70.5% for reflecting on what it means to be an engineer (Q10: 3.78 ± 0.93). The broadest spread was on Q4, which had the largest neutral proportion (29%) and the largest negative tail (9.7%). In MPT, endorsement was 83.3% (Q3: 4.24 ± 0.75), 78.6% (Q4: 4.02 ± 0.62), and 75.6% (Q10: 4.05 ± 0.92), with negatives at ≤7.3%.

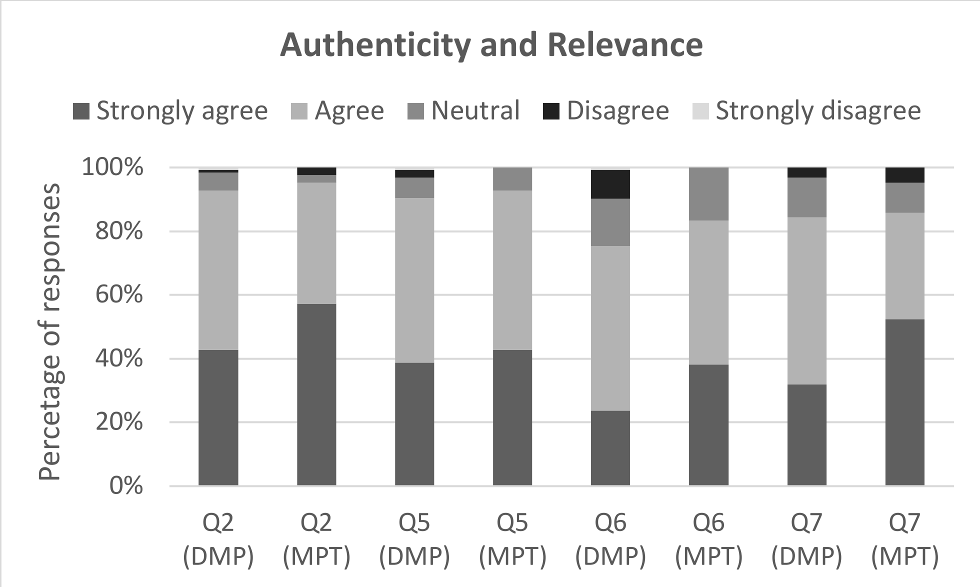

Figure 3. Stacked histograms for authenticity and relevance (Q2, Q5, Q6 and Q7). Q2: Design and manufacture connection, Q5: Relevant to future career, Q6: Industry-like responsibilities, and Q7: Realistic and achievable.

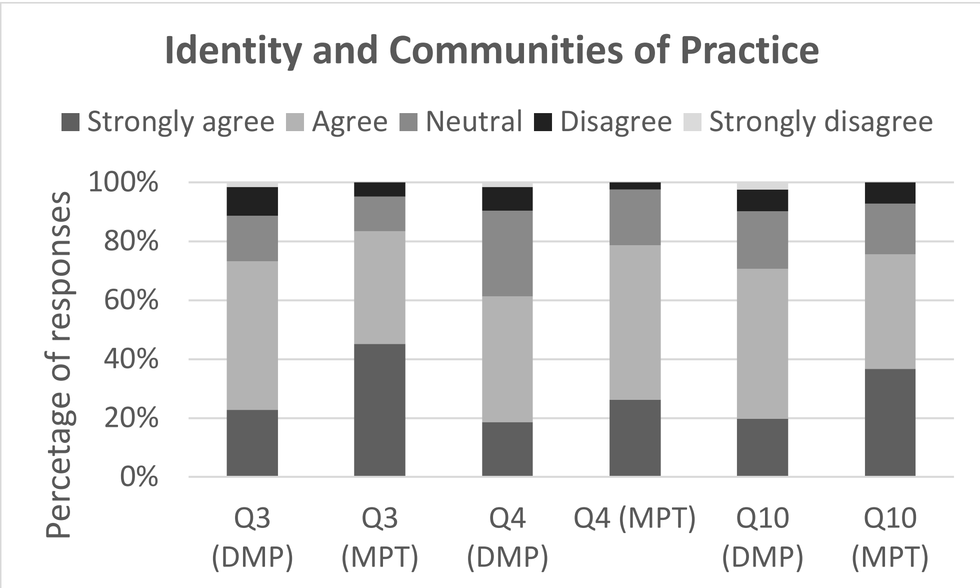

Figure 4. Stacked histograms for identity and communities of practice (Q3, Q4 and Q10). Q3: Understand collaboration in practice, Q4: Role of engineers (identity) and Q10: Reflect on being an engineer.

The single-item indicators showed the same trend (as shown in Figure 5). Motivation (Q8) was positive in both cohorts with 67.2% in DMP (3.88 ± 0.91) and 81.0% in MPT (4.24 ± 0.82), while self-efficacy for working across technical backgrounds (Q9) was 58.7% in DMP (3.69 ± 0.97) and 83.3% in MPT (4.21 ± 0.78). These results suggest that the client–supplier arrangement supported engagement and perceived capability, particularly for students enacting the manufacturing role.

