ASSESSING PERFORMANCE IN ENGINEERING DESIGN EDUCATION FROM A MULTIDISCIPLINARY PERSPECTIVE: AN ANALYSIS OF INSTRUCTORS' COURSE REVIEW REPORTS

Ndiaye, Yakhoub;
Blessing, Lucienne

Singapore University of Technology and Design

ABSTRACT

Performance assessment plays a crucial role in engineering education. Yet most instructor assessment focuses on student outcomes to analyse achievements. Although there is extensive research analysing student productions, however, few studies have explored assessment from instructor perspectives, especially when reporting their assessment practice. This study examines instructors' assessment of student performance through the lens of course review reports (CRRs). The CRRs were collected from 5 core undergraduate courses submitted for annual review and were related to the mappings of the measurable outcomes to performance indicators, assessment methods, and level of engagement. Regardless of the variability in reporting the student design experience, instructors' assessment and potential gaps, as well as strong existing correlations between some indicators and associated assessment methods, the study showed that the CRR may be a powerful and complementary approach to investigate the complexity of multidisciplinary design and design assessment.

Keywords: Performance assessment, Design education, Design engineering, Measurable outcomes, Research methodologies and methods

Contact:
Ndiaye, Yakhoub
Singapore University of Technology and Design
Singapore
yakhoub_ndiaye@sutd.edu.sg

Cite this article: Ndiaye, Y., Blessing, L. (2023) 'Assessing Performance in Engineering Design Education from a Multidisciplinary Perspective: An Analysis of Instructors' Course Review Reports', in *Proceedings of the International Conference on Engineering Design (ICED23),* Bordeaux, France, 24-28 July 2023. DOI:10.1017/pds.2023.67

1 INTRODUCTION

Educational assessment plays a crucial role in student learning, especially in complex fields such as engineering design (ED) education. It is probably one of the most complex and challenging phases in the teaching-learning processes instructors have to go through. ED instructions generally involve teaching and assessing complex engineering tasks. As students have to demonstrate their learning progression, educators have the challenging task of assessing competencies and thus measuring performance. Yet, different types of assessment have been referenced within the education research literature (e.g., norm-, criterion-referenced, ipsative). One specific and still highly supported type in ED education is performance-based assessment for which learning attainment is based on standards and criteria to establish performance (Cedefop, 2016). Through this approach, assessment focuses on performance, that is, how well students perform the design task. Despite considerable research and the new opportunities provided by advanced technologies, research shows that effective assessment is still lacking, especially in a complex, highly subjective, and multidisciplinary subject such as design. Therefore, design assessment plays a pivotal role in student learning for several reasons. We discuss some of them in the following paragraphs.

1.1 Assessment of student design learning through project-based learning

ED instructions are generally approached through project-based learning (PBL). PBL is seen as a comprehensive approach to teaching and learning ED that is able to engage students in the investigation of authentic problems (Shekar, 2014). It usually implies that students work in groups, thus adding to the individual student assessment a group assessment that is sometimes difficult to grasp. PBL often requires students to work with to-be-defined objectives individually and collectively to address the associated needs to solve the assigned problem. This necessitates the development of soft skills such as collaborating, communicating, planning, etc., which often are to be learnt within the PBL tasks.

ED is open-ended field: students' outcomes are likely to be different, even when given a similar task. Therefore, and for instance, using a similar assessment rubric may have some limitations due to the uniqueness of students' outcomes. It has been suggested some time ago that PBL requires new innovative and effective assessment approaches and methods (e.g., Savin-Baden, 2007). However, ED assessment has not really changed, as student works continues to be assessed through labour-intensive and time-consuming screening of their learning and their design results, involving different forms of assessment (e.g., diagnostic, formative, summative, self/peer) depending on the nature of projects. Moreover, since ED has core vocational and professional components, assessment also tends to be certifying. It is worth noting that new advanced technologies such as AI are being associated with the complex assessment process. However, based on a literature review, Khan, Blessing & Ndiaye (2023) showed that despite growing interest and use of advanced techniques, ED assessment lacks a systematic and integrative approach to design competency and competency assessment. Most of the technologies used in the ED assessment focus on some aspects of a design competency. We view design competency as the ability to integrate and coordinate relevant knowledge, skills, and attitudes and their underlying components (affective, cognitive, motivational, etc.) simultaneously.

