Dan Trowsdale, UNIVERSITY OF LEEDS, d.b.trowsdale@leeds.ac.uk
Alison McKay, UNIVERSITY OF LEEDS, a.mckay@leeds.ac.uk

EdVee: A Visual Diagnostic and Course Design Tool for Constructive Alignment

ABSTRACT

The adoption of digital technologies in higher education offers new opportunities for student learning but also adds complexity to course design and development processes. Although practice varies across institutions and nations, a common response is that teams of people are now involved in the development and creation of blended and online courses. Members of such teams typically include instructional designers, academics, learning designers and technologists, and production teams, and courses are developed over time, often across separate locations and organisations. These factors are creating a need for tools that support the sharing of design information in distributed course design teams. This paper introduces such a course design tool, EdVee, which supports pedagogical innovation through the sharing and visualisation of constructive alignment of learning outcomes, content, learning, and teaching activities and assessment. Key concepts that underpin EdVee are drawn from systems engineering and product development. We demonstrate its value to course design through two case studies: the design of a new course and the evaluation of an existing course.

KEYWORDS

curriculum design, design-for-learning, constructive alignment, visual mapping

INTRODUCTION

The designing and re-designing of learning in higher education requires trade-offs across a variety of factors. For example, the design of courses includes: practical considerations (such as cohort size, delivery schedule, timetabling, room sizes, and the availability of technology); learner and pedagogical considerations (such as curricular requirements, learner journeys, the sequence of content, pace, inclusivity, and the educational background and level of the cohort); and staff considerations, such as workload. Balancing of these often conflicting demands can be considered a wicked problem in that it exhibits all three of Farrell and Hooker's (2013) characteristics: no single stakeholder can establish a full understanding of the whole problem from the perspective of all stakeholders (finitude); solutions are likely to raise a number of interconnected issues (complexity); and both the feasibility and adoption of proposed solutions is governed by social and cultural norms which influence overall success (normativity). Masterman (2019) argues that the solution of such problems, and so of course design itself, requires a balance of art and science and so suitable tools, methods, and frameworks. This paper introduces such a tool, EdVee, for use during the design and development of new courses and as a diagnostic evaluation tool to support improvements to existing course designs.

The development of EdVee was inspired by many years of course design and re-design coupled with the authors' professional experiences in consumer product and engineering design. For this reason, we begin, in the background section, with a review that draws together literature related to 3-D product and course design and concludes with design requirements for course design tools. This is followed, in the design requirements section, with an overview of the method used to develop EdVee. We demonstrate the value of EdVee through application in the context of two course design activities. EdVee, including a template for its use, is introduced in the course design section, followed by the case studies themselves. Finally, we discuss implications of EdVee for course design and identify areas for further development in the discussion and conclusion section.

BACKGROUND

In this section we draw together and build on learning from two cognate areas (3-D product design and course design) to inform the definition in the following section of high-level design requirements for course design tools.

Current practice in 3-D product design and development

There are many examples of systematic product and engineering design processes. All are driven by design requirements that are used to inform decisions made in both creative design and evaluation processes (e.g. see Giard 2005; Pahl and Beitz 2013; Pugh 1991; Sommerville 2011). Sommerville's waterfall method (see Figure 1) is widely used in both product and software design. In this model, high-level design requirements cascade through the process with evaluation against requirements informing subsequent design iterations. Designers and engineers create candidate design solutions in response to these requirements which are evaluated against requirements, both as part of the design activity and at so-called "stage gates" in the product development process. The UK Design Council's double diamond 4-D model was developed in 2004 as a general purpose design process to support manufacturers and businesses. This model emphasises the importance of a mix of divergent and convergent thought processes (see Figure 2) which are represented through two diamonds: (1) discover and define (explore the problem or need and define requirements) and (2) develop and deliver (develop ideas, prototype, and test) followed by delivering the product or solution.

Figure 1. Waterfall model of product development (Sommerville 2011)

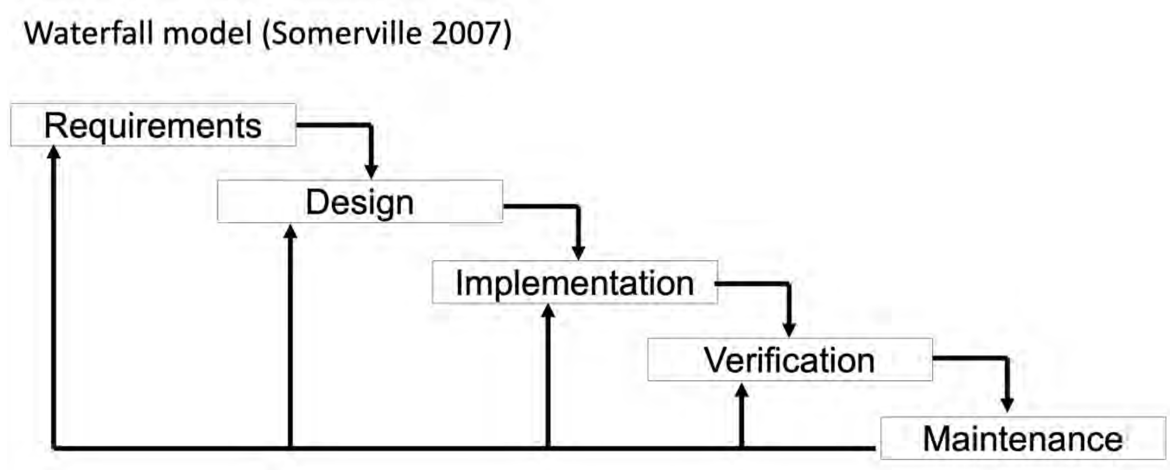
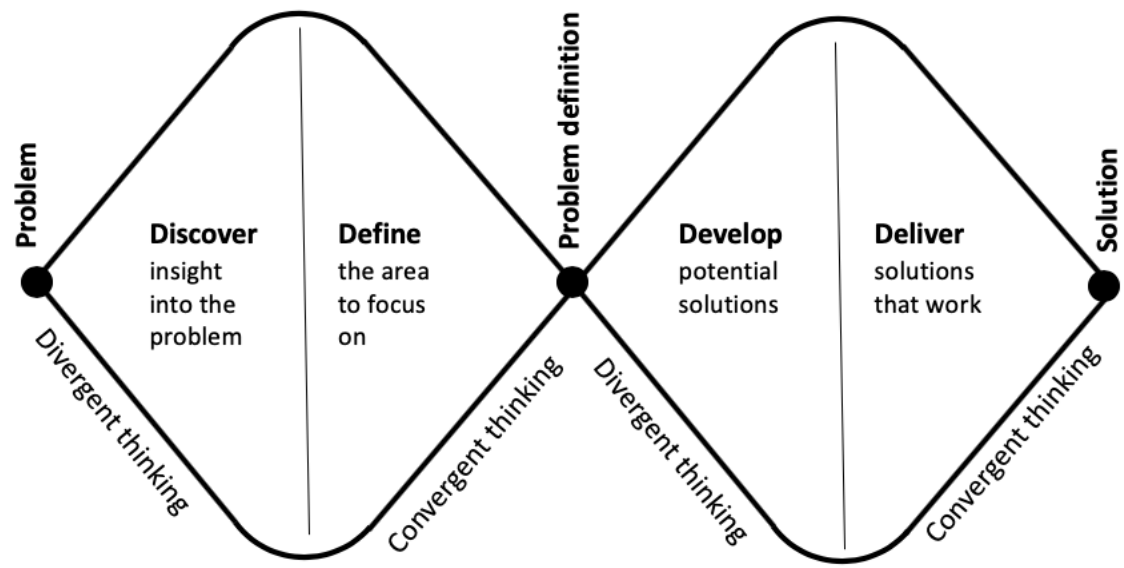


Figure 2. Double Diamond adapted from Design Council's 4-D Double Diamond model



Product and engineering design processes are carried out in the context of product development processes (e.g., see Cagan and Vogel 2002; Ulrich and Eppinger 2004). These are business processes that ensure products with the required functionality and quality are delivered to markets on time and with minimal costs. Depending on the complexity and kind of product being designed, different design approaches are used to develop, evaluate, and optimise design solutions. For example, the five-stage design thinking process (discover, define, ideate, prototype, test), developed at Hasso Plattner Institute of Design at Stanford University (commonly referred to as "d.school") and popularised by global design consultancy IDEO (IDEO 2020), is well suited to design activities where understanding of users' experiences, priorities, and constraints needs to be built. These process steps are enacted through cycles of design iteration with each cycle including all five steps. On the other hand, in the design of systems with better understood users but higher degrees of technical complexity, such as aircrafts, systems engineering approaches (Blanchard and Fabrycky 1990 and the systems engineering vee model (Elliott and Deasley 2007) are used to decompose the overall system into a collection of smaller sub-systems, each contributing to the overall design requirements.

Alongside these different product design and development processes, many methods and tools (from here on, collectively referred to as "tools") have been developed to support design visualisation. A summary is provided in Table 1. These tools vary in their level of complexity, with some taking many hours to complete and others providing quick visualisations to support the interpretations of complex information. Tools such as sketching and prototyping, being quick and easy to use, are especially important in the early stages of design where design exploration and iteration are important and seeing-moving-seeing cycles of design iteration improve designers' creativity (Schon and Wiggins 1992). Ferguson (1992) identifies three kinds of sketches: thinking sketches, talking sketches, and prescriptive sketches. Of particular relevance to course design are "talking sketches" which support group discussions, and "prescriptive sketches" which are used to communicate detailed representations to people outside of the design process. In this way, prescriptive sketches can act as interfaces between course design and development processes by supporting communication of design intent to the people inside a design team, such as technical or inclusivity specialists, and with people outside the design team, such as quality assurance or programme managers (Schrage 1999).

