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An Engineering Course as a Design Object

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Abstract

Developing a course is a substantive design activity. Within a complex and dynamic context and user base, educators must scope ambiguous problems and develop detailed solutions that are often novel and iterated upon over time. While much attention has been given to course design as a process, less attention has been paid to what a course is as a design object. When instructors adopt a course design model, either explicitly or implicitly, they are often accepting implicit premises of what a course is and what components comprise it, which can carry advantages and disadvantages relative to the instructors' goals, students' needs, and departmental/college-wide priorities. This paper uses a multiple perspective approach to explore the nature of an engineering course as a design object. We engage three models, each representing a design tradition common within the field of engineering education. For each model, we discuss its associated design process, implicit or explicit assumptions about design objects that emerge from this process, and how the model might translate to the specific context of engineering course design. We selected three models (engineering design, backward design, and design thinking) to provide distinct, illustrative, and generative perspectives that would also be applicable to many engineering educators. After applying each of these models to courses as design objects, we compare models and explicate the implications they may hold for course design. These implications are organized around three themes: (1) bounds of the problem and solution spaces, (2) role of users and designers and (3) course evolution over time. We close with a series of reflective questions educators might use when considering models for course design.

Keywords: course design, design object, design thinking, engineering design, backward design

Introduction

Designing courses is a nontrivial task [1,2] and an abundance of approaches, models, and methods have been developed to guide the design of courses [3–5]. In creating a course, educators face several considerations regarding the scope of learning outcomes; the kinds of activities, content, or projects learners may engage in; the nature of interactions between instructors and students and among students themselves; the structure or flexibility of the experience; and many more [2,5]. As such, the potential design space is large and complex. Comparing the tradeoffs between alternatives may result in several conflicting dimensions. Engineers also deal with the creation of complex design objects or artifacts that could be developed through a variety of models, methods, or approaches [6], some of which may prove useful for designing courses. To better understand the challenges of designing courses in engineering education and the affordances and limitations of different models, we propose to view courses as design objects through a multiple perspective approach [7,8]. A multiple perspective approach intentionally selects distinct ways of framing some topic or object to uncover assumptions hidden in different perspectives, create comparisons of strengths and weaknesses across perspectives, open new opportunities for synthesis, and inform more intentional selection of a given perspective for a task [7,8].

We draw on three perspectives for viewing courses as design objects: engineering design, design thinking, and backward design. This is not a comprehensive or exhaustive set of models from engineering and engineering education, as a comprehensive list would contain more perspectives than could be feasibly covered within a single paper. However, following the multiple perspective approach, these perspectives were selected because they are sufficiently distinct to enable comparisons and potentially reveal assumptions [7]. Each perspective has also been used in engineering education to varying degrees, heightening the relevance of any discovered similarities, differences, or assumptions. For engineering design, we draw on Clive Dym's engineering design model [9] as his textbook has a broad reach across capstone courses. For design thinking, we leverage Carlgren, Rauth, and Elmquist's [10] empirical framework, which provides a comprehensive, thematic description that is informed by a variety of practical contexts. Finally, we draw on Backward Design [2] as these models have seen considerable application in engineering education, e.g., the Content, Assessment, and Pedagogy framework [5,11–13], and are taught in some of the engineering education graduate programs in the United States.

The remaining manuscript is structured as follows to facilitate the comparisons between these perspectives and implications for their application. First, we present each model, discuss the components of a design object created by the model, and highlight assumptions the model carries for design objects. Next, we compare the models, their assumptions, and their components. Finally, we explore implications from this comparison for teaching, selecting models to guide instructional design, and learning in the form of reflective questions for instructors.

Model 1: Engineering Design

For the "traditional" engineering design lens, we draw upon the influential engineering design model from Dym (see, [9]). Objects designed through this model are intended to meet several *criteria* within the scope of a set of *constraints*. Object are intended to perform some *functions* within this space, addressing both criteria and constraints. These objects are iteratively designed, from early concept exploration to preliminary modeling and testing to finalized detailed design. Below we apply this lens to courses as design objects, starting with the components it implies for a course, the process involved in course creation, and any assumptions it leads to.

A course will have criteria it needs to meet. These are specified upfront by a client. The primary client for a course will often be a representative or multiple representatives from the university, college, or department for which the course is being designed. For example, the client might be a departmental curriculum committee that views the course as needed to fulfill a specific role in the curriculum of one or more majors. The client could also be the instructor(s) or the students. Criteria will often reflect the goals or outcomes the client(s) hope to achieve through the course. Learning outcomes are clear outcomes for many courses, however there could be other targeted outcomes such as changing student motivation, preparation for future courses, remediation for learning gaps, identity building, or acquainting students with certain ideas or professional fields (e.g., from practicing engineers).

A course will have constraints placed on it. These will need to be identified by the client or the designer(s), i.e., instructor(s), as limits placed on the course. Some constraints may be externally defined or mandated, such as course duration and timing, location, and eligible student population. Other constraints may require more consideration, although may still be subject to external forces, such as what content can and cannot be covered, what content is assumed to already be known by students, and what kinds of assessments or data can be feasibly collected to assess specific learning outcomes.

Finally, a course will need to perform several functions. These are more abstract than criteria or constraints, relating to what a course must do or perform for some group. Such functions may include giving students an opportunity to develop knowledge, skills, perspectives, conceptual understanding, or ability with a variety of tools or methods. Another key function of a course is testing or assessing whether such knowledge, skills, perspectives, conceptual understanding, or abilities, were successfully developed by students. Other possible student-oriented course functions could include providing a place for discussion and reflection, providing real-world or authentic experiences to apply knowledge and skills, or supporting affective growth. Courses may also have instructor-oriented functions, e.g., professional growth.

