

Integrated Curriculum Design - Effect on First Year Design and Manufacturing Education

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Abstract

Foundational design and manufacturing courses expose engineering students to a wide range of topics, but students often experience these as fragmented and struggle to see how they connect within an authentic design-to-manufacture workflow. This paper reports the redesign of [REDACTED] Design and Manufacturing at [REDACTED]. Guided by constructive alignment, curriculum integration, and CDIO principles, the course was restructured around a single off-the-shelf bending press kit. Three staged assessments required students to progressively apply knowledge and skills acquired in lectures, computer labs, and newly introduced Project Classes. Effectiveness was evaluated using a retrospective pre-post analysis of student evaluation data from two pre- and two post-redesign offerings with Mann-Whitney U tests, and codebook thematic analysis. Post-redesign student satisfaction was significantly higher across all six survey questions ($p < 0.005$, Bonferroni-adjusted), with mean increases of 0.17 to 0.39 (/6) points and common language effect sizes of 0.55 to 0.59. Qualitative comments also shifted from fragmentation towards coherence and relevance. The findings suggest that an integrated, project-centred redesign can improve students' perceptions of coherence, relevance, and overall course quality in foundational design and manufacturing education.

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1 Introduction

Foundational design and manufacturing education is expected to introduce first-year engineering students to a broad, tightly connected set of skills. Yet it is often taught and assessed as a series of separate topics. In a single course, students may encounter engineering standards, computer-aided design (CAD), drawings, measurement and metrology, machining processes (e.g., turning and milling), tolerances and fits, process planning documentation, computer-aided manufacturing (CAM), hand tools training, assembly procedures, and introductory high-volume manufacturing concepts. While each topic is valuable, students frequently report difficulty understanding how these elements fit together within a coherent design-to-manufacture workflow, and may experience the course as fragmented.

A key challenge is therefore not only what content is covered, but how students are supported to integrate that content into a usable model of engineering practice. Constructive alignment provides a widely used theoretical basis for addressing this by aligning learning outcomes, learning activities, and assessments so that students are repeatedly required to demonstrate the intended learning in authentic ways (Biggs, 1996). In parallel, engineering education research indicates broad benefits from active and experiential approaches, including problem- and project-based learning, particularly where students are required to apply concepts rather than recall them (Prince, 2004). The CDIO framework further reinforces these ideas by positioning engineering fundamentals within the context of conceiving, designing, implementing and operating real-world systems, and by recommending an integrated curriculum and integrated learning experiences that interweave technical knowledge with product/process/system building skills (CDIO Initiative, 2020). At a programme scale, integrated curricula such as UCL's Integrated Engineering Programme illustrate how carefully designed "project threads" can provide structure and continuity that help students connect disciplinary knowledge with authentic engineering activity (Mitchell et al., 2021).

However, integration is not binary. Harden describes curriculum integration as a continuum, where higher levels require deliberate coordination of content, learning activities, and assessment (Harden, 2000). Consistent with this, work on curriculum sequencing highlights that coherence is strengthened when learning is intentionally staged and communicated so that later tasks build on earlier "building blocks" (O'Neill et al., 2014). In practice, integrated project structures often rely on team-based work and authentic production constraints, which can introduce known implementation challenges (e.g., workload management and group coordination) that must be managed through assessment design and support (Felder & Brent, 1994). For mechanical engineering contexts, project-based learning has also been discussed as a mechanism for connecting design knowledge with production considerations, supporting students to experience engineering design as an applied, iterative activity rather than disconnected tools (Kuppuswamy & Mhakure, 2020).

Guided by constructive alignment (Biggs, 1996) and curriculum integration principles (Harden, 2000), we present a redesign of a first-year design and manufacturing course () that uses an integrated project and assessment structure to address perceived fragmentation, utilising an off-the-shelf Bending Press kit (GUNT, Hamburg, Germany). The intended contribution is twofold: (i) a transferable model for structuring first-year design and manufacturing education

around a coherent design-to-manufacture workflow, and (ii) evidence to inform engineering educators seeking to improve perceived coherence and application in foundational manufacturing curricula.