Table 1. Tools and methods to support the visualisation of design problems

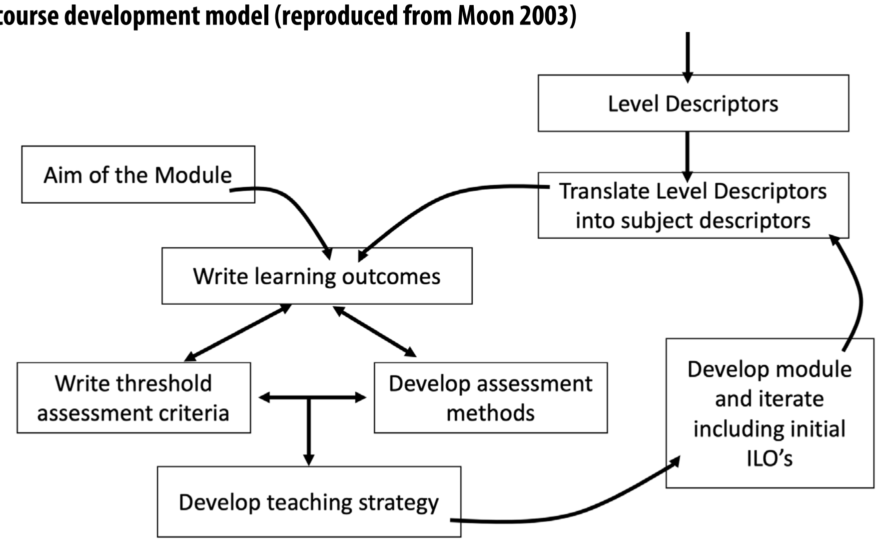
Name	Common usage	Typical visualisation method
Visual mapping	Identification of needs: A method to visually represent problems, models or systems to create insights into the relationships between complex elements of a problem.	Mind maps and spider diagrams
Soft systems and rich pictures	Problem analysis: Visually representing systems and relationships to develop human insights into complex and wicked problems.	Complex visual/map
Task analysis	Requirements definition and design evaluation: Exploring and defining the steps for intended users to employ when using the product to meet a goal.	Process flow/system diagrams
Quality function deployment (QFD)	Requirements identification: Structured approach to defining and capturing customer needs and translating them into design requirements that address those needs.	House of quality grids
	Requirements definition: Translation of customer and other stakeholder needs into design requirements.	
	Design evaluation: Evaluation of design features against customer needs and/or design requirements.	
Design sketching	Sketches are used through the entire design processes, at different levels of fidelity, to support the visualisation and communication of design ideas and creative processes, in addition to the 3-D product shapes and their contexts, e.g., relationships to users and the spaces in which they will be used.	Hand-drawn sketches of product shapes and their usage contexts
Design prototyping	Design prototypes are used through the entire design processes, at increasing levels of fidelity, to support the evaluation (and so development) of design ideas, especially with target users.	Physical models
Computer aided design systems	Development and detailed design of 3-D shapes for use in design visualisation, analysis, and optimisation.	Digital renders and line drawings of product shapes
Failure modes effects analysis (FMEA)	Design evaluation: Inductive reasoning and highly structured process of analysing assemblies, components, and sub-components to identify possible failure points.	Tables and fishbone diagrams
Design structure matrix (DSM)	Design analysis: Visualisation of relationships between components and subcomponents to other components.	Matrix

Current practice in course design

Like product development processes in manufacturing organisations, universities' course development processes are often general purpose stage-gated processes that respond to curricular and organisational strategies. The process may point to specific requirements, for example, many universities have blended learning strategies to guide the incorporation of digital learning into curricula,[1] and national bodies[2] provide guidance on and requirements for course design. Again, like product development processes, the goal of course development processes is to enable the delivery of new and improved courses on time, with available resources and of requisite quality. Course design processes, on the other hand, are subject specific in that design requirements, in the form of learning outcomes and associated curricular needs and are key drivers.

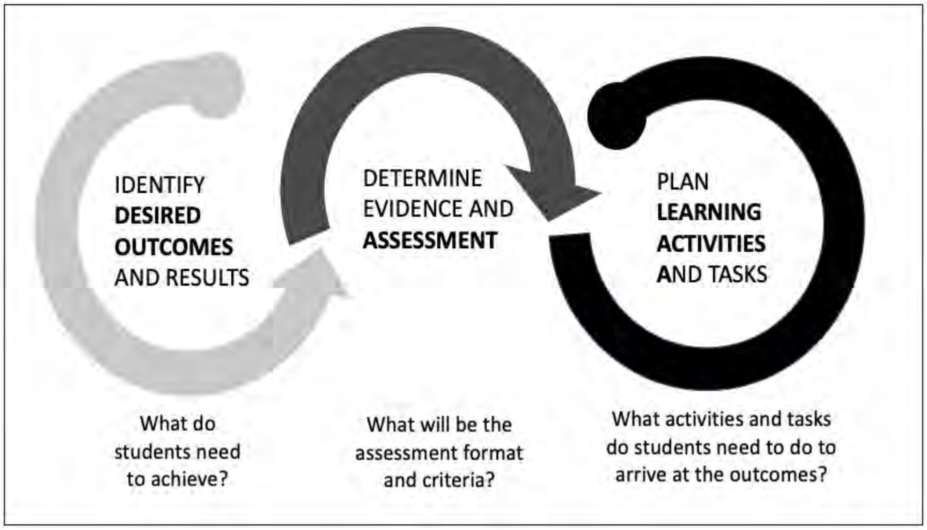
Current course design tools tend to be frameworks that support the practice of design-for-learning (Dalziel 2015). Conole (2019) argues that there is real value in such frameworks because they encourage new ways of thinking and Masterman (2019) argues that design tools can stimulate innovation. However, given the increasing complexity arising from the advent of digital and blended learning (Goodyear and Carvalho 2019), there remains a need for tools that allow course designers to take a more holistic view of course design, especially early in the design process. As in the design of products, there are many process models for course (and instructional) design (Moon 2003). Examples include Carpe Diem (Armellini, Salmon, and Hawkridge 2009), CAIeRO, (Farmer and Usher 2018) and Design Develop Implement (Seeto and Vlachopoulos 2015). Most are underpinned in some way by fundamental principles of curriculum design with content and how learning is supported and assessed, cascading down from educational purposes or aims of the course. Moon (2003) presents the model shown in Figure 3 which also follows this pattern but with the addition of design iteration. Course design processes share common features such as a focus on goals, and the importance of including students in the design process and design evaluation. For example, ADDIE (Analyse, Design, Develop, Implement, Evaluate) is described by Michael Molenda (2015) as being synonymous with systematic models for instructional design and also embodies these characteristics.

Figure 3. Moon's course development model (reproduced from Moon 2003)



The goals of course design processes typically cover the delivery of subject matter content and learning activities that enable students to meet the learning outcomes which are aligned to a target curriculum and in the context of wider educational programmes and student experience (Biggs and Tang 2011). One example, the "backwards design" model for course design proposed by Wiggins and McTighe (2005) shown in Figure 4, highlights similarities between product and course design processes by proposing three stages of development: identify desired outcomes and results (design outcomes), determine the evidence required for assessment (design requirements), and plan learning activities and tasks (design of activities). With respect to solution development, Laurillard (2013) highlights the importance of design science as an emerging discipline for creating new courses and other authors propose the use of specific design methods. For example, Matthews (2019) proposes the use of actor-network theory in course design, Goodyear (2015) explores ways in which design can be used to focus on students' learning activities, and Carvalho, Martinez-Maldonado, and Goodyear (2019) highlight benefits of using a so-called "instrumental genesis" approach in course design.

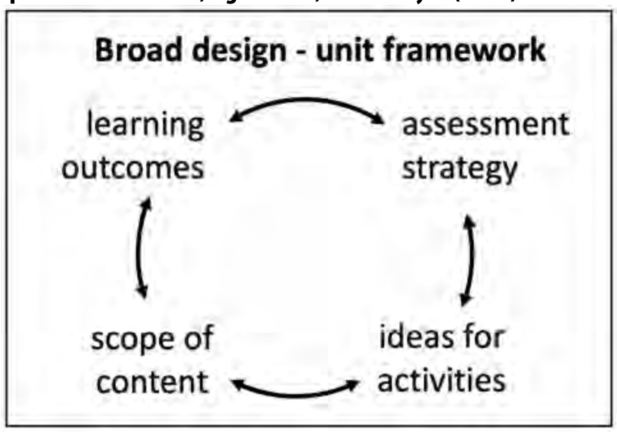
Figure 4. Backwards design model adapted from Wiggins and McTighe (2005)



A key driver for any course design activity is the subject content to be covered which itself is the result of a [curriculum] design process. Curriculum design process models have been debated for well over a century with early proponents being Bobbit (1918) and Tyler ([1949] 2013). Tyler's four stage "curriculum process" proposes that curricula should be concerned with: (1) educational purposes (e.g., objectives, learning outcomes, attitudes, skills); (2) how these might be delivered to learners (e.g., selecting content, developing learning experiences); (3) how courses delivering them are best organised (e.g., course structures); and (4) ways to determine whether the purposes are attained (e.g., through assessment of learners and course evaluation processes). Wraga (2017) reflects on Tyler's work and suggests it promotes a problem solving approach to curriculum design. Similar, largely linear, models have been proposed by Taba (1962) and Grundy (1987), and more recently, Stenhouse (2014). In contrast, cyclical models of curriculum design (e.g. Nicholls and Nicholls [1978] 2018; Wheeler 1974) emphasise a reflective and evaluative continuous process of curriculum design to accommodate changes that reflect developments in society or knowledge and dynamic models. For example, Brady (1990), Skilbeck (1990), Walker (1992), and Print (1993) propose more flexible approaches, allowing the order of planning to be decided by the designer, starting with any element such as objectives, syllabus, or assessment. Advantages of such approaches include their support for creativity, but there are practical challenges such as the need for designers to decide where to start. Thus, like the design of physical artefacts, the design of courses is an iterative process.