1.2 Mastery vs. performance-oriented assessment in ED education

Performance measurement is key in assessing student competency and getting an overview of their expertise. This appears to be essential for engineering disciplines. Pintrich (2000, 2003) distinguished two types of goal-based learning approach: mastery goals and performance goals. He found that mastery goals are adaptative and more adaptative than performance. Mastery-orientated students focused more on mastering the content to be learnt. They usually showed relatively higher motivation and engagement to learn, explore things, create, and understand the design contents; whereas performance-orientated students focused more task performance. Their motivation to learn seems to be conditional. For instance, these students generally wanted to be the best performers (approach oriented) or do not want to reveal their incompetency (avoidance orientation) for several reasons. Despite some benefits (e.g., assessing all students with regard to the same criteria or rubric), this performance goal orientation has shown some limitations. Performance is measured and assessed at a specific point in time, instantaneously, and is situated and valid for a specific moment during the task.

https://doi.org/10.1017/pds.2023.67 Published online by Cambridge University Press

Its measurement is specified in a given time. From a cognitivist perspective, learning is a change in long-term memory (Kirschner, 2002). Therefore, performance-oriented teaching and learning may not be relevant. Additionally, as Pintrich (2000) discussed, learners may have multiple goal orientations, which means that learning may include both mastery and performance goal orientations. Students may be eager to learn and master new contents and simultaneously to obtain good performance or grades on the performed task. With regard to PBL, such situations indeed occur if the emphasis on students' project evaluation does not obscure student mastery orientation, especially if PBL in education is a long-lasting process. In performance-based assessments, instructors often need students to provide performance data for the assessment. This implies the development of assessment rubrics, criteria, and testing that are typically summative since the focus is on the end-product, i.e. the performance (Troman 1989).

1.3 Outcome-based learning and assessment

Outcome-based learning (OBL) has received considerable attention. OBL is results-orientated. The learning outcomes (LOs) are the focal point of the learning process (Crespo et al., 2010). According to the European Centre for the Development of Vocational Training (Cedefop, 2014), LOs are (a): 'statements of what a learner knows, understands, and is able to do on completion of a learning process, which are defined in terms of knowledge, skills, and competence'; (b) 'sets of knowledge, skills, and / or competences an individual has acquired and/or is able to demonstrate after completion of a learning process, either formal, nonformal, or informal' (pp 164-165). Thus, by these definitions, LOs are an articulation between the intended and achieved LOs. It facilitates the evaluation of the curriculum, as the LOs provide a reference point for judging the curriculum (Davis, 2003). When coupled with student-centred learning, OBL seems to be an advancement in engineering education (Streveler et al., 2014). Based on a literature review, Bititci et al. (2012) pointed out that there is a need to introduce a holistic systems-based approach for rethinking performance measurement research. Most ED outcomes are analysed based on student productions, meaning that assessment in ED education, whether formative or summative, is highly production-focused. Although this approach is essential, it may fail to account holistically for student design processes and perspectives, and instructor reflexive feedback as well. A complementary approach is the analysis of instructors' course review reports (CRRs), which, if relevantly used, can provide new insights to researchers and instructors as well about the development of their students' expertise. The CRRs allow instructors to review their courses and highlight opportunities and issues in teaching and assessing the course and enhancing their student learning. However, from a research point of view, it remains unclear how the CRR can provide a new overview on instructors' assessment, especially if such document is produced annually and not regularly.

1.4 Purpose and research questions

This study described in this paper seeks to analyse the complexity of engineering design assessment through the analysis of the course review reports (CRRs) completed by instructors. The overall research questions are as follows:

- RQ1: How can the CRRs provide new insights into instructors' assessment?
- RQ2: What are the opportunities and potential gaps identified in the reports that would benefit teaching, learning and assessing engineering design from a multidisciplinary perspective?
- RQ3: Are there alignments or misalignments between the so-called level of engagement (LOE), performance indicators (SLO-PIs), and the assessment method?

2 METHOD

2.1 Data collection and analysis

Data were collected as part of the accreditation exercise of an Asian university, following approval of the university's Institutional Review Board IRB. A total of five design core courses representative of three university pillars were selected based on the availability of the CRRs produced as part of the accreditation exercise. The collection contained student submissions such as individual journals, portfolios, reviews and feedback reports, and instructors' CRRs. Table 1 summarises the distribution of the collected data. First, we exported and organised the data with an Excel spreadsheet. We then

https://doi.org/10.1017/pds.2023.67 Published online by Cambridge University Press

performed a content analysis and a multiple correspondence analysis (MCA) on data using R software for both visualisation and statistical calculations. The MCA was conducted to analyse the relations between variables (SLO-PIs and LOE) and the variable categories (see Appendix for a sample of SLO-PIs: 13 categories, and LOE: 3 categories) of the CRRs. Lecturers filled the CRRs as part of their course review.

Table 1. Summary of data collection

Courses	Description	CRR	Terms	Sample	Year
C1	Design thinking	1	2	All university students, mixed teams	2021
C2	Software system design	1	5	Specialisation	2020
C3	Engineering design	1	5	Specialisation	2021
C4	Data-driven decision making	1	5	Specialisation	2020
C5	Multidisciplinary design	1	7-8	All university students, mixed teams	2020

2.2 The course review report and its structure

The course review report (CRR) as its name indicates is a document which allows instructors to review their design course. The document is composed of 6 sections (see Table 2) that reviews the course in terms of course-specific measurable outcomes (MOs) to the university's performance indicators of student learning outcomes (SLO-PIs), assessment approaches as well as Level of Engagement (LOE). The LOE categories were: *Introduced* (I): the instructors spend a little time initiating the content or skill but there is no explicit learning objective (LO), assignment, or grading; *Teach* (T): included in compulsory activity; there is a related LO; students get to apply and receive feedback (often in assessment); *Apply* (A): assume the students possess this skill; use it to reach some other learning outcome; Blank: SLO not addressed in this subject. The report also permits to highlight student design learning experience, the opportunities and challenges of teaching and assessing the course.

