CDIO ALIGNMENT IN B.ENG. MODULE SPECIFICATIONS: AN AI-ASSISTED QUALITATIVE ANALYSIS

Kirsten From

DTU Learning Lab, Technical University of Denmark (DTU)

ABSTRACT

This paper examines documented CDIO alignment across the full portfolio of Bachelor of Engineering module specifications at DTU. Using AI-assisted qualitative document analysis, 284 publicly available module specifications were analysed with the CDIO Standards 3.0 and Syllabus 3.0 as the formal analytical point of departure. Microsoft Copilot was used to support semantic reading at scale, while interpretive judgement remained with the researcher. The analysis focused on overall documented alignment rather than isolated standards. Each module was categorised on an ordinal scale of documented CDIO alignment: Weak, Weak-Medium, Medium, Medium-Strong, and Strong. Across the portfolio, 8 modules (2.8%) were classified as Weak, 132 (46.5%) as Weak–Medium, 129 (45.4%) as Medium, 10 (3.5%) as Medium–Strong, and 5 (1.8%) as Strong. The findings suggest that strongly documented CDIO alignment is relatively rare in the module specifications, while a large proportion of the portfolio shows some visible alignment without documenting it strongly enough to count as clearly substantial. The overall picture is therefore one of a portfolio dominated by partial or limited alignment, alongside a smaller number of more clearly convincing cases. The study also suggests that stronger documented alignment tends to emerge where several pedagogical elements are articulated in mutually supportive ways within a module, so that the specification presents a coherent learning design rather than a set of separate signals. The paper contributes both a portfolio-level picture of documented CDIO alignment and a methodological discussion of AI-assisted qualitative document analysis in educational quality assurance.

KEYWORDS

CDIO alignment, AI-assisted qualitative document analysis, engineering education, module specifications, educational quality assurance, CDIO Standards: 1-8, 11

INTRODUCTION

Educating engineers for a VUCA world has become an increasingly urgent challenge in recent years. Volatility, uncertainty, complexity, and ambiguity now characterise not only geopolitical and economic systems but also the technological infrastructures that underpin contemporary societies. Accelerating developments in digitalisation and AI, combined with climate-related pressures, are reshaping expectations of what engineers should know and be able to do - and by extension, what engineering education should prepare them for.

These dynamics also formed part of the rationale behind the recent revision of the CDIO Initiative's Standards and Syllabus to version 3.0 (Malmqvist et al., 2022). Since its inception in 2001, CDIO has positioned itself as a framework for practice-oriented engineering education, aiming to support member institutions in continuously improving their programmes. Version 3.0 responded to emerging global and professional demands by introducing optional standards that reflect expanded conceptions of engineering practice (Malmqvist et al., 2022).

The Technical University of Denmark (DTU) adopted the CDIO framework from 2008 (DTU, 2013), particularly within its Bachelor of Engineering programmes. Since then, programme-level implementation has been assessed several times through internal self-evaluations. While such evaluations offer important insights, they also have recognised limitations - most notably their reliance on the perspectives and interpretations of those responsible for the programme (Rouvrais & Lassudrie, 2014). CDIO itself emphasises that the Standards are intended as guidelines for continuous improvement rather than as a formal accreditation regime.

Over time, organisational restructuring, staff turnover, and shifting priorities mean that institutional knowledge about CDIO at DTU may have become unevenly distributed. In the wake of the 3.0 revision - and in the context of intensifying VUCA pressures - it may therefore be a good time to revisit how CDIO is currently being expressed across the B.Eng. programmes at DTU.

This makes module specifications a relevant but complicated site for examining CDIO alignment. On the one hand, they can show whether elements associated with CDIO are documented across a programme portfolio. On the other hand, they do not provide direct access to enacted teaching practice, and they do not automatically reveal whether apparently CDIO-like language reflects a coherent pedagogy or only a partial articulation. This is especially important in a large portfolio, where the question is not only whether CDIO-related elements appear, but how convincingly they are documented across many different modules.