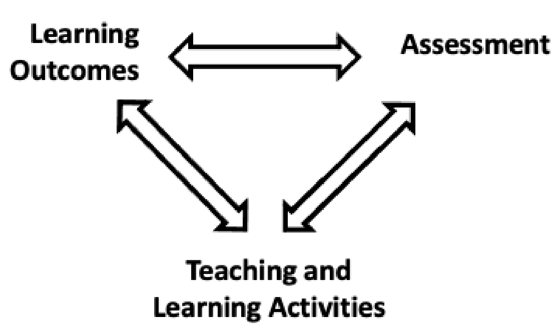
Butcher, Davies, and Highton (2006) emphasise the importance of learning outcomes which can be considered as part of the curriculum and design goals or requirements that drive course design processes. Wisdom (2001) argues that defining learning outcomes is not a one-off activity, but an iterative process where learning outcomes are revisited and re-evaluated throughout the course design process. Bennett, Agostinho, and Lockyer (2017) also argue that design for learning is a dynamic process with the period teachers spend on design happening before, during, and after the creation of a design for learning. They suggest that a typical course design process begins with a top down approach, starting with a broad framework of the unit of learning, with details being added and elaborated as the design goes through cycles of development or iteration. The main learning design activities are focused around iterations between learning outcomes, the scope of content, the assessment strategy, and ideas for activities (see Figure 5).

Figure 5. "Design Activities" adapted from Bennett, Agostinho, and Lockyer (2017)



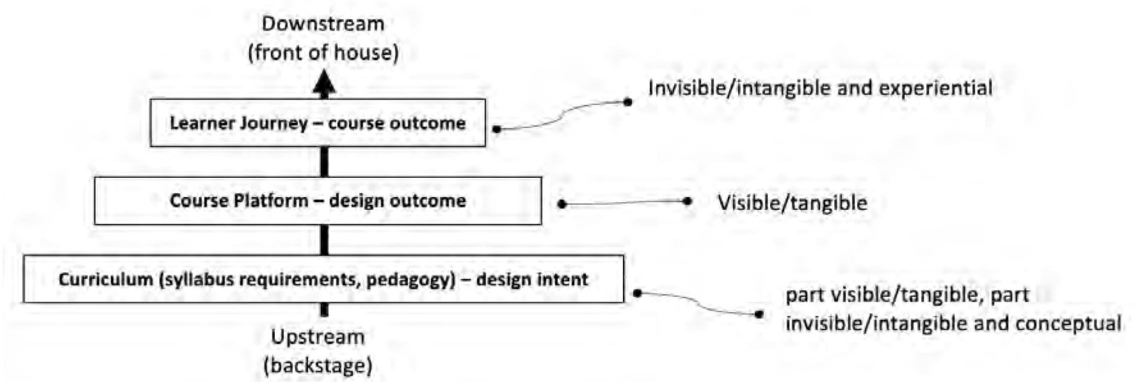
Biggs and Tang (2011) provide constructive alignment, one of the dominant models for describing course designs, with "educational purposes" from Tyler, replaced with intended learning outcomes (ILOs). The Biggs and Tang triad connects intended learning outcomes (ILOs) to assessment and to teaching and learning activities (see Figure 6). The importance for course designers to ensure alignment between learning outcomes, assessment, and teaching and learning activities is recognised by many authors (e.g., see Biggs and Tang 2011; Butcher, Davies, and Highton 2006; Ramsden 2003). Alignment alone, however, is not enough, and ensuring that both teaching and learning activities (whether computer-based or not) support active and engaged learning is also widely recognised as being essential (Biggs and Tang 2011; Conole and Fill 2005; Race 2014).

Figure 6. Biggs and Tang's Constructive Alignment Triad



EdVee builds on the premise that there are both tangible and intangible (visible and invisible) aspects to any course design process. Figure 7 provides a diagrammatic representation of these as a series of layers. Viewed through a service design lens (Penin 2018), the layers transition from backstage (upstream in a service design process) to front of house (or downstream in the design process). For example, learning design objectives range from tangible but invisible (to learners) pedagogical goals on the base layer of curriculum design; through the visible and tangible middle course layer where learning outcomes are defined; to the desired (invisible and intangible) course outcomes on the top layer. Constructive alignment provides coherence across these layers. Graphical representations can help to visualise, and make tangible, some of the intangible elements, e.g., the pedagogical design of a course including constructive alignment. Such visualisations enable the sharing of the intangible elements, supporting collaboration between course designers, and can be thought of as design "sketches" or "prototypes."

Figure 7. Layers of a learning design (authors' own figure)



Design requirements

Like service design, the results of a course design process are intangible and difficult to represent and evaluate before delivery. Penin (2018) highlights key differences between the design of service and physical products. Like services, courses tend to be intangible and have a temporal dimension, meaning a given course is likely to be experienced differently by different users and there is a need for synchronisation with users during delivery. Early stage prototyping is recognised as a key activity in design processes and Schrage (1999) asserts that making tangible and shareable conceptual models at an early stage of the design process is extremely valuable. This leads to our first design requirement.

- Requirement 1: Provide a design prototyping capability to facilitate the sharing and evaluation of design ideas.

Although disciplines and institutions may differ, a review of higher education courses is typically carried out regularly to satisfy quality assurance processes. Such course reviews may be supported by student satisfaction scores which, to some extent, act as a form of design evaluation. The iteration of courses for traditional delivery mechanisms, e.g., face-to-face lectures, can be relatively straightforward and cost effective to implement through adjustments to lecture plans by the course leader and other quick solutions. Online courses, on the other hand, are often meticulously planned and produced by design and production teams. Because of this, there is a greater emphasis to get the design right the first time, before delivery, as updates can be costly and may not be easily implemented by the course leader. In the development of both online and blended courses, collaboration within course design teams is recognised as an important factor (Zundans-Fraser 2014) but also one with challenges in how to do it well. Newell and Bain (2020) suggest that higher education staff express a strong willingness to collaborate on course design, but that cultures and processes inhibit the full potential of collaboration in course design teams. Bringing together design requirements (in the form of learning outcomes) and design solutions (learning activities, subject matter content, and assessment) in design prototypes leads to our next two design requirements.

- Requirement 2: Support design iteration and the evaluation of design solutions against design requirements.
- Requirement 3: Accommodate the complexities of course design by integrating current models of curriculum design with course design processes.

Current practice in achieving constructive alignment within the design of a course tends to rely on the use of matrix-based methods. However, matrices only relate two aspects of alignment at a time, for example, content and assessment or assessment and learning outcomes (see Table 2). As a result, although grids such as these are very useful for considering relationships between pairs of aspects, matrix-based approaches become more challenging to use with the need to capture three or more aspects simultaneously, which leads to our fourth design requirement.

- Requirement 4: Provide visualisations to highlight constructive alignments and non-alignments across all aspects of a course design.

Table 2. Derived from Butcher, Davies, and Highton (2006)

		Learning outcomes				
Assessments	Assignment 1	**A**	**B**	**C**	**D**	**E**
	Assignment 2	x		x	x	
	Assignment 3		x			x
	Examination					x

METHOD

EdVee was developed using an abductive design process in response to the design requirements identified in the design requirements section and as part of a research through design process (Frayling 1993), where the act of designing identifies both a need and establishes a solution. It builds on the authors' experiences in two areas: the development of blended and in-person higher education student learning activities and industrial product development processes (McKay et al. 2021). In this paper (see next section) we introduce the design of EdVee and a template for its application that was used in its evaluation. EdVee was applied in the early stages of the course design processes to support course design workshop activities and as a representation tool. In each case, EdVee was introduced as an experimental method to investigate the underpinning of constructive alignment. Details of workshops used, participant selection, and post-workshop interviews are provided in the following section.

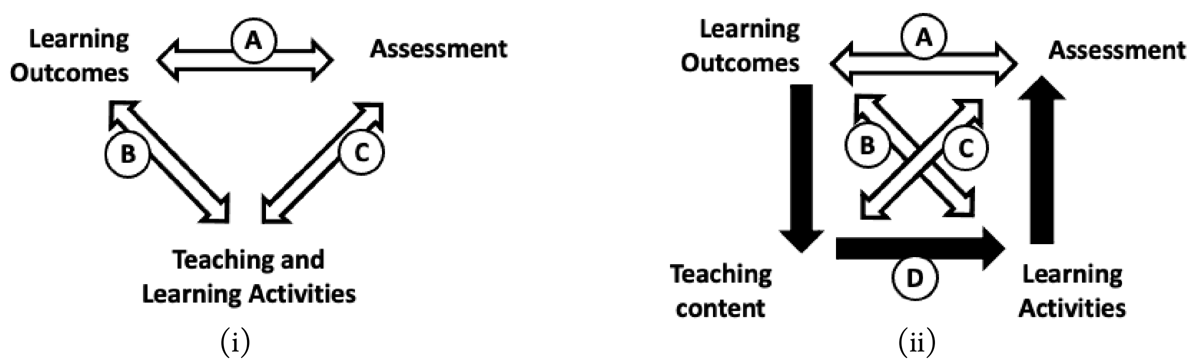
EDVEE: A COURSE DESIGN AND DIAGNOSTIC TOOL FOR CONSTRUCTIVE ALIGNMENT

The goal of EdVee is to support the visualisation of constructive alignments and non-alignments within course designs. In this section we highlight EdVee's distinguishing features: an extended version of Biggs' and Tang's constructive alignment triad on which it is built and the use of concepts from systems engineering. This combination enables the visualisation of relationships between the four elements of the extended triad. We conclude this section by introducing a template that facilitates the use of EdVee by practitioners.