Table 2. Course review report (CRR) sections

No	Sections	Interpretation
1	Measurable outcomes	Provides the list of MOs of the course
2	Course syllabus	Gives a description of the topics and nature of the course, and any changes from previous years.
3	Mapping of MOs to performance indicators of SLOs	Highlights connections between the course-specific MOs, the university SLO-PIs, and LOE
4	Mapping of MOs vs. assessment methods	Specifies connections between the MOs and the assessment methods and rubrics, as well as the average students' marks for each component.
5	Design Experience	Describes how design projects have been incorporated in the course and a description of how well students performed, i.e. the instructor perceived student experience..
6	Continuous improvement	Present and future actions based on reflections or input from students, to improve the teaching and learning in the course

This paper focuses on **section 3** and **section 4** of the Course Review Report to analyse the relationships between the selected performance indicators (SLO-PIs) to assess the course-specific measurable outcomes MOs, the level of engagement of the content (LOE), and the instructors' assessment methods. The **Appendix** provides a sample of the SLO-PIs, and MOs.

3 RESULTS

The analysis of the CRRs revealed **two key results**:

1. **Result 1**: The reporting performed in the CRRs may highlight **potential gaps** and **variability of the assessment practice** showing that the CRR may be a crucial approach to investigate the complexity of design assessment.

https://doi.org/10.1017/pds.2023.67 Published online by Cambridge University Press

Interpretation 1: There were differences among instructors in selecting the PIs and LOE to assess the course-specific MOs. We aim to see to what extent it varies in relation with the design aspects. Not surprisingly, we also identified some SLO-PIs and LOE that were not relevant for the reviewed courses.

2. **Result 2**: Whereas the majority of course-specific learning objectives were **essentially taught**, and **assessed**, we noticed that some learning objectives were **assessed while just introduced**.

Additionally, to understand the relations between the SLO-PIs and the LOE, we run a correspondence analysis that revealed **2 clusters of performance** involved in assessing students' MOs within the core courses, and **one cluster** that groups indicators that were not considered as part of the teaching, learning and assessment.

Interpretation 2: Teaching is crucial in supporting student development. Due to the design complexity, and intersections of the design components within the courses, some instructors assessed student learning when the contents were only introduced. As it can be seen in the Figure 1 below, the performance indicators were not used uniformly to introduce, teach and assess student learning. However, this did not prevent the introduced aspects from being assessed. This is highlighted (in *Yellow colour*) in Figure 3.

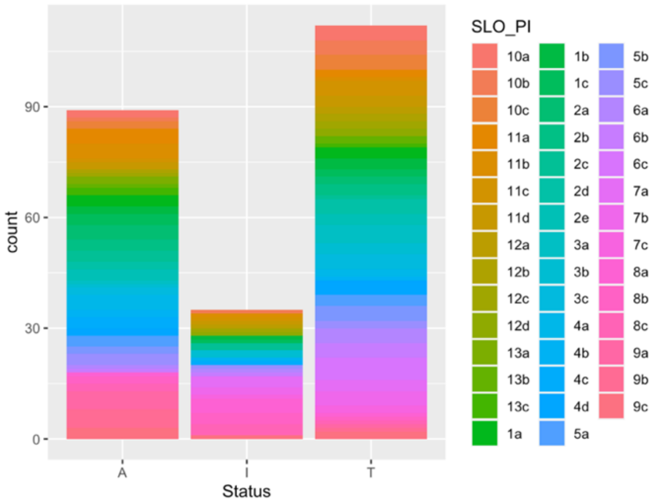

Figure 1. Distribution of the relations between the levels of engagement (LOE) and the performance indicators of student LOs (SLO-PIs). Legend, T: teach, I: introduce; A: apply.

Performance indicators are mostly used to measure design expectations and outcomes, especially in the teaching (T) phase rather than the application (A) and introductory (I) phases. As some instructors may reported "I, T, A" to indicate the LOE in some reports, an important hypothesis here was that when a design component is applied (A) it means that it is/has been taught (T) and introduced (I); when it is taught, it is/has only been introduced.