At the construct level, averaging item statistics within categories yields a consistent picture. For authenticity and relevance (Q2, Q5, Q6, Q7), the mean of item means was 4.15 in DMP and 4.35 in MPT, with average positive rates of ~86% and ~90%, respectively. For identity and communities of practice (Q3, Q4, Q10) the mean of item means was 3.76 (DMP) and 4.10 (MPT), with ~68% and ~79% positive. Internal consistency was acceptable for the two multi-item constructs: α = 0.79 (DMP) and 0.75 (MPT) for authenticity/relevance; α = 0.79 (DMP) and 0.71 (MPT) for identity/CoP.

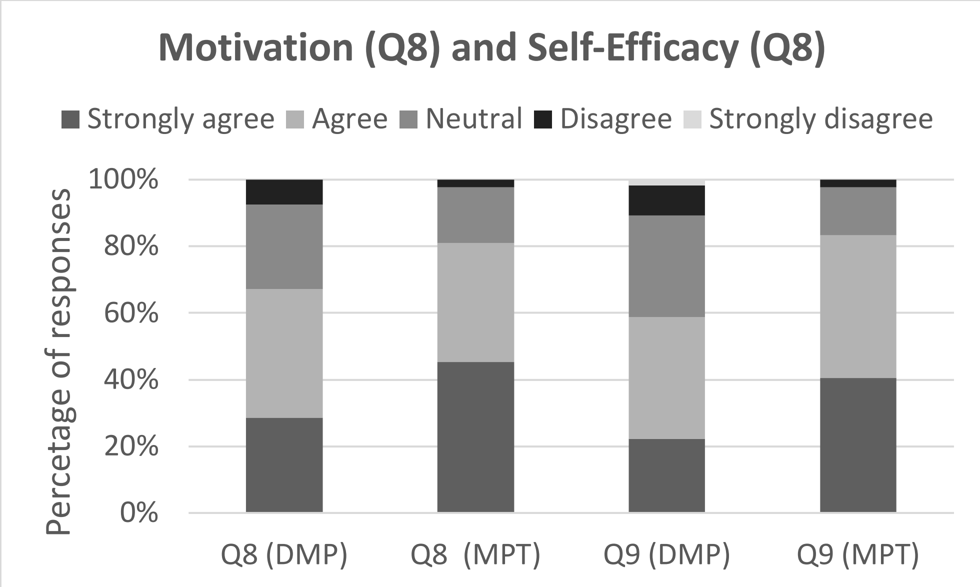

Figure 5. Stacked histograms for Motivation (Q8) and self-efficacy (Q9). Q8: Motivated to engage more deeply and Q9: Confidence across technical backgrounds.

Open responses converged on three themes. First, students described the project as concretising the design and manufacture link, with repeated mention of tolerances, finishing, and feasibility (e.g., *"It's more complicated than just calculation; manufacturing tolerances need to be considered too"* [DMP #33]; "*I no longer take design for granted and design is an integral part of manufacturing*" [MPT #14]).

Second, the client and supplier structure surfaced roles and hand-offs, with emphasis on communication and coordination ("*I understand client and manufacturer relationships better and how production lines work*" [DMP #24]; "*The shared project showed how the supplier and customer relationship works and what each values*" [MPT #1]).

Third, students reported increased motivation and confidence, and offered practical advice to future cohorts ("*Get as involved as possible and ask for process-specific advice*" [DMP #20]; "*Enrol in both subjects at the same time and you get more out of it*" [DMP #36]; "*Start preparation from week 1 and don't leave it to the end*" [MPT #13]).

Overall, both cohorts strongly endorsed the project's authenticity and relevance, with right-skewed distributions. Identity/CoP items were positive but more diffuse in DMP, while MPT reported higher motivation and self-efficacy. Open responses converged on three themes: concretising the design and manufacture link, making client and supplier roles and hand-offs visible, and gains in motivation and confidence. These results indicate the project achieved its central intent while revealing cohort differences; the Discussion interprets these patterns through the four lenses and derives design and curriculum implications.

Discussion

This study examined whether aligning two core subjects through a client and supplier project makes the design and manufacture relationship visible early in the curriculum and supports student identity, motivation, and confidence. Results indicate that it does: both cohorts strongly endorsed authenticity and relevance, identity and collaboration items were positive, motivation and cross-disciplinary confidence were higher among MPT students, and open responses about tolerances, handoffs, feasibility, and explicit roles help explain these patterns.