This leads to the following research question:

What insights into CDIO alignment and implementation status can AI-assisted qualitative document analysis at scale offer?

Terminology: To align with usage in the CDIO International conference host country (UK), the terms *modules* and *module specifications* are used instead of the Danish terms courses and course descriptions.

METHODOLOGY

Theory

Chapter 2 in Rethinking Engineering Education (Crawley, Malmqvist, Östlund, Brodeur, & Edström, 2014) is used here as the main foundational point of departure. The chapter explicitly refers to a pedagogical foundation for CDIO and points toward a set of educational traditions rather than one single unified theory. Among the references most relevant here are Biggs on constructive alignment, Marton and Säljö on deep and surface approaches to learning, Kolb on experiential learning, and Johnson on contextual teaching and learning. These theories were not used as a predefined coding frame from the outset, but as interpretive support for clarifying distinctions that became necessary during the analysis.

Biggs and Tang (2011) provide the clearest account of constructive alignment, and this is particularly relevant to CDIO because it foregrounds coherence between intended learning outcomes, teaching and learning activities, and assessment. The related idea of backwash is also important, since assessment strongly shapes what students actually attend to and learn. This fits closely with CDIO's concern for outcomes, integrated curriculum, active learning, and assessment.

Marton and Säljö (1976) represent the tradition of deep and surface approaches to learning, which is also explicitly part of the reference background of Chapter 2. This tradition is relevant because it distinguishes between richer forms of learning oriented toward meaning and relationships, and more superficial forms of engagement based on reproduction or box-ticking. That distinction is highly pertinent to CDIO, where apparently active or project-like forms of teaching may still remain educationally shallow.

Kolb (1984) is the main reference here for experiential learning. Kolb's account of learning through experience, reflection, conceptualisation, and experimentation resonates strongly with CDIO's emphasis on integrated learning experiences, design-implement work, and engineering education in the context of practice. Experiential learning therefore offers an important part of the pedagogical language through which CDIO can be understood.

Johnson (2002) provides the most direct reference for contextual teaching and learning. This is relevant because CDIO explicitly frames engineering education in relation to the context of conceiving, designing, implementing, and operating real products, processes, systems, and services. Contextual learning helps explain why such context matters pedagogically: not as background illustration alone, but as something that gives knowledge relevance, meaning, and direction.

Bloom et al. (1956) and Krathwohl (2002) remain important for the question of cognitive demand. Bloom's taxonomy, and its later revision, provide a widely used language for distinguishing between lower-order and higher-order forms of learning. In the present context, this matters because engineering tasks may appear innovative or project-based while still implying only routine understanding or application rather than analysis, evaluation, or creation.

Method

An AI-assisted document analysis of the module specifications was conducted, drawing on directed qualitative content analysis (Hsieh & Shannon, 2005). The CDIO Standards 3.0 (Malmqvist et al., 2020) and CDIO Syllabus 3.0 (Malmqvist et al., 2022) were used as a combined analytical framework to examine module specifications for documented CDIO alignment.

Ontological and epistemological approach

In this study, module specifications are not treated as an objective mirror of enacted teaching practice. Rather, in line with document analysis traditions (Bowen, 2009), they are understood as institutional documents (Prior, 2008): texts produced and used in socially organised ways that may reflect institutional purposes, conventions, and the circumstances of their authors at the time of writing.

At the same time, module specifications do remain valid empirical material. Document analysis involves examining and interpreting texts to elicit meaning and develop understanding (Bowen, 2009). Accordingly, no claims are made about teaching practice. Instead, the analysis concerns documented intent and declared pedagogical commitments, inferred from what is explicitly articulated in the documents.