A multiple correspondence analysis was conducted to analyse the relationships between the selected PIs, and LOE to assess student learning. The analysis (in Figure 2) revealed 3 categories (or clusters): **cluster 1** (PIs: 7c, 12abd, 13abc) grouped indicators that were not selected in the following courses (C2, C3, C4, and C5); whereas **cluster 2** (PIs: 1abc, 2abe, 4cd, 8ac, 9b, 10c, 11abcd, 12c) and **cluster 3** (PIs: 2cd, 3abc, 4ab, 5abc, 6abc, 7ab, 8b, 9a, 10ab) included the introductory, teaching or application level of the addressed contents.

https://doi.org/10.1017/pds.2023.67 Published online by Cambridge University Press

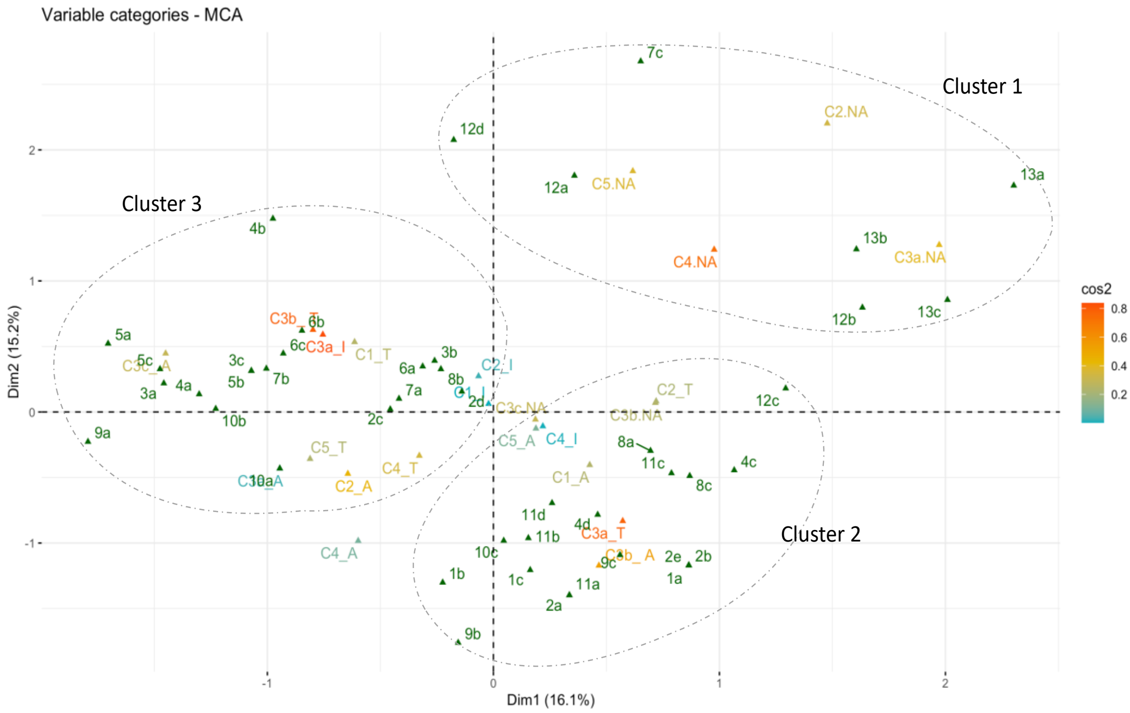

Figure 2. Correspondence analysis: Relations between the SLO-PIs and LOE categories on axes 1-2.

Figure 2 shows the relations between the variable categories of the performance indicators and the level of engagement to assess the MOs by highlighting the quality of the representation (i.e., squared cosine cos2 measuring the degree of association between categories and a particular axis). It can be interpreted as follows: Categories with a similar profile are grouped together. Overall and within the analysed design course, 2 clusters of indicators can be identified when assessing performances:

- **Cluster 1** (top right) grouped PIs not selected as part of the assessment and related to the student evaluation of conflicting or competing societal and environmental values (7c), adaptation to technology changes and engagement for life-long learning (12abd), as well as problem framing, skill adaptation and ability to engage in complex environments (13abc).
- **Cluster 2** is composed of the following PIs: 1abc, 2abe, 4cd, 8ac, 9b, 10c, 11abcd, 12c. This cluster addresses the measurement of student application of STEM knowledge (1abc), their ability to recognise and examine complex engineering problems and to address them by applying scientific and engineering principles (2abe). It also focuses on assessing student investigations and how they synthesise information (4cd) while being professional and aware of ethical principles (8ac). Furthermore, the cluster includes some teamwork (9b, 11abcd), technical (10c), and information search (12c) skills.
- And **cluster 3** addresses PIs that appears to be correlated with some contents of the 5 courses. Those PIs were: 2cd (requires students to draw substantiated conclusions), 3abc (produce statement and design solutions for complex problems), 4ab and 5abc (good laboratory practice to solve problems and carry out prediction), 6abc (take responsibilities to find the design solution), 7ab (knowledge of environmental and social issues), 8b (evaluate ethical dimensions of the design problem), 9a (time management, teamwork), 10ab (appropriate communication and writing skills). This cluster seems to be in opposition to the first two clusters.