2 Methods

2.1 Course Context

Design and Manufacturing is a large first-year core course at [REDACTED], taken by all students in Mechanical, Mechatronics and Robotics, Aerospace, Manufacturing, and Nuclear Engineering. The course is offered in Term 2 and Term 3 each year and typically enrolls around 500 students per 10-week teaching term. It introduces foundational knowledge and skills, including CAD, engineering drawings, machining processes, CAM, tolerances and fits, process planning, high volume manufacturing, and hands-on workshop practice.

2.2 Theoretical Frameworks

The redesign was guided by three complementary curriculum design frameworks. First, constructive alignment was used as the primary design principle, requiring explicit alignment between intended learning outcomes, learning activities, and assessment evidence so that students are assessed on what they are intended to learn, through tasks that require application rather than topic recall (Biggs, 1996). Second, curriculum integration theory informed the overall structure, using a unifying project to reduce “siloes” learning and to support students to connect content and skills across the term, consistent with higher rungs of integration where learning is coordinated around shared tasks and outcomes (Harden, 2000). Third, the redesign was aligned with the CDIO emphasis on integrated learning experiences that connect engineering fundamentals to authentic workflows spanning design and implementation, supporting students to learn technical concepts in the context of producing and evaluating artefacts (CDIO Initiative, 2020). Evidence from active and project-based learning in engineering education was used as supporting justification for embedding skills practice within an applied project sequence rather than treating software and workshop skills as disconnected exercises (Prince, 2004).

2.3 Curriculum Redesign Procedure

In this work, the course was redesigned so that multiple hands-on and digital tasks contribute to one integrated engineering project. The redesign aims to make the “big picture” explicit: each topic is introduced as a necessary step in producing a functional artefact, rather than as an isolated competency. The redesign followed a staged curriculum design process:

2.3.1 Outcome and assessment mapping

Course learning outcomes (CLOs) were reviewed and mapped to assessments to ensure each outcome was assessed through tasks that reflected its applied use in design-and-manufacture practice. This mapping was used to identify where previous assessment structures could contribute to perceptions of fragmentation, and where integration would be most beneficial to learning coherence.

2.3.2 Selection of an integrating artefact

A bending press kit (GUNT, Hamberg, Germany), as shown in Figure 1, was adopted as the integrating artefact for the term. The kit provides a common reference point across teaching activities as well as assessments, allowing students to move between physical components, digital representations, manufacturing

planning, virtual machining toolpath generation, and hands-on production and assembly. This choice operationalised curriculum integration by making “what this is for” visible: each topic is introduced and practised as a necessary step in progressing the same artefact, rather than as an isolated competency.

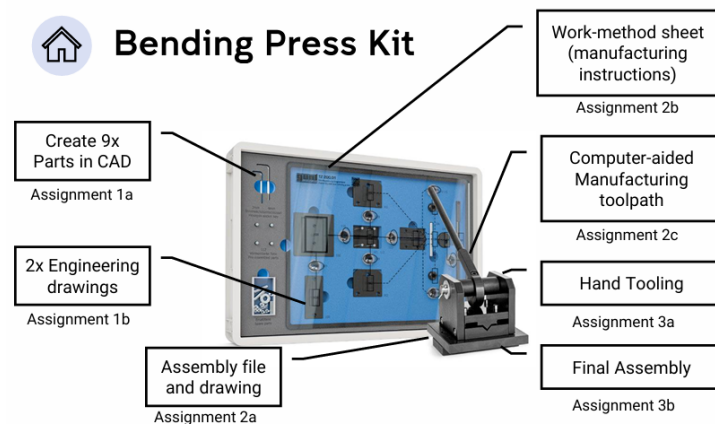


Figure. 1. GUNT Bending Press Kit (TZ 200.01, GUNT, Hamburg, Germany)

2.3.3 Design of staged assessments as a single project workflow

Assessment was redesigned as a staged sequence where each assessment (except the final exam) represents a distinct phase of the same project workflow. The first assessment stage is an individual component CAD and engineering drawing task (30%) in which students measure selected kit components, build accurate 3D CAD models, and produce standards-compliant engineering drawings (AS 1100) from their models. The second stage (25%) builds on these outputs through assembly modelling and documentation, requiring students to create a CAD assembly of the kit, prepare process planning documentation for the manual machining of selected components, and generate CAM toolpaths for machining a kit component. The third stage (15%) occurs in class and focuses on hands-on capability, requiring students to manufacture a specified component using hand tools and to demonstrate correct assembly and disassembly of the bending press kit.