Data and units of analysis

For the academic year 2025 - 2026, all 301 module specifications of the complete portfolio of B.Eng. modules (across 21 specialisations) are made public in the DTU course base (www.kurser.dtu.dk). All module specifications were downloaded. Some modules have duplicates due to being offered in different locations, or more than once throughout the year, hence, it was decided to keep only one instance of each module reducing the dataset to 284 unique specifications. Each specification follows a fixed structure where the main elements are 8-12 learning objectives, overall objectives, content descriptions, assessment type. These were the focus of the analysis.

Use of AI in document analysis

Microsoft Copilot was used as a thinking tool to support exploratory, corpus-wide reading of the module specifications within the analytical lens described above. Its role was to assist in surfacing recurring formulations, candidate patterns, and possible tensions relevant to documented CDIO alignment across a dataset that would have been difficult to engage with holistically through close manual reading alone.

The analysis was iterative from the outset and involved repeated movement between the CDIO framework, the module specifications, and AI-supported reading. AI-supported outputs were not treated as final interpretations in themselves but were repeatedly checked and reconsidered in order to keep interpretive judgement with the researcher. Due to the size of the dataset, it was not feasible to verify every AI-supported reading individually. Instead, analytic quality was supported through iterative review of cases where interpretations appeared uncertain, inconsistent, or pedagogically unconvincing. Diagnostic instances were cases where AI-supported readings appeared overly generous, inconsistent with the analytical lens, or insufficiently attentive to tensions between learning outcomes, content, and assessment. These diagnostic instances informed the refinement and stabilisation of the analytical lens. A targeted validation sample of 30 unique module specifications was reviewed during the refinement process. Of these, 7 borderline cases were revisited in order to clarify and settle their final placement.

As the analysis progressed, it became clear that the CDIO Standards and Syllabus alone did not fully specify how stronger and weaker forms of documented alignment should be distinguished in practice. In particular, some modules appeared CDIO-aligned in wording or format, yet seemed less persuasive when considered in pedagogical terms. The later refinement of the analysis therefore drew on a small number of educational theories, not because these had been imposed deductively from the outset, but because they made it possible to articulate more explicitly the pedagogical assumptions already informing the judgement of what counted as more genuine alignment and what appeared aligned in name only. Interpretive judgements remained the responsibility of the researcher.

The analytical lens – including the evidence hierarchy and the alignment considerations guiding interpretation – is described below.

Analytical lens

CDIO Standards 3.0 and CDIO Syllabus 3.0 documents were used as an analytical lens to interpret documented CDIO alignment. CDIO Standards 9, 10, and 12 were excluded from the analysis, as they concern faculty competence and programme-level evaluation, which are not documented at module level. Alignment for Standard 2 cannot be evaluated at programme level in this study and was therefore considered at module level instead. Standard 4 (Introduction to Engineering) was included only where explicitly relevant at module level.

Rather than being operationalised as discrete indicators, the standards and syllabus informed a holistic, semantic interpretation of intended pedagogy. Each module specification was read as a whole in order to assess the strength and coherence of documented CDIO alignment, examining how learning objectives, content and activities, assessment forms, and pedagogical language combined across the specification.

During the analysis, it became clear that the CDIO Standards and Syllabus alone did not fully explain why some module specifications appeared more convincingly aligned than others. In particular, some modules appeared CDIO-aligned in wording or format, yet seemed less persuasive when considered in pedagogical terms. The considerations below were therefore formulated to make these distinctions more explicit and to support more consistent judgement across the portfolio.

The considerations emerged from recurring distinctions that became important during the refinement of the analysis. In particular, borderline cases often differed only marginally in terms of openness, higher-order thinking, authenticity, integration, or assessment alignment, yet these differences became important when deciding whether a module should be placed in Weak–Medium, Medium, or Medium–Strong. The considerations were therefore formulated as a way of making these recurring distinctions explicit and supporting more consistent judgement across the portfolio. For example, repeated difficulty in distinguishing between design as independent judgement and design as bounded implementation contributed to the consideration of design-as-create versus design-as-assembly, while repeated tensions between ambitious learning language and traditional written examinations contributed to the consideration of assessment alignment.