EdVee and constructive alignment

The architecture of EdVee is underpinned by an extended version of Biggs' and Tang's constructive alignment triad. A diagrammatic representation of this triad is provided in Figure 8 (i) beside an illustration of the adapted architecture of EdVee (ii). In summary, the relationship (A) between learning outcomes and assessment is preserved, but Biggs' and Tang's grouping of teaching and learning activities is separated into teaching content (on the left-hand side) and learning activities (on the right-hand side). This separation between teaching content and learning activities means that firstly, the relationships in the original model labelled (B) and (C) are elaborated with direct relationships from learning outcomes to learning activities (B) and teaching content (C); and secondly, a new relationship (D), between teaching content and learning activities, becomes explicit.

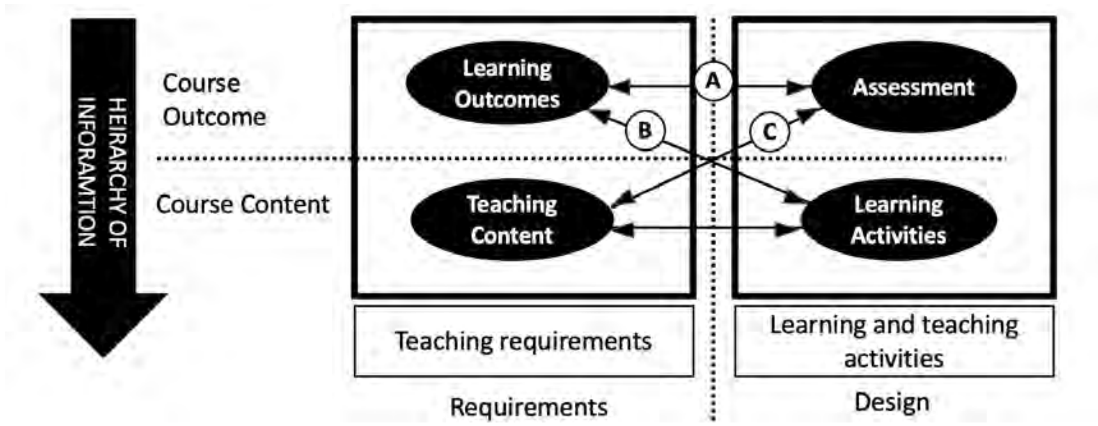
Figure 8. (i) Biggs' and Tang's constructive alignment triad; (ii) how EdVee maps onto Biggs' and Tang's triad



In this extended model the term "teaching and learning activities" has been deliberately split and replaced with, "teaching content" to represent the taught content or syllabus on the teaching side of EdVee, and "learning activities" to represent teaching and learning activities on the other. The rationale for this separation is to support a teacher-as-designer mindset which emphasises learning as the design outcome, and so the goal, of course design. Thus, there is a mindset shift from designing "activities the teacher does," to, "activities which support learning." This view is supported by literature (e.g., Biggs and Tang 2011; Race 2014) and is proposed as a positive mindset shift from a pedagogical viewpoint, particularly to novice course designers or those with limited experience of course design.

Figure 9 shows the arrangement of learning outcomes, assessment, content, and learning activities in EdVee. The diagram is overlaid with a dotted 2x2 grid to highlight the hierarchy of the vertical axis, course outcomes and course content, and the horizontal axis, teaching requirements, and design-for-learning.

Figure 9. Core architecture of EdVee

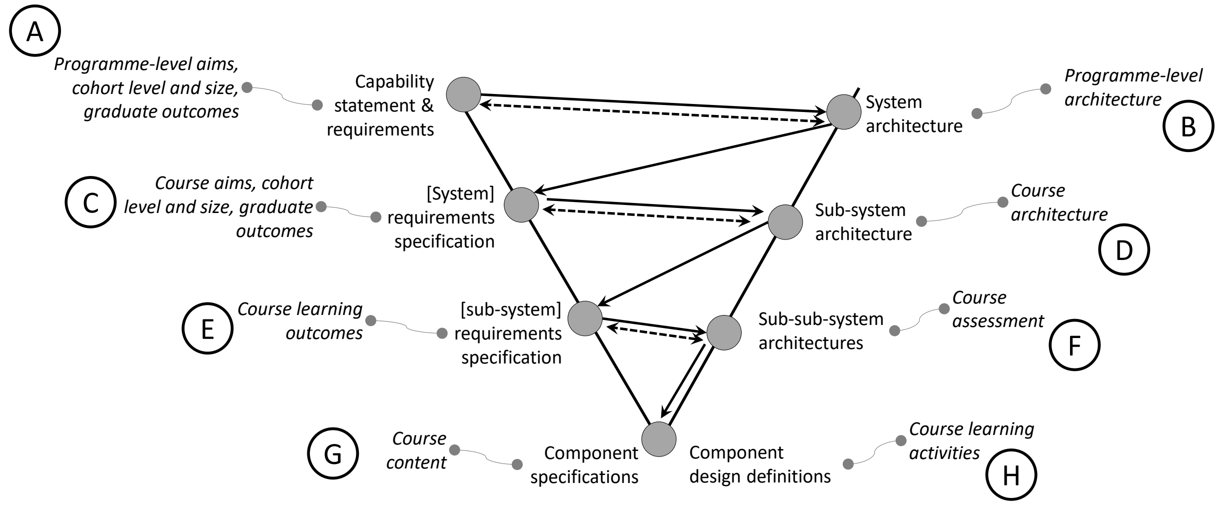


Users of EdVee are encouraged to think of "learning outcomes" and "teaching content," on the left-hand side, as being design requirements which are "translated" into "learning activities" and "assessment," on the right-hand side, that enable and evaluate learning. This translation process is particularly important when designing-for-learning in an online context where learners' and teachers' activities are not necessarily synchronised and, as a result, the teacher typically has fewer opportunities to intervene in students' learning activities. For this reason, teaching activities in EdVee are included within the term "learning activities," which includes teacher-led learning support activities (such as the delivery or production of videos, seminars, and lectures) and student-led learning activities (such as watching videos, private study, and reading).

EdVee and the systems design vee model

Elliott and Deasley's (2007) systems engineering vee model is used in complex design and engineering projects to highlight the interconnectedness between system-level design requirements, overall solution concepts, and, for a given concept, requirements allocated to particular subsystems. McKay et al.'s (2018) system design vee model is an elaboration of Elliott and Deasley's model that separates design from product realisation, resulting in a framework where design requirements sit on the left-hand side of the vee and design solutions sit on the right-hand side. This model and the way in which it was used to inform the design of EdVee is illustrated in Figure 9.

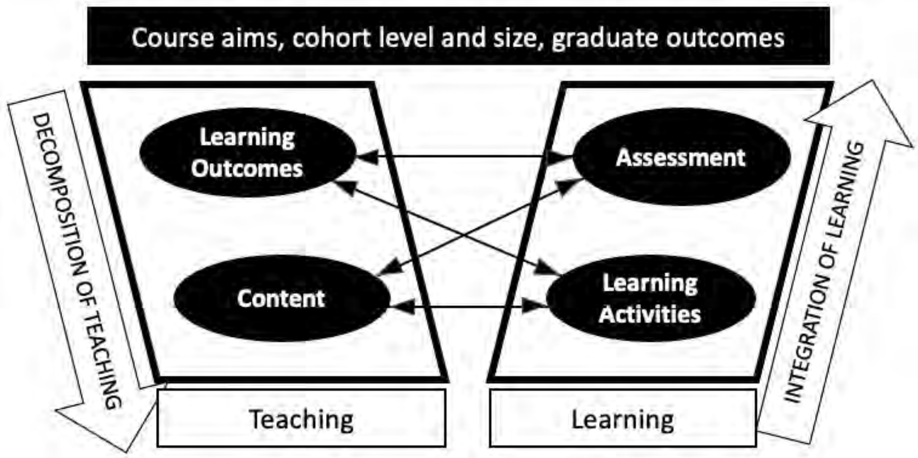
Figure 10. Systems design vee and its application to course design. Adapted from McKay et al. (2018)



EdVee exploits three features of systems engineering: systems perspective, zigzagging process, and verification of solutions against requirements. By taking a systems perspective, courses are treated as parts of wider systems, such as educational programmes with their own goals (see A in Figure 10), and course design activities are conducted in this wider context. The systems engineering zig-zagging process, shown in Figure 10 by solid arrows between the two sides of the vee, is used to design solutions (B, D, F, and H) in response to design requirements (e.g., A, C, E, and G). As a result, EdVee relates course requirements to system (e.g., programme) requirements via system solutions. By making these dependencies between requirements, e.g., at a course level, and design decisions at higher (e.g., programme) levels visible, opportunities for divergent design thinking (at both system and subsystem levels) are created. Finally, the dashed lines in Figure 10 show the verification of solutions against requirements. This is used in EdVee to support the verification of learning and teaching activities against teaching requirements.