Across the staged tasks, the design intent is cumulative dependency: deliverables produced earlier are required inputs for later tasks, mirroring an authentic design-to-manufacture pipeline (e.g., measured parts → CAD → engineering drawings → CAD assembly → assembly drawings → manual machining process planning → CAM → hands-on manufacture and assembly) and strengthening constructive alignment between outcomes, activities and assessment evidence. Feedback processes were structured so that students received assessment feedback in time to inform later project stages, supporting iteration and improvement within the same project context.

It is worth noting that the final exam (30%) remains separate from the staged project assessments and provides an individual check on conceptual understanding and CAD/CAM competence through theory questions and practical tasks.

2.3.4 Alignment of class activities to project stages

Class teaching and learning activities were then sequenced “just in time” to support each assessment stage across three types of teaching settings: *Lectures*, *Computer Labs* and *Project Classes*. *Lecture* topics were scheduled to introduce core concepts before they were required in deliverables. *Computer Labs* were aligned to provide

scaffolded practice in the specific software skills needed for the next project milestone, including CAD and drawings in SOLIDWORKS (Dassault Systèmes, Vélizy-Villacoublay, France), and CAM workflows in Fusion (Autodesk, San Francisco, USA). *Project Classes* were introduced for the first time in the current work, and were explicitly designed to focus on hands-on skills directly relevant to the project, including measurement tools, workshop exposure to turning and milling processes, hand tools practice, and structured kit assembly/disassembly activities. In this way, *Project Classes* served as the applied integration point where planning and documentation were connected to inspecting and making physical parts.

2.4 Evaluation and Data Analysis

To evaluate the effect of this integrated curriculum design, the study adopts a retrospective, pre–post programme evaluation approach using existing institutional student course evaluation results (Ethics approved by [REDACTED] Human Research Ethics Committee, Reference [REDACTED]). Student responses were collected from two offerings pre course design (2024 T2 and T3) and two offerings post redesign (2025 T2 and T3) for six six-point Likert-style questions, with responses ranging from “strongly disagree” to “strongly agree”:

1. “Overall I was satisfied with the quality of the course”
2. “I felt part of a learning community”
3. “The course resources helped me learn”
4. “The assessment tasks were relevant to the course content”
5. “The course encouraged me to be self-directed in my learning”
6. “Assignments gave me opportunities to demonstrate my knowledge”

A Mann-Whitney U test was adopted as a non-parametric test for ordinal data to evaluate the null hypothesis that the distributions of responses from two cohorts are consistent. First, we confirm that there is no statistically significant difference between the responses gathered from the two cohorts in 2024 (pre-redesign), as well as the two cohorts in 2025 (post-redesign). Mann-Whitney U tests were then conducted to evaluate the effectiveness of this curriculum redesign by comparing pooled student responses between 2024 and 2025.

To supplement the qualitative data, we also analysed student feedback comments. We used a codebook thematic analysis approach for two open-ended questions: “*What were the best things about this course?*” and “*What could be improved?*”. The target theme was defined a priori with inclusion/exclusion rules and positive/negative lexical indicators, depicted in Table A1 in the Appendix. A Python script retrieved all comments containing any of the predefined search terms, after which each comment was manually coded for (a) theme presence/absence and (b) positive/negative valence. Automated searching was used only for retrieval; all coding decisions were researcher-made, consistent with structured, codebook-led thematic analysis.

3 Results

Mann-Whitney U tests indicate that there are no meaningful differences between the Terms 2 and 3 cohorts within each year ($p > 0.05$) across all quantitative questions, and therefore the data were pooled by year for subsequent analysis to examine the effectiveness of the course redesign. Figure 1 depicts the boxplots for each question, organised by the teaching term.