These are not to be understood as criteria or a checklist, but as interpretive supports that orient holistic judgement by drawing attention to dimensions along which documented CDIO alignment may be strengthened or weakened.

CDIO alignment considerations

These considerations were formulated in response to recurring tensions in the material, where module specifications appeared CDIO-aligned in wording or format, yet seemed less convincing when considered in pedagogical terms.

Open-endedness and higher-order thinking, including whether tasks allowed for more than one plausible solution, non-trivial decision-making, or creative problem solving. *This consideration emerged from cases that appeared project- or design-oriented in wording, but where tasks seemed tightly structured, cognitively limited, or primarily oriented toward routine execution rather than analysis, evaluation, or creation.*

Design-as-create versus design-as-assembly, distinguishing between activities that required students to independently formulate and justify design decisions and those that primarily involved implementing predefined solutions. *This distinction emerged from modules that used the language of design, but where student work appeared mainly to involve carrying out given solutions rather than engaging in more genuinely generative design work.*

Assessment alignment, particularly whether assessment formats supported the evaluation of complex outcomes (e.g. design reasoning, integration, process) or whether traditional sit-down written examinations dominated. *This consideration emerged from cases in which ambitious or practice-oriented learning outcomes appeared poorly matched by assessment formats, raising concerns associated with constructive alignment and the backwash effect of assessment.*

Integration, understood as the application of a variety of disciplinary knowledge, process skills, and other competencies within the same learning activities rather than as add-on elements. *This consideration emerged from modules in which knowledge, skills, and activities appeared alongside one another in the specification, but without clear evidence that they were brought together within the same learning work.*

Authenticity, including the presence of realistic contexts, constraints, or problems that are not just abstract or purely illustrative examples. *This consideration emerged from cases in which real-world context was mentioned, but seemed to function mainly as illustrative background rather than as a meaningful condition shaping the pedagogical design of the module.*

Categorisation and scoring

Based on the analysis, each module was categorised on an ordinal scale of documented CDIO alignment: Weak, Weak–Medium, Medium, Medium–Strong, and Strong. Each category was assigned a corresponding score from 1 to 5 in order to support visualisation of the findings.

The intermediate categories Weak–Medium and Medium–Strong were used to distinguish cases that leaned clearly downward or upward from Medium without being fully convincing as Weak or Strong.

RESULTS

The results are reported at the level of overall documented CDIO alignment, since the more meaningful judgement in this study concerned the coherence of the module specification as a whole rather than isolated strengths on individual standards.

Across the 284 module specifications, 8 modules (2.8%) were classified as Weak, 132 (46.5%) as Weak–Medium, 129 (45.4%) as Medium, 10 (3.5%) as Medium–Strong, and 5 (1.8%) as Strong.