To understand the assessment methods that were covered within the five core courses and in relation with the selected performance indicators and level of engagement, we constructed a matrix summarised in the Figure 3.

https://doi.org/10.1017/pds.2023.67 Published online by Cambridge University Press

PIs	C1's Ass Meth	C1_LOE	C2's Ass Meth	C2_LOE	C3's Ass Meth	C3_LOE	C4's Ass Meth	C4_LOE	C5's Ass Meth	C5_LOE
1a	IJ, PJ, 2D, CP	A		T	HW, RW, PE, TP	T, A	CP, PJ, EX, HA	T	RW, IJ	A
1b	PJ, CP	I		A	HW, CP, 2D, RW, PE, TP	T, A	CP, PJ, EX	T	RW, IJ	T
1c	IJ, PJ, 2D, CP	I		A	HW, CP, 2D, RW, PE, TP	T, A	CP, PJ, EX, HA	T	RW, IJ	A
2a	PJ, CP	A		A	HW, CP, 2D, RW, PE, TP	T, A	CP, PJ, EX, HA	T	RW, IJ	A
2b	PJ, 2D, CP	A		T	HW, CP, 2D, RW, PE, TP	T, A	CP, PJ, EX	T	RW, IJ	A
2c	IJ, PJ, 2D, CP	A		A	HW, CP, 2D, RW, PE, TP	I, T		I	RW, IJ	A
2d	PJ, CP, 2D	A		T	HW, RW, PE, TP	I, T	CP, PJ, EX, HA	T	RW, IJ	A
2e	IJ, PJ, 2D, CP	A		T	HW, CP, RW, PE, TP	T, A	CP, PJ, EX	T	RW, IJ	A
3a	PJ, CP	T		A	HW, CP, 2D, RW, PE, TP	I, T	CP, PJ, EX, HA	T	RW, IJ	T
3b	PJ, CP	T		I	RW, PE	I	CP, PJ, EX, HA	T	RW, IJ	A
3c	PJ, 2D, CP	T		A	HW, CP, 2D, RW, PE, TP	I, T	CP, PJ, HA, EX	T	RW, IJ	A
4a	PJ, CP	A	EX, PJ, QZ, PS	A	HW, RW, PE, TP	I, T, A	CP, PJ, HA, EX	T	RW, IJ	A
4b	PJ, 2D, CP	T	EX, PJ, QZ, PS	I	2D, RW, PE, HW, CP, TP	I, T, A			RW, IJ	A
4c	PJ, CP	A	EX, PJ, QZ, PS	I	HW, CP, 2D, RW, PE, TP	T, A			RW, IJ	A
4d	PJ, CP	T	EX, PJ, QZ, PS	T	HW, CP, 2D, RW, PE, TP	T, A	CP, PJ, EX, HA	T	RW, IJ	A
5a	IJ, PJ, 2D, CP	T		A	HW, CP, RW, PE, TP	I, T, A	CP, PJ, HA, EX	T	RW, IJ	A
5b	PJ, CP, 2D	T		A	HW, CP, 2D, RW, PE, TP	I, T	CP, PJ, HA, EX	T	RW, IJ	A
5c	IJ, PJ, 2D, CP	I		A	HW, RW, PE, TP	I, T, A	CP, PJ, HA, EX	T	RW, IJ	A
6a		I		T	HW, CP, 2D, RW, PE, TP	I, T	CP, PJ, EX	T	RW, IJ	A
6b	PJ, CP	T		I	RW, PE	I, T	CP, PJ, EX	T	RW, IJ	A
6c	PJ, CP	T		T	RW, PE, CP, 2D, TP	I, T	CP, PJ, HA, EX	T	RW, IJ	T
7a	PJ, CP	I	EX, PJ, QZ, PS	I	RW, PE	I	CP, PJ, EX, HA	T	RW, IJ	T
7b		I	EX, PJ, QZ, PS	I	RW, PE, CP, 2D, TP	I, T	CP, PJ, EX, HA	T	RW, IJ	T
7c	PJ, CP	I	EX, PJ, QZ, PS		HW, RW, PE, TP, CP, 2D	I, T				
8a		I	EX, PJ, QZ, PS	I	HW, CP, RW, PE, TP	T	CP, PJ, EX	I	RW, IJ	A
8b		A	EX, PJ, QZ, PS	I	HW, CP, RW, PE, TP	I, T	CP, PJ, EX	I	RW, IJ	A
8c	PJ, 2D, CP	A	EX, PJ, QZ, PS	I	HW, CP, RW, PE, TP	T	CP, PJ, EX	I	RW, IJ	A
9a	PJ, 2D, CP	A		A	HW, CP, 2D, RW, PE, TP	I, T, A	CP, PJ, EX, HA	A	IJ, PR, CP	T
9b	PJ, 2D, CP	A		A	HW, CP, 2D, RW, PE, TP	T, A	CP, PJ, EX, HA	A	IJ, PR, CP	T
9c	IJ, PJ, 2D	A		I	HW, CP, 2D, RW, PE, TP	T, A	CP, PJ, EX, HA	T	IJ, PR, CP	A
10a	IJ, PJ, 2D	T		A	HW, CP, 2D, RW, PE, TP	A	CP, PJ, EX, HA	T	RW, IJ	T
10b	IJ, PJ, 2D	I		A	HW, CP, 2D, RW, PE, TP	I, T	CP, PJ, EX, HA	T	RW, IJ	T
10c	PJ, 2D, CP	A		A	CP, 2D, RW, TP	T	CP, PJ, EX, HA	T	RW, IJ	T
11a	PJ, 2D, CP	A	EX, PJ, QZ, PS	A	HW, CP, 2D, RW, PE, TP	T, A	CP, PJ, EX, HA	T	RW, IJ, PR, CP	A
11b	PJ, 2D, CP	I	EX, PJ, QZ, PS	A	HW, CP, 2D, RW, PE, TP	T	CP, PJ, EX, HA	A	IJ, PR, CP	A
11c	PJ, 2D, CP	I	EX, PJ, QZ, PS	T	HW, CP, 2D, RW, PE, TP	T	CP, PJ, EX, HA	T	RW, IJ	A
11d	PJ, CP	I	EX, PJ, QZ, PS	A	HW, CP, 2D, RW, PE, TP	T	CP, PJ, EX, HA	T	RW, IJ, PR, CP	A
12a	IJ, PJ, 2D, CP	I		T	HW, CP, 2D, RW, PE, TP	I, T				
12b	PJ, CP	A		T	HW, CP, 2D, RW, PE, TP	T				
12c	PJ, CP	I		T	HW, CP, 2D, RW, PE, TP	T			RW, IJ	A
12d		T		I	HW, CP, 2D, RW, PE, TP	I, T				
13a		A							RW, IJ	A
13b		T		T					RW, IJ	A
13c	IJ, PJ, 2D, CP	A		T					RW, IJ, PR, CP	A