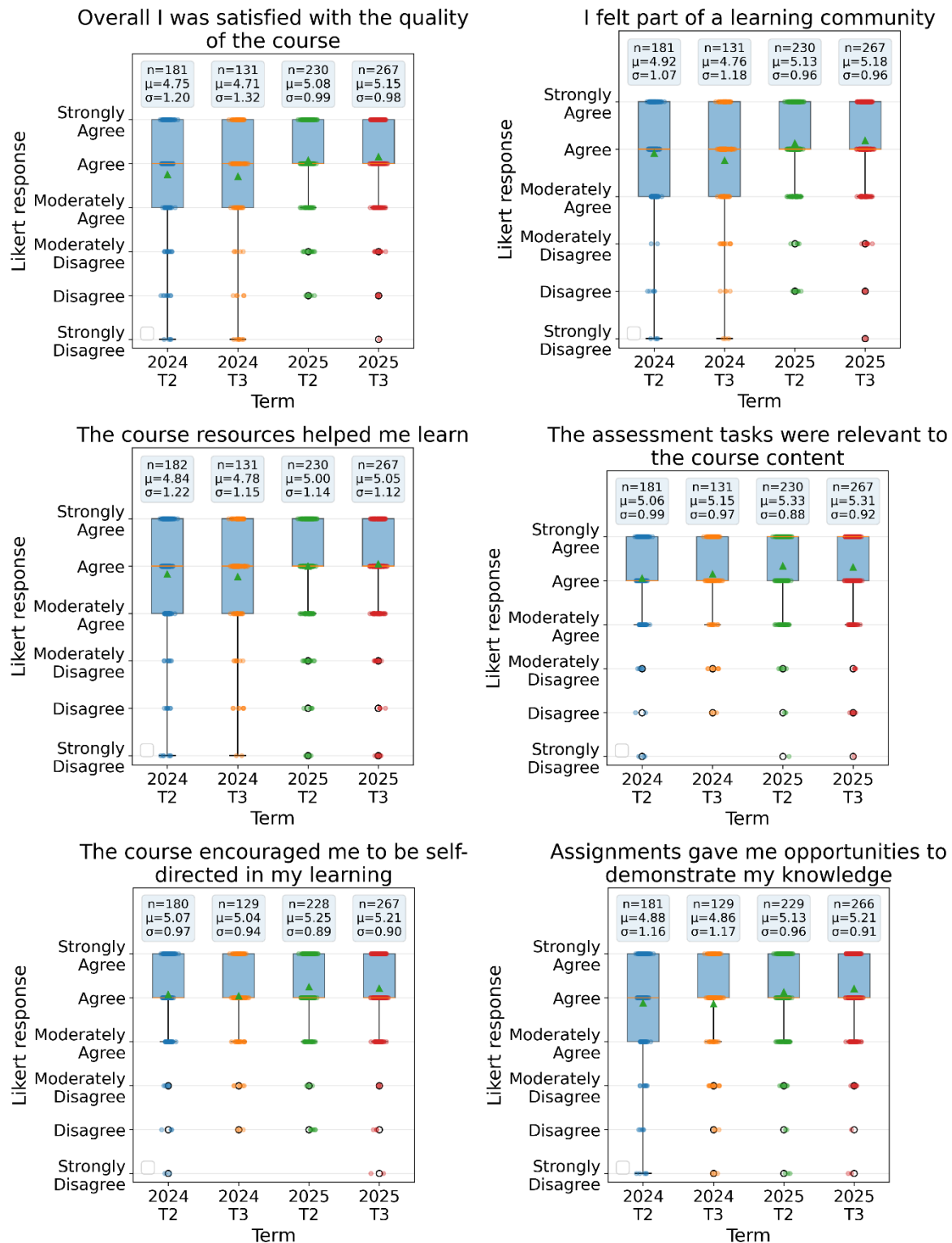


Figure 1. Qualitative Student Feedback by Term

Recall that the intervention (course redesign) was applied between the 2024 and 2025 offerings. Once the data was pooled into year groups for each question, a Mann-Whitney U test was applied for each question to directly compare pre- and post datasets. Across all questions, responses in 2025 were significantly higher than in 2024 ($p < 0.01$), with all results remaining significant after Bonferroni correction. Mean scores increased by approximately 0.17 to 0.39 points on a six-point Likert

scale. Effect sizes (CLES $\approx$ 0.55–0.59) indicate a consistent shift toward more positive responses, with students in 2025 more likely to report higher levels of agreement. Examination of response distributions showed a reduction in lower-category responses and substantial increases in “Agree” and “Strongly Agree” selections, alongside a general decrease in standard deviation, suggesting greater consensus among students following the course redesign. These statistics are depicted in Table 1.