Figure 11 integrates the architectural elements of EdVee (shown in Figure 9) with the lower two levels of the systems design vee in Figure 10. The upper two levels in Figure 10 are shown at the top of Figure 11 as "course aims, level and size of cohort, and graduate outcomes." These higher level requirements are influenced by external factors (e.g., discipline/accreditation bodies), and during course design processes, learning outcomes, and assessments are designed in response to them. Content and learning activities are then designed to allow students to meet the learning outcomes and succeed in the assessments. On the left-hand side of Figure 11, "learning outcomes" are decomposed into taught content. On the right-hand side, "learning activities" are designed to deliver the taught content through learning experiences to meet the higher-level course requirements of "assessment" on the right hand side whilst also being related to the high level learning outcomes on the left hand side. Moving up the right-hand side is the "integration of learning" in the form of learning activities, resulting in assessment of capability and knowledge.

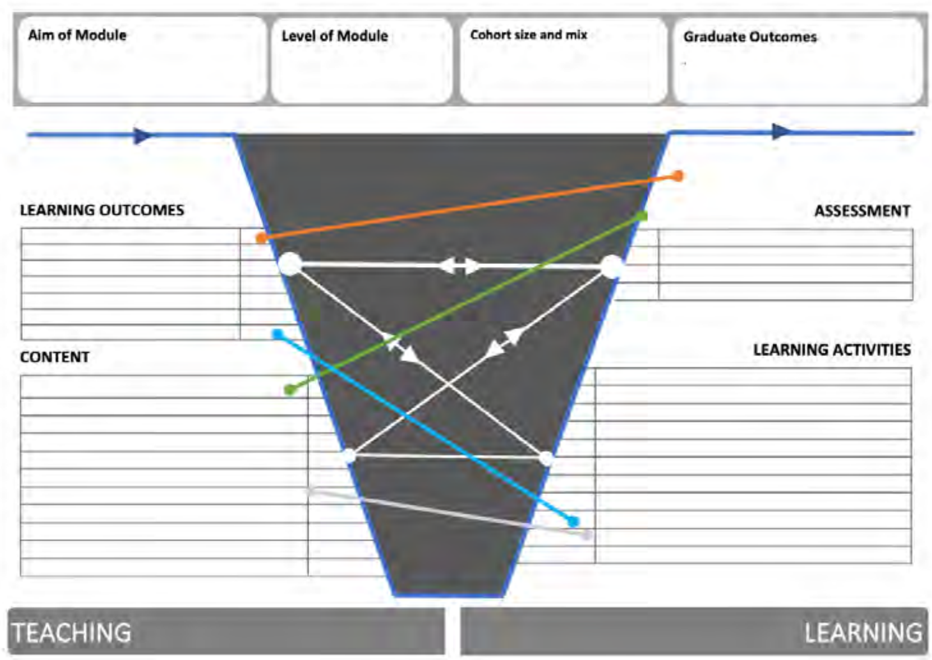
Figure 11. Key elements of the EdVee architecture



The EdVee template

The EdVee template[3], designed to support course design activities, and shown in Figure 12, provides sections for text to be added: learning outcomes, content, assessment, and learning activities. The white lines with arrows illustrate the zig-zagging between sections and provide a visual guide on how different parts of EdVee relate to each other. The coloured lines can be duplicated and re-positioned to represent relationships between elements within a course design. Throughout this paper we have used the word "course" to describe a unit of learning which makes up part of a degree programme. In the UK, it is common to use the word "module" to describe a unit of learning as the word "course" typically refers to whole programmes of study. The EdVee template uses the word "module" because it was developed in the UK.

Figure 12. Blank EdVee template



Using the EdVee template to support course design activities involves a three-step process.

1) Define the overall aims and graduate outcomes, and also practical aspects, such as the cohort size and level. It is assumed that key information such as this is known prior to using EdVee, because they form the design requirements and constraints for any course design process.
2) Add all known information related to the course design, e.g., this could include learning outcomes and content (topics/syllabus) requirements on the left-hand side and the intended assessment and kinds of learning activities on the right-hand side. It should be noted, however, that such information may change or be added as a natural part of the course design process. For example, EdVee can lead the design team to question the alignment and content of these elements and, if necessary, further develop them.
3) Duplicate and align the coloured lines to represent connections between different aspects of the EdVee model. These lines form a "mesh" that allows course designers to visualise the overall coherence of the proposed design. (See Figure 13 for an example.)

The mesh represents dependencies between elements of a course design, making explicit and visible alignments and misalignments between these elements. In this way, the following questions can be addressed.

a) Learning outcomes and assessment: Are all learning outcomes assessed?
b) Assessment and content: Does the content cover the requirements of all assessments?
c) Learning outcomes and learning activities: Are the learning activities appropriate for the intended learning outcomes?
d) Content and learning activities: Do the learning activities enable the delivery of all content?

Given a completed template, it can then be used to support iterative course design processes, such as those highlighted earlier. This is explored via two case studies in the next section.

CASE STUDIES: APPLICATIONS OF EDVEE FOR COURSE DESIGN AND EVALUATION

To illustrate the value of EdVee, two case studies are presented. The first shows how EdVee can be used in the design of a new course and the second in the evaluation of an existing course. In both cases, EdVee was introduced as an experimental method to visualise, and so to facilitate the investigation of, constructive alignment within them.

EdVee as a course design tool (case 1)

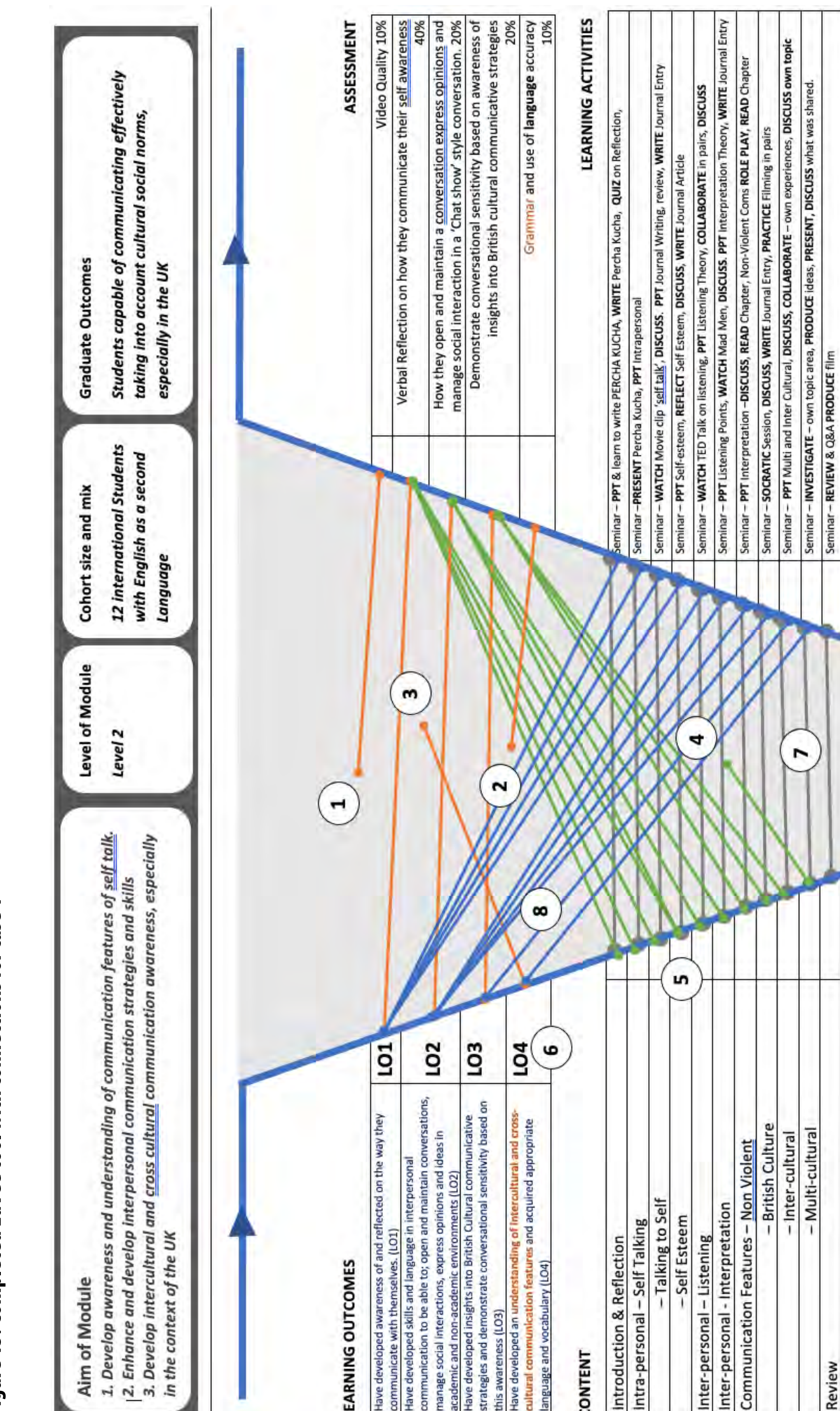
This case involved the design of a new face-to-face course. EdVee was used to support a design workshop involving two participants: the course leader (an individual academic) and the first author of this paper. Initial design requirements were in the form of a course proposal document that included learning outcomes and a handwritten list of required content to be taught and draft learning activities. A few days before the EdVee workshop, the participants co-created an outline schedule of learning activities using post-it notes on a flip chart. The outcome of the session was used by the first author to populate the blank EdVee template.

In the workshop, the participants developed the initial template to produce the course description shown in Figure 13. The important aspects to note in this is the positioning of the connecting lines. These lines indicate constructive alignment in this early-stage design. The following labelled regions are of particular relevance to this paper.