Legends: Assessment Method: Ass Meth; Individual journal: IJ; Project: PJ; 2D Project: 2D; Class participation: CP; Exam: EX; Quizzes: QZ; Problem sets: PS; Homework assignment: HA; Review: RW; Prototype evaluation: PE; Term paper: TP; Peer Review: PR.

Figure 3. Relations between assessment methods, indicators and level of engagement

We identified **8 key indicators** (*Orange colour*) that were simultaneously involved in the 5 core courses and strongly correlated with clusters 2 and 3. Those indicators were: 4a: Use appropriate tools to analyse data, verify and validate experimental results; 4d: synthesise information from conducting complex problem investigation; 7a: demonstrate knowledge of the role of engineering in society; 8c: apply an understanding of professional, ethical & moral responsibilities; 11a: demonstrate ability to work in and lead a team to identify and solve multidisciplinary problems, 11b: able to recognise the roles of individuals in team setting and fulfil appropriate roles to accomplish team success, 11c: gain understanding of engineering and management principles from relevant subjects, 11d: able to apply engineering and management principles in carrying the project in multidisciplinary environments. Therefore, despite the potential gaps and variability in reporting the assessment in the CRRs, these are crucial skills that instructors focused on within student learning and its assessment.

https://doi.org/10.1017/pds.2023.67 Published online by Cambridge University Press

4 DISCUSSION

Our findings emphasised the complexity of multidisciplinary design assessment from the perspective of the course review reports. An interesting aspect that emerged from the analysis of the CRRs is that there might be potential gaps in reporting the assessment practice. A possible explanation is that different design approaches may be supported depending on the design course (goal, content, skill, ..), instructor and student background, etc. However, this is not necessary perceived as an issue since design may be approached with different views and perspectives. In fact Jaeger & Adair (2014) showed that identical learning objectives in two consecutive engineering design courses were not redundancy; rather, they helped to enforce the design framework with regard to different design projects and subjects. There were possible gaps related to the selection of performance indicators and associated level of engagement helping to assess the MOs. This may also indicate that the defined learning objectives and MOs were not all relevant for all the design courses. More importantly, instructors may have different interpretations of learning outcomes, the level of content complexity and indicators that measure those performances.

The study showed that some learning objectives were mainly *taught* and *applied* and few were *introduced*. When *introduced*, meaning that the instructors spent a little time initiating the content or skill without an explicit learning objective, it is noted that they assessed those introduced contents. Multiple explanations are possible: (1) This may be an inconsistency. (2) Based on their background, instructors might have different interpretations of what is introduced that could affect their teaching approaches. (3) Some might introduce the content to recall (diagnostic assessment) students' prior knowledge addressed (assessed or applied) in a past term or related course. (4) This could be supported by some lecturers who considered design as a *messy* subject. Other reasons are possible. The analysed reports did not evidenced whether and how these contents were taught in other courses, and how instructors elaborated on their colleagues' assessment. Therefore, an explicit collaborative approach seemed to be lacking from the perspective of the CRRs. Regarding PBL, it is shown that instructors' collaboration is key to student success and instructor effectiveness, as it may help students to integrate science and engineering (e.g., Shekar, 2014).