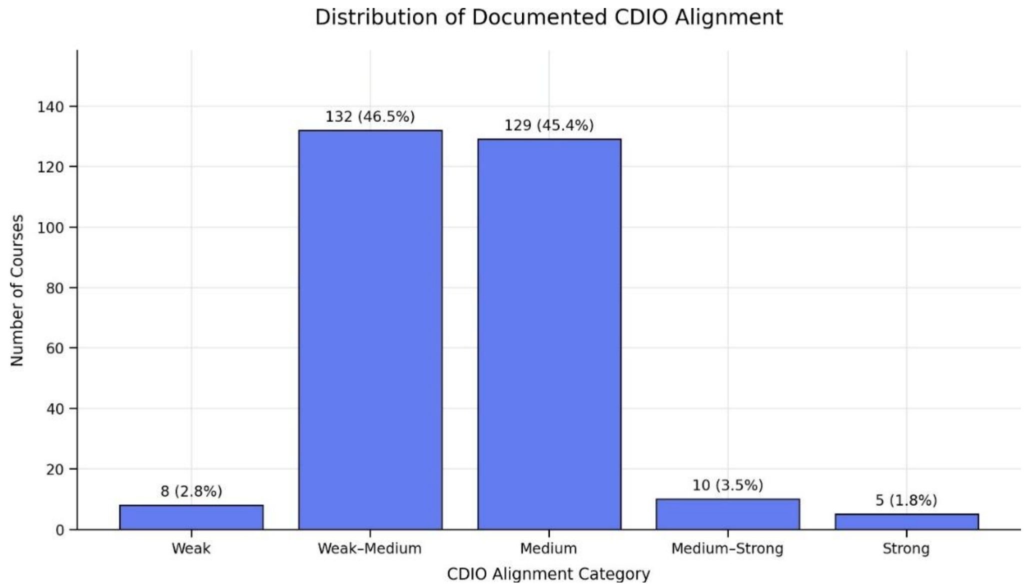

Figure 1: Final validated distribution of documented CDIO alignment across the 284 module specifications.

The distribution indicates that strongly documented CDIO alignment is relatively rare in the module specifications, while a large proportion of the portfolio shows some visible alignment without documenting it strongly enough to count as clearly substantial. In many cases, module specifications appear to include CDIO-relevant elements, but these are only partially articulated or weakly supported when the specification is read as a whole.

The overall picture is therefore one of a portfolio dominated by partial or fragile alignment, alongside a smaller number of more clearly convincing cases. The modules in the Medium–Strong and Strong categories are those where the specifications more clearly document a coherent pedagogical logic, typically through some combination of openness, higher-order thinking, authentic context, design or development work, and assessment formats that plausibly support such learning. By contrast, the large number of Weak–Medium specifications suggests that many modules contain some visible CDIO-related elements, but not enough to form a strongly convincing whole.

DISCUSSION

What stronger CDIO alignment looks like

A question that emerged in the study is what stronger CDIO alignment actually looks like at module level. This study suggests that stronger alignment does not require every CDIO standard to be represented in every module. Rather, it appears where several pedagogical elements are articulated in mutually supportive ways within the same module, so that the specification presents a coherent learning design rather than a set of separate signals. In the stronger cases, higher-order thinking, openness, design or development work, authentic context, and assessment seem to reinforce one another.

Although integration is central to the CDIO framework, it was not among the most clearly articulated dimensions in many of the module specifications and was less often the decisive factor in distinguishing stronger from weaker cases.

Importantly, this study does not aim to assign responsibility or attribute shortcomings to individual actors. Moreover, the findings do not permit such inferences, as no claims about enacted teaching practice can be made. It is therefore possible that integrative and contextual elements are present in practice but not explicitly articulated in the module specifications. What can be concluded with confidence is that this is how CDIO alignment is currently documented in the analysed module specifications.

Reflections on the use of AI in document analysis

One clear methodological takeaway concerns the use of AI-assisted semantic analysis. While large language models are effective at identifying patterns in language across large datasets, semantic reading alone proved insufficient. Several modules initially identified by the AI as CDIO-aligned were, upon closer inspection, found to lack pivotal elements such as explicit higher-order thinking or integrative intent.

This underscored the necessity of human interpretive oversight, including the formulation of explicit alignment considerations and an evidence hierarchy to constrain interpretation. At the same time, this raises an open methodological question about how human caution and AI-supported pattern recognition should best be balanced in future document analyses.While speculative, this question points to the value of future methodological experimentation to calibrate human-AI collaboration prior to large-scale analysis.

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BIOGRAPHICAL INFORMATION

Kirsten From is an educational developer at DTU Learning Lab at the Technical University of Denmark (DTU), where she works with teacher training and educational development in engineering education. Her work focuses on supporting educational practice and development in higher education.

Corresponding author:

Kirsten From
Technical University of Denmark (DTU)
DTU Learning Lab
Koppels Allé 402
2800 Kgs. Lyngby
Denmark
kifr@dtu.dk