- At 1 and 2: lines with floating ends indicate that some assessment is not related to any learning outcome (1) or content (1 and 2). For example, at (1), the assessment of video quality is not related to any specific learning outcomes. Correcting this could involve revision of the assessment criteria and/or the learning outcomes.
- The floating end at (3) linked to learning outcome at (6) indicates that L04 does have a learning activity associated with content, but as indicated by the floating end at (4) is not assessed.
- The convergence of multiple lines at (5) indicates that content is being assessed twice. This may be acceptable or not.
- At (7) the horizontal lines indicate that all content/topics have learning activities associated with them.
- As seen at (8) LO1 and LO2 have several learning activities associated with them, whereas LO3 and LO4 only have one learning activity for each.

It may be that the designer intends to not fully align some content; for example, it may not be a requirement for every taught element to be assessed, however the mesh represents the designed alignment, intended or otherwise. EdVee was particularly useful in highlighting aspects of the course design which were not aligned. A detailed discussion was generated based on the EdVee diagram, particularly around the justification of content in relation to learning outcomes and also around the value and nature of some learning activities. The course designer also questioned whether selected assessment types were fully aligned with learning outcomes. As a result, some content and activities were removed and some activities were added to support the chosen assessment formats. The most significant change was that one learning outcome was re-evaluated and later considered to be outside of the course scope, allowing more time to support other aspects of the course. The course leader commented, "Without being too dramatic - I think the workshops with you and the design model were absolutely invaluable and fascinating to see the thought processes on paper and where tweaking was needed."

Figure 13. Completed EdVee tool with connections for case 1



EdVee as a course evaluation tool (case 2)

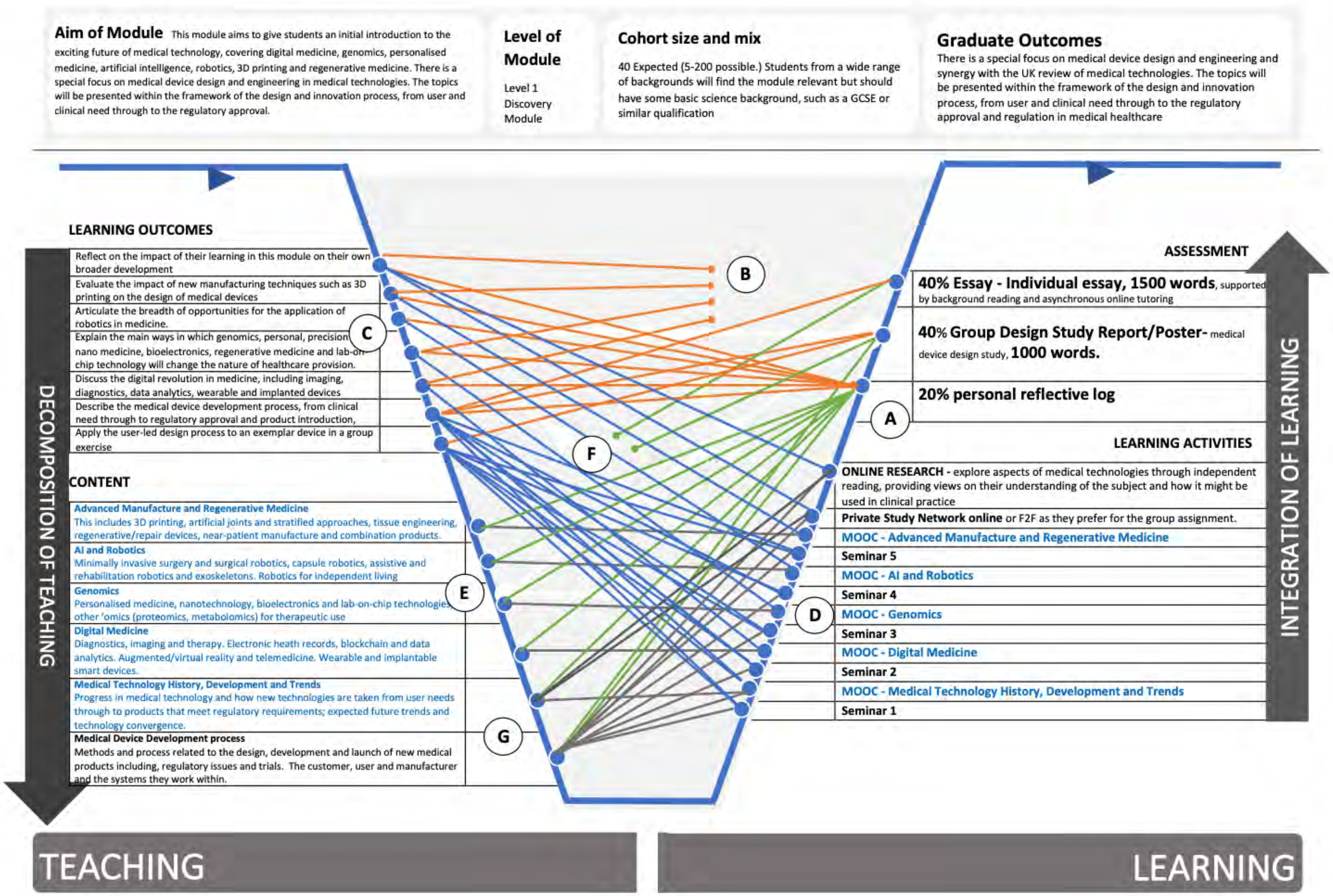
The second course design team included five academic content leads, a course leader, a course manager, two course design managers, and two writers developing a blended learning course. EdVee was incorporated in roundtable discussions with the course leader, the course manager, and one of the academic leads to evaluate the outline of the course. Course learning outcomes and assessment needed to be shared, but ownership and creation of online content and learning activities was distributed. This added complexity to the design process and a requirement to collaborate. The initial course proposal form included learning outcomes from each of the academic leads with two overarching learning outcomes for reflection and application. An outline course delivery map in a word document indicated the sequence of content. Course delivery was supported by weekly face-to-face seminars running in parallel to online materials. Three assessments were proposed: an individual essay, a group project report, and a reflective log. Scripts and learning activities were still to be developed.

A completed EdVee template (see Figure 14) was populated using known information from the course proposal form and outline course map. The following issues could be seen on the completed EdVee.

- Individual learning outcomes mapped perfectly between three of the sections: learning outcomes (C)—learning activities (D)—content (E).
- Many of the learning outcomes and content were linked to one assessment (the reflective log) which was worth only 20% of the course mark (A).
- Four of the learning outcomes (B) did not link directly to the two main assessments.
- The two main assessments did not link clearly to content (F) and, because of this, it was not possible to see a direct link between these assessments and corresponding learning activities on the map.
- Many learning activities were connected with one aspect of content (G).

The completed EdVee template was used to generate discussion around constructive alignment. One of the issues discussed was the varied nature of the learning outcomes and how they could possibly be included within each assessment. There was also discussion around how assessment criteria could be written for such a broad range of individual and content specific learning outcomes. The discussion extended to how assessments could be more explicitly linked to content and directly supported by learning activities. It also highlighted the value of the seminars, which were still being written, to support the connection between learning outcomes and assessment.

Figure 14. Case study two. EdVee with a complex team—first iteration



These useful pedagogical discussions were directly prompted by reading the EdVee diagram as a team. As a result of using EdVee, the team decided to rewrite four learning outcomes to better support the overall intentions of the course aims and graduate outcomes, rather than individual elements of content.

For example:

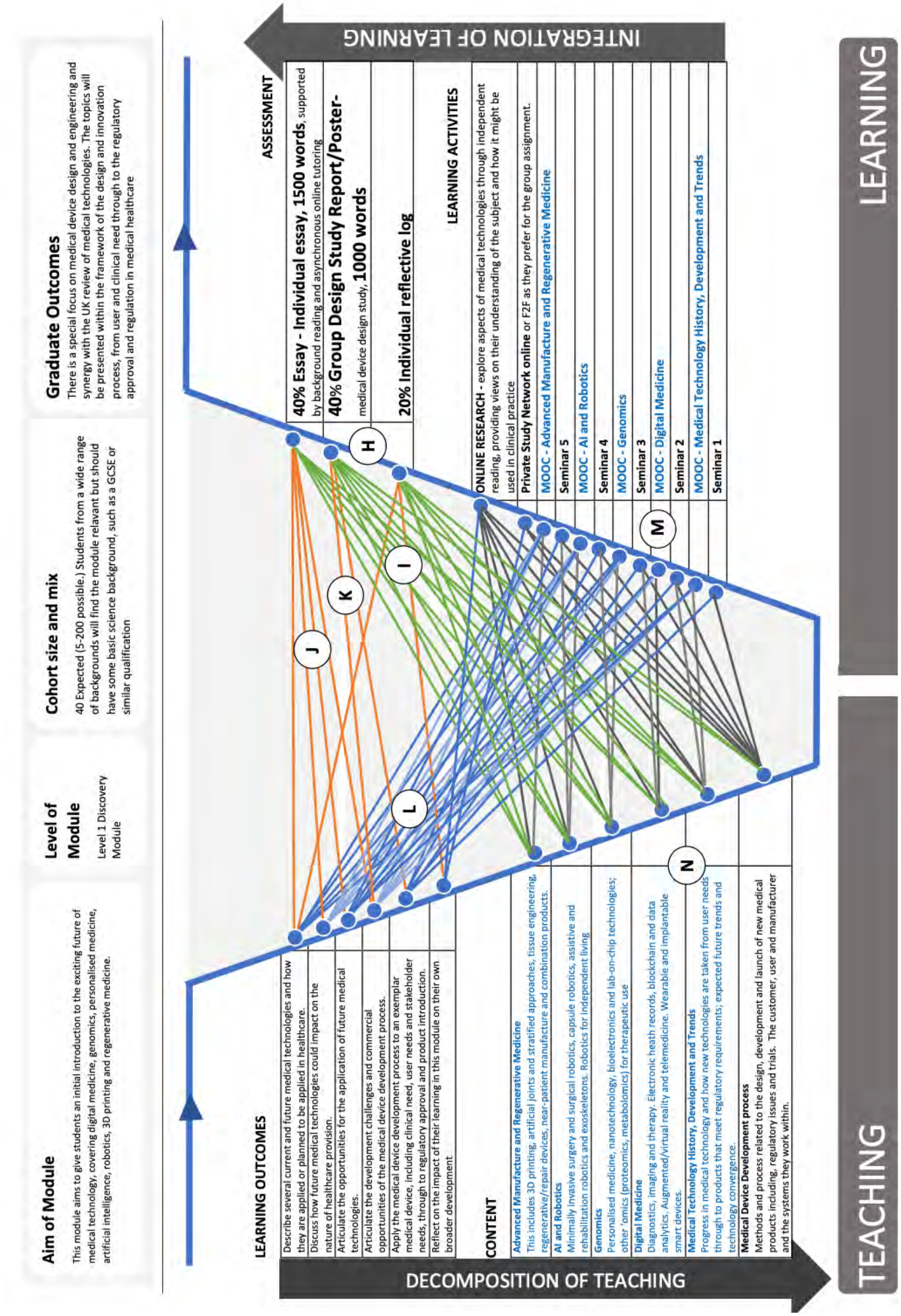
- Explain the main ways in which genomics, personal, precision, and nano medicine, bioelectronics, regenerative medicine, and lab-on-chip technology will change the nature of healthcare provision.
  changed to,
- Discuss how future medical technologies could impact the nature of healthcare provision.