Authenticity and relevance showed the strongest signal. Positive endorsements clustered in the mid-eighties to around ninety percent, and internal consistency was acceptable with Cronbach's alpha near 0.75 to 0.79. Two design features appear central. Students worked with realised artefacts produced through investment casting and post processing, which made upstream decisions visibly consequential. Assessment aligned constraints such as fillets, perpendicular and minimum slot width converted manufacturability from an abstract idea to a concrete design variable. These features are characteristic of effective PBL and fit the right skewed distributions.

Professional identity, communities of practice, motivation, and self-efficacy showed higher endorsement among MPT students, indicating clearer effects for those more directly engaged in the manufacturing and realisation stages. Students repeatedly referenced roles and hand offs and what clients and suppliers value, suggesting that participation in shared work supported identity development. Higher motivation and confidence among MPT students are plausible because they confronted process realities and then brought parts to specification through drilling, tapping, and inspection. In DMP the broader distributions, especially on the item about the role of engineers, indicate a need for additional support to connect design judgements with social and organisational dimensions. Two targeted adjustments are likely to help. Provide brief observation or rotation through casting or post processing. Close the feedback loop with short rubric guided comparisons between design intent and realised geometry or surface finish.

The client and supplier pattern offers a practical route to curriculum coherence in the core and not only in capstone. It aligns with existing remits, reduces duplication of project infrastructure, and creates a shared artefact stream for teaching and assessment. Three design principles follow from our experience. Bind upstream and downstream through a formal hand off and feasibility checks. Engineer visible interdependence through roles, responsibilities, and simple indicators that matter to both subjects. Make artefacts the common currency that students inspect, finish, and evaluate.

Observed cohort differences should be read with care. MPT's higher means and positive rates likely reflect proximity to manufacture and inspection, while selection and timing may also contribute. A large share of MPT respondents were co-enrolled in DMP, sample sizes were unequal, and responses could not be linked at the individual level. Differences are therefore descriptive and used to locate where the design affords stronger exposure to intended mechanisms and how to extend those affordances.

Several limitations shape the claims. The instrument was custom developed and mapped to four lenses, as opposed to relying on a standardised scale. We reported distributions, medians, means with standard deviations, and Cronbach's alpha for multi-item constructs, and we used qualitative responses for triangulation. Data were self-reported at a single time point. Anonymous identifiers differed by subject, which prevented paired analyses for cross enrolled students. The setting was a single institution and semester with a focus on casting, so generalisability requires caution.

Looking ahead, three priorities follow directly. Introduce brief joint hand over reviews with checklists and targeted reflection prompts in DMP that compare design intent with realised artefacts. Add a lightweight observation or rotation for DMP students during casting or post processing to increase competence experiences. Extend the evidence base with pre- and post-measures for self-efficacy, needs satisfaction, and identity or communities of practice, alongside simple performance indicators such as rework required, dimensional fidelity, and surface finish class. Replication across semesters and extension to machining, forming, and additive processes will test portability and boundary conditions.

In summary, a cross-subject project that assigns client and supplier roles can deliver high perceived authenticity and relevance in the core while advancing identity, motivation, and confidence. Cohort differences highlight where proximity to downstream realisation sharpens effects and suggest practical adjustments that can amplify benefits for all students. The model provides a scalable pathway to make the core curriculum feel more like engineering, earlier, and for more students.

Conclusion

This study examined a cross-subject project that aligned design upstream and manufacture downstream in two core Master of Engineering subjects. The design used clear client and supplier roles, a formal hand off with shared specifications, and realised artefacts produced through casting and post processing. Students strongly endorsed authenticity and relevance. Identity and collaboration items were positive, and motivation and self-efficacy were higher for students closest to downstream manufacture. Open responses emphasised tolerances, feasibility, and visible hand offs. Collectively, the findings indicate that early cross subject integration can make the design and manufacture relationship legible and can support professional readiness.

The contribution is twofold. First, the study provides evidence that authentic and interdependent projects can operate successfully in the core rather than only in capstone. Second, it offers a portable pattern for curriculum integration grounded in four complementary lenses. Three elements make the pattern actionable. Bind upstream and downstream with a real transfer and feasibility checks. Engineer visible interdependence through explicit roles, responsibilities, and simple indicators that matter to both subjects. Make artefacts the common currency that students inspect, finish, and evaluate. These elements can be adopted wherever upstream decisions meet downstream realisation, including machining, forming, and additive processes, as well as analogous pairings in electronics, civil, or biomedical contexts.

Interpretation should be cautious because data are self-reported at a single time point, identifiers could not be linked across subjects, and the study took place in one semester at one institution. The convergence of quantitative distributions and qualitative accounts strengthens confidence in the conclusions. Future work should add pre and post measures for self-efficacy, identity, and needs satisfaction, include simple performance indicators of realised parts, and follow cohorts across semesters. Multi-site replications will test portability and boundary conditions. For programs seeking earlier coherence and stronger professional formation, the client and supplier project pattern offers a feasible and scalable route to make the core of the curriculum feel more like engineering.

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