Table 1. Pooled Comparison Statistics

Question #	p value	Effect Size (CLES)	Mean Difference
1	0.000004	0.588	0.385
2	0.000024	0.580	0.302
3	0.001652	0.560	0.215
4	0.000108	0.571	0.224
5	0.003859	0.552	0.168
6	0.000215	0.569	0.298

Finally, thematic analysis revealed a strong increase in the prevalence of positive sentiments regarding course structure, integration and coherence. Table 2 depicts the number of times we detected positive and negative instances of the singular theme, for each term. In brackets, the number is normalised over the number of respondents for that term. Note that the prevalence of negative sentiments also decreased, despite the same number of occurrences (that is to say, the cohort size also increased between terms).

Table 2. Results of Thematic analysis

Term	Negative	Positive
2024 T2	9 (5.0%)	5 (2.7%)
2024 T3	12 (9.2%)	1 (0.8%)
2025 T2	12 (5.2%)	15 (6.5%)
2025 T3	12 (4.5%)	12 (4.5%)

Here we present some most representative comments from pre- and post-course redesign, respectively:

Pre course redesign:

- *“By separating the lecture content and the lab, the course feels very fragmented and disorganised and also makes trying to grasp the concepts and skills taught extremely difficult.”* (2023)
- *“This lack of cohesion made me apprehensive...Some things taught in lectures also weren't well reflected outside of the course.”* (2023)

Post course redesign:

- *“I love how the course is designed to give us an overview of the entire manufacturing process. It was good to see the relevance of each step in the overall picture.”* (2025)
- *“Everything tied in together so neatly, and it felt like we were directly applying our knowledge to well thought out assessments that helped us learn things.”* (2025)

4 Discussion and Conclusions

The findings indicate that the redesign of [REDACTED] was associated with a clear improvement in how students experienced the course. Across all six evaluation items, post-redesign responses were significantly more positive, with consistent effect sizes and modest but meaningful increases in mean scores. Importantly, no significant within-year differences were observed between Terms 2 and 3 in either 2024 or 2025, which supports pooling the cohorts by year and suggests that the observed shift was not simply routine term-to-term variation. The qualitative findings reinforce this interpretation. Prior to the redesign, students described the course as fragmented and lacking cohesion between lectures, software-based labs and practical work. Following the redesign, students were more likely to describe the course as connected, relevant, and helpful for understanding the design-to-manufacture workflow. Taken together, these results suggest that the redesign addressed the central problem identified at the outset of this work: students often struggle to see how foundational design and manufacturing topics fit together.

These results are consistent with the theoretical frameworks that guided this work. From a constructive alignment perspective (Biggs, 1996), the course was redesigned so that learning outcomes, learning activities, and assessments were visibly linked. Rather than encountering CAD, drawings, process planning, CAM and hands-on skills as separate requirements, students progressed through a staged sequence in which each output became the input for the next stage of the project. This cumulative structure appears to have made the purpose of each topic more explicit. The improvement in students' ratings of assessment relevance and opportunities to demonstrate knowledge is particularly important, as it suggests that students could better understand why they were undertaking particular tasks and how those tasks related to course learning. Therefore, the redesign did not reduce technical breadth, but instead changed how that breadth was organised and experienced.