This was a significant change which required institutional Quality Assurance approval. A second iteration of the EdVee template (Figure 15) was created and populated with the new learning outcomes. Key changes made were as follows.

- At (J) and (K) the new learning outcomes are linked to the two main assessments (H) which are connected through content (N) to activities (M) which relate back to learning outcomes at (L).
- At (I) specific learning outcomes are connected to the reflective log.
- At (I) and (L) the clustering of links indicates a spread of connections across learning outcomes, content areas, learning activities, and assessment.
- At (M) there are links between the seminars and sections of the course content.

The introduction of EdVee had a limited impact on the overall structure of the course design which remained unchanged. However, the creation of the new learning outcomes significantly influenced the downstream focus of the online content created by the academics, writers, and video producers. The course leader said, "The course design process and those workshops we had helped a lot in shaping and bringing content together. I used the V diagrams as a cross-check to make sure we had the right things included."

Figure 15: Case study two. EdVee with a complex team—second iteration



DISCUSSION

In this section we evaluate EdVee against five design requirements defined in the design requirements section by using experiences from the case studies reported above.

Requirement 1: Provide a design prototyping capability to facilitate the sharing and evaluation of design ideas

Schrage (1999) recognises the value of prototypes for early testing and the sharing of ideas in collaborative design processes, and Beetham and Sharpe (2019) identify six key branches of scholarship related to design-for-learning in a digital world. Two of these branches can be realised through the building of prototypes: the need (a) to be able to make representations of learning designs (for evaluation, sharing, and re-purposing) and (b) for visual design tools (to support design decision-making, for example, in design workshops). The EdVee template was used in both case studies to create visual representations of course designs (see Figures 13–14). These representations can be regarded as low fidelity prototypes that accommodate the four aspects of the EdVee model and alignments (or not) between them. The prototypes were used to inform discussions and decision-making in early-stage design workshops and their value is highlighted through the feedback provided by the course leaders in the case studies. Thus, through its underpinning structure and template, EdVee provides a prototyping capability for course design. Further, the visual nature of these prototypes facilitates sharing, and so discussion and evaluation, of design ideas. Such discussions, generated through the use of EdVee, are important because, like other forms of prototype, they encourage divergent thinking as part of the course design process.

Requirement 2: Support design iteration and the evaluation of design solutions against design requirements

Given their embedded structure, EdVee prototypes can be seen as a form of structured sketch. Ferguson (1992) highlights how visuals or “talking sketches” can be used for sharing ideas and Schon and Wiggins (1992) emphasise the value of sketches in enabling the see-move-see cycles of design iterations to support “design moves.” The prototypes presented above supported the evaluation of the designs by highlighting misalignments between learning outcomes, assessment, content, and learning activities. Further, as outlined in the EdVee course design section, two iterations of the second case are reported where the first prototype informed design decisions for the next and subsequent iterations. In this way, we have illustrated how EdVee supports both design evaluation, with respect to both course requirements (i.e., learning outcomes and curricular content), and pedagogical requirements for coherence between these two requirements and assessment and learning activities. One of the key benefits to students is how the tool clarifies the intentional alignment of learning outcomes to learning activities to content to assessment. This explicit link could be highlighted to the students, perhaps even using the tool, to explain the intended design of the course, how the learning activities the students engage in supports content, and how it relates to assessment. Another benefit to students is the potential of the tool to highlight to staff potential misalignments, which may create distracting and unnecessary content, thus focusing student workload on the learning outcomes.

Requirement 3: Accommodate the complexities of course design by integrating current models of curriculum design with course design processes

EdVee accommodates two sources of complexity in course design: those in the course design process and those in the result of this process, i.e., the course definition. The process of populating the EdVee template starts with course aims and associated educational purposes and then focuses on their realisation through the design of a coherent course. This aligns with widely used curriculum design models (e.g., from authors such as Bobbit 1918, and Tyler [1949] 2013) and more recent course design process models (e.g., Moon 2003, and Backwards Design from Wiggins and McTighe 2005). With respect to the course definition itself, there is much literature on the pedagogy of individual learning activities and assessments. One of the complexities for course designers is thinking about the different layers of a learning design, as shown in Figure 7. The focus of EdVee lies in the lower and middle layers. In particular, the learning outcomes and content sitting in the base layer provide requirements for the design of course platforms (middle layer). The design of a course platform includes the assessments and learning activities, which are influenced by both the bottom layer and the choice of platform. For example, the same learning outcomes and content may be delivered in different ways for face-to-face, blended, and distance learning platforms. With respect to the top layer in Figure 7, EdVee does not include the design of learner journeys, but EdVee's separation of content and learning activities provides milestones (in the form of activities) for learners.

Requirement 4: Provide visualisations to highlight constructive alignments and non-alignments

These are inherent features of EdVee. The EdVee model supports the decomposition of courses into different types and, by using visual mapping methods, the EdVee template provides a way of building a graphical representation of the conceptual design of a course. Once populated, EdVee models visualise the constructive alignment (Biggs and Tang 2011) and non-alignment of a design (see Figures 13–15). The cases reported in this paper provide examples of applications of EdVee to the design of courses but from ongoing work, we are confident that EdVee can be applied at other levels of granularity, e.g., programmes composed of multiple courses and parts of courses, such as individual assessments and learning activities.

CONCLUSIONS

For any new course, the activities for a teacher-as-designer are multi-faceted, requiring skill to design each of the many different elements of a course. For example, the consideration and formulation of graduate outcomes, learning outcomes, teaching content, the design of teaching and learning activities, and assessment. Tools which improve the effectiveness and efficiency of a course design offer obvious benefits to both tutors and students. The EdVee model does not design teaching strategies, learning experiences, or learning activities, this is the skill of the "teacher-as-designer." However, by bringing product and engineering design principles and systems thinking to course design, EdVee provides a systematic means of visualising, sharing, and communicating course designs. This, in turn, provides a mechanism for making course design a more collaborative, team-based activity through design tools that support effective communication and sharing of design ideas.

The visual nature of EdVee supports the sharing of the design with colleagues within a design team at an early conceptual stage. Although sharing ideas can be beneficial for designers with different levels of experience, obtaining input from colleagues is something that is particularly beneficial for novice course designers. EdVee visualisations can act as tools for seeking feedback from more experienced designers early in the design process, which could save time and effort before time is spent developing teaching materials, learning activities, or assessment in more detail. By enabling the visualisation of such relationships, design teams can see where constructive alignment is under- or over-achieved and insights gained can inform iterative design cycles. In this way, EdVee can be used to evaluate concepts in initial design sprints and in the creation and mock-up of early course design prototypes. As more stakeholders become involved in course design, development, and delivery (e.g., through the adoption of digital learning platforms and tools), the need for course design methods and tools such as EdVee will increase.

As with any design process, course design can be seen as a socio-technical process (Clegg 2000) and a key challenge lies in mediating social and technical dimensions. EdVee addresses two of Clegg's socio-technical design process principles: System components should be congruent, and systems should be simple in design and make problems visible. Further work is needed to consider how design thinking and design activities manifest themselves in this collaborative socio-technical design process. In particular, EdVee provides a systematic approach but further work is needed to understand the social dimensions of course design processes such as team cultures, human aspects such as capabilities and attitudes, and organisational factors such as the role of social networks in effective collaboration in course design. On this basis, significant process improvements will become feasible and opportunities created to embed into course design processes features of high performing design teams such as the avoidance of design fixation, maximising the creativity of all team members, creating more opportunities for design ideation, and enabling the exploration of wider design innovation spaces.

ACKNOWLEDGMENTS

Leeds Institute of Teaching Excellence funded the project as part of an Innovation and Excellence Fellowship without which, the time to develop and pilot EdVee would not have been available. Course team members supported the experimental approach with their time and intellect and kindly offered feedback. Feedback from reviewers has been instrumental in its development.