This exploratory study evidenced that there were few interesting connections between some indicators, the assessment methods used, the content's level of engagement as determined by the correspondence analysis (MCA) and the matrix. However, the MCA scattering across the graphs also revealed lacks of relationships of certain PIs. This is reinforced by the quality of the representation (i.e., squared cosine cos2) values under .5. Many research (see, e.g., Mina & Heywood, 2021) have drawn attention to the disconnection of engineering from teaching practice. For instance, Streveler & Smith (2006) discussed that there is confusion between engineering research (supported by some instructors, experts in their fields) and engineering education research (supported by educational researchers). Williams (2003) argued that engineering design has evolved into an all-encompassing profession and is suffering from the shift to multiplicity. Therefore, the findings discussed here are in line with the pertinent existing literature.

5 CONCLUSION

This study examines instructors' assessment from the perspective of the course review reports of five core undergraduate engineering design courses. The analysis showed how these core design courses might be related, and how their design contents was introduced, taught, and applied from a multidisciplinary perspective. The study highlights some opportunities and potential gaps in performance-based assessment and associated indicators, as well as how instructors reported their practice through the CRRs. We conclude that the analysis of CRRs can help get insights of the instructors' assessment and some of the design components (helping to address the first RQ). Differences in using indicators to assess learning are not necessarily perceived as a core issue and, in some cases, may be an opportunity to teach and assess design from a multidisciplinary perspective. However, due to several reasons (e.g., multiple interpretations, inconsistency of reporting), the integration and transfer of the indicators of performance, assessment methods, and level of engagement among the design courses appeared challenging (RQ2). Altogether, what particularly stands out is on one hand the importance of design connectivity between key indicators of performance in the design courses; On the other hand the instructor assessment practice and how their

https://doi.org/10.1017/pds.2023.67 Published online by Cambridge University Press

reported it through the CRR which may result to the prevalence of a misalignment of the MOs, indicators and LOE, helping to address our last research question.

5.1 Limitations

This study has some limitations. Given the small sample size, caution must be used. By combining all existing core courses representative of the pillars, these findings might be affected and the potential gaps and inconsistencies addressed. Therefore, the findings evidenced here are very sensitive to how instructors completed the review and the level of details provided to describe their teaching, assessment, and student design experience. Additional analyses could be performed to examine specific details in the CRRs. For instance, it would be interesting to obtain insights directly from instructors on how they approach and complete the CRR.

5.2 Implications

Despite these limitations, the findings of this study may have implications for engineering design instructions. It showed that the CRR is potentially an indicative measure of a multidisciplinary design curriculum. The CRR is used to analyse design experience and potentially the extent to which design assessment and components evolved within courses. The study may be beneficial for engineering instructors and curriculum designers. From a research point of view, the CRR is a powerful tool for analysing instructions and design assessment in particular. To date, this may not yet be a common practice in engineering design. By pointing out the opportunities and challenges of conceptual and practical alignments and misalignments between what was measured (the MOs), how (the assessment approach) and which aspects (the PIs), how they are approached (the LOE), it is suggested that systematic and integrated approaches to performance assessment should be established for teaching and assessing design. It is argued that effective alignment of content, assessment, and delivery is an essential element of outcome-based education, especially in engineering education (Streveler et al., 2012). Additionally, effect sizes based on the outcomes of aligned-based instructional approaches have been reported to be greater than those in non-aligned instructions (e.g., Cohen 1987; Biggs, 1996). Further research is needed to analyse the relationships between measurable outcomes, performance, assessment methods, and student design experience, as well as how instructors commented and critiqued design courses for continuous and constructive improvements.

REFERENCES

Biggs, J. (1996). “Enhancing teaching through constructive alignment”. *Higher Education*, Vol. 32, pp. 347–364. https://doi.org/10.1007/BF00138871

Bititci, U., Garengo, P., Dörfler, V., and Nudurupati, S. (2012), “Performance measurement: challenges for tomorrow”. *International Journal of Management Reviews*, Vol. 14 No. 3, 305-327. https://doi.org/10.1111/j.1468-2370.2011.00318.x

Cedefop (2014). Terminology of European education and training policy: a selection of 130 key terms. Second edition. Luxembourg: Publications Office. http://www.cedefop.europa.eu/en/publications-and-resources/publications/4117

Cedefop (2016). Application of LOs approaches across Europe: A comparative study. Luxembourg: Publications Office. Cedefop reference series; No 105. http://dx.doi.org/10.2801/735711

Cohen, S. A. (1987). Instructional alignment: Searching for a magic bullet. *Educational Researcher*, Vol. 16 No. 8, pp. 16-20. https://doi.org/10.3102/0013189X016008016

Crespo, R. M., Najjar, J., Derntl, M., Leony, D., Neumann, S., Oberhuemer, P., ... & Kloos, C. D. (2010, April). “Aligning assessment with LOs in outcome-based education”. IEEE EDUCON 2010 Conference (pp. 1239-1246). IEEE.