The results also support the value of curriculum integration in foundational engineering education. Harden (2000) argues that meaningful integration requires deliberate coordination across content, teaching activities, and assessment, rather than simply presenting related topics within the same course. In this work, this coordination was operationalised through a shared project artefact, staged assessments, and just-in-time sequencing of lectures, computer labs, and Project Classes. The bending press kit provided a common reference point across the term, allowing students to move between physical components, digital models, technical drawings, manufacturing documentation, CAM toolpaths, and hands-on assembly. For novice learners, this kind of stable artefact is likely to be especially valuable because it helps translate abstract topics into a visible engineering workflow. The newly introduced Project Classes appear to have played a particularly important role by creating a setting in which planning, inspection, manufacture, and assembly could be directly connected. This aligns with broader evidence that project-based and experiential learning are most effective when students apply knowledge in context rather than treat topics as isolated skills (Prince, 2004).

The qualitative data add an important interpretive layer to the statistical results. The standard institutional survey items capture broad dimensions of the student experience, but they do not explicitly ask whether the course felt coherent or fragmented. The open-text responses therefore provide more direct evidence that

students perceived a structural change in the course. The shift from comments about disconnection and confusion to comments about seeing the “overall picture” suggests that the redesign improved not only satisfaction, but also students’ understanding of how design and manufacturing topics relate to one another in practice. This is an important outcome in first-year education, where students are still developing their initial mental models of what engineering work involves. In this respect, the redesign appears to have supported a transition from topic-based learning towards process-based understanding, which was one of its central aims.

Several limitations should be acknowledged. First, this was a retrospective pre-post study using existing student evaluation data, so the findings are associative rather than causal. Other differences between cohorts, staffing, or teaching context may also have influenced student responses. Second, the quantitative data were derived from voluntary student evaluations and may therefore be affected by response bias. Third, this paper focuses primarily on student perceptions and thematic feedback. While these are important indicators of course coherence and perceived relevance, they do not by themselves demonstrate improved technical attainment. Future work should therefore examine aggregated assessment performance in more detail and explore whether the reported gains in coherence are accompanied by improved academic outcomes. Despite these limitations, the results provide strong preliminary evidence that an integrated, project-centred curriculum structure can improve how students experience foundational design and manufacturing education in a large first-year course.

In conclusion, redesigning [REDACTED] at [REDACTED] around a single integrated project was associated with more positive student perceptions of course quality, learning community, resource usefulness, assessment relevance, self-directed learning, and opportunities to demonstrate knowledge. More importantly, the qualitative findings suggest that students moved from perceiving the course as fragmented to recognising it as a coherent introduction to the design-to-manufacture process. For large foundational engineering courses that must cover diverse digital, theoretical, and hands-on content, a project-centred curriculum organised around cumulative assessment stages offers a practical and transferable way to make the “big picture” of engineering practice more visible to students.

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Appendix

Table A1. Parameters of Thematic Analysis

Theme Name	Integrative Structure and Coherence
Description	Student perceptions that course components (CAD, CAM, hand tools, assessments) are connected vs. disconnected.
Inclusion Criteria	Mentions of things fitting/flowing/aligning across weeks, classes, assessments; references to a single/common project tying learning together; explicit statements that the structure "made sense" or "flower well".
Exclusion Criteria	Exclude pure workload/pace complaints unless the student explicitly ties them to (dis)connection; exclude affect-only comments with no reference to linkage.
Positive Search Terms	connect; connected; connection; connect*; coher*; cohes*; cohesiv*; integrat*; link; linked; link*; align; align*; flow; flow*; smooth; smooth*; fit; fit*; together; whole; overall; unified; unity; consistent; consist*; continu*; structure; structur*; sequence; sequenc*; progression; progress; step; sense; build; builds; building; build*; follow; followon; follow-on; chain; chain*; project; same; common; shared; assessment; assess; assess*; assignment; assign; assign*; task; tasks; unit; units; week; weekly; weeks; holistic; complete; linkage; tie; tied; bending; gunt; kit; press
Negative Search Terms	disconnect; disconnected; disconnect*; separate; separat*; apart; disjoint; disjoint*; fragment; fragmented; fragment*; scatter; scattered; scatter*; incoherent; incoher*; misalign; misaligned; misalign*; inconsistent; inconsist*; conflict; conflict*; contradict; contradict*; random; random*; jump; jump*; switch; switch*; unrelated; unrelat*; notrelated; noflow; incongruent; incongru*; noncohesive; noncoherent; nointegration; notintegrated; unintegrated