DECLARATION OF INTERESTS

The authors reported no conflicts of interest.

AUTHOR BIOGRAPHIES

Dan Trowsdale is an experienced product designer and design educator. His research focuses on how visual, play, and design thinking techniques can support the collaboration of design teams during the process of course design.

Alison McKay is a mechanical engineer and design educator. Her research brings socio-technical systems perspectives to the design of engineering information systems, design descriptions, and supply chain innovation.

NOTES

1. For example, the University of Leeds Blended Learning Strategy at https://ses.leeds.ac.uk/info/22149/a-z_of_policies_and_key_documents/634/blended_learning_strategy [Accessed on November 4, 2021].

2. For example, in the UK, the Office for Students and, in this context, the Quality Assurance Agency for Higher Education (http://www.qaa.ac.uk/) [Accessed on November 4, 2021].
3. A Word version is available from https://dantrowsdale.co.uk/resources/ [Accessed December 18, 2021].

ETHICS

1. This research was covered by the university's ethical approval committee.

REFERENCES

Armellini, Alejandro, Gilly Salmon, and David Hawkridge. 2009. "The Carpe Diem Journey: Designing for Learning Transformation." 135–48. York, UK: Higher Education Academy.

Beetham, Helen, and Rhona Sharpe, eds. 2019. *Rethinking Pedagogy for a Digital Age: Principles and Practices of Design*. New York: Routledge.

Bennett, Sue, Shirley Agostinho, and Lori Lockyer. 2017. "The Process of Designing for Learning: Understanding University Teachers' Design Work." *Educational Technology Research and Development* 65 (1): 125–45.

Biggs, John, and Catherine Tang. 2011. *Teaching for Quality Learning at University*. McGraw-Hill Education: UK.

Blanchard, Benjamin S., and Wolter J. Fabrycky. 1990. *Systems Engineering and Analysis*. Vol. 4. Englewood Cliffs, NJ: Prentice Hall.

Bobbitt, Franklin. 1918. *The Curriculum*. Boston: Houghton Mifflin.

Brady, Laurie. 1990. *Curriculum Development*. Pennsylvania State University: Prentice Hall.

Butcher, Christopher, Clara Davies, and Melissa Highton. 2006. *Designing Learning: From Module Outline to Effective Teaching*. New York: Routledge.

Cagan, Jonathan M., and Craig M. Vogel. 2002. *Creating Breakthrough Products: Innovation from Product Planning to Program Approval*. Ft Press.

Carvalho, Lucila, Roberto Martinez-Maldonado, and Peter Goodyear. 2019. "Instrumental Genesis in the Design Studio." *International Journal of Computer-Supported Collaborative Learning* 14 (1): 77–107.

Clegg, Chris W. 2000. "Sociotechnical Principles for System Design." *Applied Ergonomics* 31 (5): 463–77.

Conole, Gráinne. 2019. "Frameworks to Guide Practice." In *Rethinking Pedagogy for a Digital Age*, 164–78. New York: Routledge.

Conole, Gráinne, and Karen Fill. 2005. "A Learning Design Toolkit to Create Pedagogically Effective Learning Activities." *Journal of Interactive Media in Education* 1.

Dalziel, James. 2015. "Reflections on the Art and Science of Learning Design and the Larnaca Declaration." In *The Art and Science of Learning Design*, 3–14. Rotterdam: SensePublishers.

Design Council. 2019. "The Double Diamond: A Universally Accepted Depiction of the Design Process." Accessed November 21, 2022. https://www.designcouncil.org.uk/our-work/news-opinion/double-diamond-universally-accepted-depiction-design-process/.

Elliott, Chris, and Peter Deasley. 2007. "Creating Systems that Work: Principles of Engineering Systems for the 21st Century." *Royal Academy of Engineering* 293074.

Farmer, Robert James, and Julie Usher. 2018. "Why CAIeRO? Perceptions and Impact of Ten Years of CAIeRO at the University of Northampton."

Farrell, Robert, and Cliff Hooker. 2013. "Design, Science and Wicked Problems." *Design Studies* 34 (6): 681–705.

Ferguson, Eugene S. 1992. "The Nature of Engineering Design. Engineering and the Mind's Eye." Cambridge: MIT Press.

Frayling, Christopher. 1993. "Research in Art and Design." *Royal College of Art Research Papers* 1: 1–5.

Giard, Jacques. 2005. *Design FAQs*. Dorset Group.

Goodyear, Peter. 2015. "Teaching as Design." *Herdsa Review of Higher Education* 2 (2): 27–50.

Goodyear, Peter, and Lucila Carvalho. 2019. "The Analysis of Complex Learning Environments." In *Rethinking Pedagogy for a Digital Age*, 49–65. New York: Routledge.

Grundy, Shirley. 1987. "Curriculum: Product or Praxis?" London: Routledge.

IDEO. 2020. "What is Design Thinking?" Accessed July 10, 2020. https://www.ideou.com/blogs/inspiration/what-is-design-thinking.

Laurillard, Diana. 2013. *Teaching as a Design Science: Building Pedagogical Patterns for Learning and Technology*. New York: Routledge.

Masterman, Liz. 2019. "The Challenge of Teachers' Design Practice." In *Rethinking Pedagogy for a Digital Age*, 120–33. New York: Routledge.

Matthews, Adam. 2019. "Design as a Discipline for Postdigital Learning and Teaching: Bricolage and Actor-network Theory." *Postdigital Science and Education* 1 (2): 413–26.

McKay, Alison, Richard Baker, Richard Chittenden, and Alan de Pennington. 2018. "A Framework for Students to Visualise the Implications of Design Decisions in Global Supply Networks." In *International Conference on Engineering and Product Design Education,* Dyson School of Design Engineering: Imperial College, London, UK.

McKay, Alison., Dan B. Trowsdale, Simon A. Carrie, Gerard Duff, and Celia E. Goodburn. 2021. "A Systems Approach for Blended Learning Design". In Industry Practices, Processes and Techniques Adopted in Education, edited by Kathryn MacCallum and David Parsons, 70-100, Singapore: Springer.

Molenda, Michael. 2015. "In Search of the Elusive ADDIE Model." *Performance Improvement* 54, (2): 40–42.

Moon, Jennifer. 2003. *The Module and Programme Development Handbook: A Practical Guide to Linking Levels, Outcomes and Assessment Criteria*. London: Routledge.

Nicholls, Audrey, and Howard Nicholls. (1978) 2018. *Developing a Curriculum: A Practical Guide*. London: Routledge.

Newell, Catherine, and Alan Bain. 2020. "Academics' Perceptions of Collaboration in Higher Education Course Design." *Higher Education Research & Development* 39 (4): 748–63.

Pahl, Gerhard, and Wolfgang Beitz. 2013. *Engineering Design: A Systematic Approach*. London: Springer Science & Business Media.

Penin, Lara. 2018. *An Introduction to Service Design: Designing the Invisible*. London: Bloomsbury Publishing.

Print, Murray. 1993. "Curriculum Development and Design." London: Routledge.

Pugh, Stuart. 1991. *Total Design: Integrated Methods for Successful Product Engineering*. Wokingham, England: Addison-Wesley.

Race, Phil. 2014. *Making Learning Happen: A Guide for Post-compulsory Education*. London: Sage.

Ramsden, Paul. 2003. *Learning to Teach in Higher Education*. London: Routledge.

Schrage, Michael. 1999. *Serious Play: How the World's Best Companies Simulate to Innovate*. Harvard Business Press.

Schön, Donald A. and Glenn Wiggins. 1992. "Kinds of Seeing and their Functions in designing." *Design Studies* 13, (2): 135–56.

Seeto, Deidre, and Panos Vlachopoulos. 2015. "Design Develop Implement (DDI)—A Team-based Approach to Learning Design." In *THETA 2015 Conference, Gold Coast, Australia*.

Skilbeck, Malcolm. 1990. *School Based Curriculum Development*. Sage.

Sommerville, Ian. 2011. "Software Engineering 9th Edition." Boston: Addison-Wesley.

Stenhouse, Lawrence. 2014. "Defining the Curriculum Problem." In *Curriculum and the Teacher,* 25–28. London: Routledge.

Taba, Hilda. 1962. "Curriculum Development: Theory and Practice." Harcourt Publishers Group.

Tyler, Ralph W. (1949) 2013. "Basic Principles of Curriculum and Instruction." In *Curriculum Studies Reader E2*, 60–68. Routledge.

Ulrich, Karl T., and Steven D. Eppinger. 2004. "Product Architecture." *Product Design and Development* 3: 163–86.

Walker, James C. 1992. "A Philosophy of Leadership in Curriculum Development: A Pragmatic and Holistic Approach." *Educative Leadership*: 47.

Wheeler, Daryl K. 1974. "Curriculum Concepts and Conceptual Clarity." *Journal of Curriculum Studies* 6, (2): 112–19.

Wisdom, James. 2001. "Programme Specifications—What's the Outcome." *Educational Developments* 2: 1–3.

Wiggins, Grant, P., and Jay McTighe. 2005. *Understanding by Design*. ASCD.

Wraga, William G. 2017. "Understanding the Tyler Rationale: Basic Principles of Curriculum and Instruction in Historical Context." *Espacio, Tiempo y Educación* 4 (2): 227–52.

Zundans-Fraser, Lucia. 2014. "Self-organisation in Course Design: A Collaborative, Theory-based Approach to Course Development in Inclusive Education." PhD diss., Charles Sturt University, Bathurst.