Davis, M. H. (2003). “Outcome-based education”. *Journal of veterinary medical education*, Vol. 30 No. 3, pp. 258-263. https://doi.org/10.3138/jvme.30.3.258

Harden, R. M., Crosby, J. R., Davis, M. H. (1999). “An introduction to outcome-based education”. *Medical Teacher* Vol. 21 No. 1, pp. 7-14, https://doi.org/10.1080/01421599979969

Jaeger, M., and Adair, D. (2014). “Two consecutive project-based learning engineering design courses. An analysis of portfolio assessment results”, Fourth Interdisciplinary Engineering Design Education Conference, 2014, pp. 1-5, https://dx.doi.org/10.1109/IEDEC.2014.6784672.

Khan, S., Blessing, L., Ndiaye, Y. (2023). “Artificial intelligence for competency assessment in design education: a review of literature”. 9th International Conference on Research into Design, ICoRD'23, Indian Institute of Science, Bangalore, India, 9-11 Jan 2023, Springer.

https://doi.org/10.1017/pds.2023.67 Published online by Cambridge University Press

Kirschner, Paul A. 2002. “Cognitive load theory: implications of cognitive load theory on the design of learning”. *Learning and Instruction*, Vol. 12 No. 1, pp. 1-10, https://doi.org/10.1016/S0959-4752(01)00014-7

Mina, M., & Heywood, J. (2021). “Disconnected Engineering Education”. IEEE Frontiers in Education Conference (FIE), pp. 1-3, https://doi.org/10.1109/FIE49875.2021.9637326.

Pintrich, P. R. (2000). “Multiple goals, multiple pathways: The role of goal orientation in learning and achievement”. *Journal of Educational Psychology*, Vol. 92 No. 3, 544–555. https://doi.org/10.1037/0022-0663.92.3.544

Pintrich, P. R. (2003). “A motivational science perspective on the role of student motivation in learning and teaching contexts”. *Journal of Educational Psychology*, Vol. 95 No. 4, pp. 667–686. https://doi.org/10.1037/0022-0663.95.4.667

Troman, G. 1989. “Testing Tensions: the Politics of Educational Assessment”. *British Educational Research Journal* Vol. 15 No. 3, pp. 279–295. https://doi.org/10.1080/0141192890150305.

Savin-Baden, M. “Challenging models and perspectives of problem-based learning”, Management of change - Implementation of problem-based and project-based learning in engineering, edited by Erik de Graaff and Anette Kolmos, Sense Publishers, Rotterdam, 2007, pp. 9-29.

Shekar, A. (2014), “Project-based learning in engineering design education: Sharing best practices”. Paper presented at 2014 ASEE Annual Conference & Exposition, Indianapolis, Indiana. https://doi.org/10.18260/1-2--22949

Streveler, R., & Smith, K. A. (2006). “Rigorous research in engineering education”. *Journal of Engineering Education*, Vol. 95 No. 2, pp. 103-105.

Streveler, R. A., Smith, K. A., & Pilotte, M. (2012). “Aligning course content, assessment, and delivery: Creating a context for outcome-based education”. In Outcome-based science, technology, engineering, and mathematics education: *Innovative practices*, pp. 1-26. IGI global. https://doi.org/10.4018/978-1-4666-1809-1.ch001

Williams, R. (2003). “Education for the profession formerly known as engineering”. *Chronicle of Higher Education* Vol. 49 No. 20.

APPENDIX

A1. An example of specific measurable outcomes for the course C5

No	MOs
1	Framed design issues and design briefs by critically interpreting complex scenarios in their cultural contexts.
2	Applied technical and design principles/mathematics and science to formulate design strategies to tackle a technical design problem.
3	Conducted design and technology research, analysed and interpreted data and

A2. Structure of performance indicators for the assessment of student learning outcomes

N	Student Learning Outcome (SLO) Performance Indicators (PIs)
1	(a) Demonstrate knowledge of mathematics, science, engineering fundamentals, and engineering specialisation subjects, covering WK1 to WK4, included in the core curriculum
	(b) Identify complex engineering problems and the requirements for their solution.
	(c) Employ general principles, theories, concepts, and/or formulas from mathematics, science, and engineering as specified in WK1 to WK4 in solving complex engineering problems
2	(a) Examine approaches to solving a complex engineering problem in order to choose the more effective approach
	(b) Recognise and define complex engineering problems

** WK: characteristics of knowledge profile (not presented)*

https://doi.org/10.1017/pds.2023.67 Published online by Cambridge University Press