The process of designing a course through this model begins with a problem being presented by a client. From here, the designer(s) attempt to define the problem, including the key criteria and constraints, and identify core functions. Working with the client, designers eventually move into conceptual design, where they generate alternatives for addressing the problem are. In conceptual design, there may be multiple alternatives that address the criteria, constraints, and functions to varying degrees. None may meet them perfectly, therefore the designer(s) may need to consider tradeoffs between alternatives and decide which course configuration holds more promise than others. From here, the course enters preliminary design, prototyping, and testings, perhaps through a live course (e.g., a pilot run). Detailed design follows, where the design is refined and optimized, leading to a final design artifact.

The resulting course therefore will have been iteratively developed and tested with students. This iterative development could span a single course instance (e.g., one semester offering) or could happen over several semesters of testing and refinement. Nevertheless, the model will ultimately produce a final, well-defined artifact. This raises interesting questions regarding factors that may shift from semester to semester. For example, what happens when a new cohort of students enters who is more or less prepared than previously cohorts; or what happens when external events (e.g., the COVID-19 pandemic) dramatically affects student and teachers time, psychology, and resources? The final designed artifact may not be able to accommodate revisions needed to address these circumstances. Alternatively, depending on the instructor, this model may be applied in more of a "platform design" approach, similar to new vehicle releases, where the design object is updated each year to address contextual or environmental changes (e.g., new education research findings). Ultimately, the final form of a design artifact will be determined by the client, who may presuppose forms that resemble previous courses, leaving limited room for adaptation, innovation, or responsiveness.

Model 2: Backward Design

Unlike the other models, backward design [2] originated as an instructional design approach. A course designed through backward design will have three major components: learning outcomes; assessments; and learning experiences, instruction, or associated activities. These are designed in a predetermined sequential order, intentionally starting with desired learning outcomes, then appropriate sources of evidence to assess achievement of learning outcomes, and finally instruction and learning activities to meet the assessment and learning outcome goals. Further, backward design emphasizes alignment between each of the three components in a tightly linked network.

The first step of backward design involves developing the learning outcomes. Backward design acknowledges limitations on how much can be covered within a course. Therefore, it uses a tiered system to identify the most critical learning outcomes. The lowest tier, *worth being familiar with*, represents content with which students should have a high-level or passing understanding. The second tier, *important to know and do*, represents content in which students should develop some mastery. Finally, the highest tier, *enduring understanding*, represents the most critical concepts, skills, or ideas of the course that a student should deeply understand or master and carry with them well beyond the course itself. Backward design also proposes several filters for deciding whether content should be central to a course. Typically, there will only be a few *enduring understanding* outcomes, but there may be more outcomes that are *important to know and do* and *worth being familiar with*.

The second step involves developing the assessment component. Different types of assessments are related to the kinds of evidence they provide for learning. For example, quizzes or tests can reveal discrete factual or conceptual understanding and performance tasks while projects can demonstrate more holistic application of skills and knowledge. In aligning assessments with learning outcomes, some assessments may be more appropriate than others; quiz questions may be sufficient for outcomes that are *worth being familiar with* but projects may be necessary to assess course *enduring understanding*. All learning outcomes should be assessed in some manner appropriate to the importance of that outcome.

The final step involves developing the instructional or lesson plan and activities. These should prepare students to be successful on the assessment activities and achieve the learning outcomes of the course. These may include a variety of course activities, lectures, peer instruction, as well as key material and skills deemed important by the instructor.

Although the above description suggests considerable flexibility in the creation of each of the components, backward design nonetheless creates a well-defined model of what a course should include and informs prioritization within several of these components (e.g., enduring understanding, and aligning assessment methods with learning outcome types). The stages are likewise discussed generally in a stepwise fashion, suggesting they are ordinarily completed in a linear fashion: adding a new component and aligning it with the previous component. For deciding on course content, reference is made both to local, state, or national standards for education as well as student needs, although there is less explicit discussion on how needs are elicited from students. The primary designer within this lens is the instructor. Finally, as an instructional design approach, backward design carries the assumption that a course is the natural outcome from applying this approach.

Model 3: Design Thinking

Design thinking originated from empirical study of the cognition and behaviors of expert designers as a way to inform the education of future designers [14]. It has since become a framework to not only inform design education but to guide the practices of professional designers and bring a designerly lens to other fields that may benefit from its divergent, empathetic, open-minded, and iterative nature. Many variations on the core design thinking framework exist, reflecting nuanced approaches of different design entities (firms, schools, experts), or theoretical expansions that seek to enhance key aspects or underserved areas (for example, co-design traditions that engage users as designers [15]). Here, we leverage an empirical framework from Carlgren, Rauth, and Elmquist's [10] research of the practices of several leading companies. We chose this framework due to its grounding in the lived practices across a variety of contexts, considerations of a diversity of origins, and connections to many variations of design thinking.

Carlgren and colleagues [10] present design thinking thematically, describing five themes: user focus, problem framing, visualization, experimentation, and diversity. The user focus theme highlights the central role users play in design. Design work is underpinned by empathy for users and driven by addressing their needs. The problem framing theme describes the approach toward engaging with a design problem. Instead of considering a design problem as something to solve, design thinking emphasizes finding the appropriate problem as a guiding activity. This approach is marked by an open mind about the nature of the problem and reframing the problem throughout the design process. The visualization theme focuses on using various, low fidelity representations to manifest ideas in an understandable and relatable way. Such representations inform understanding of user data, generating design ideas, and understanding and selecting design concepts. The experimentation theme describes the iterative and action-oriented nature of design thinking. Experimentation emphasizes trying out ideas frequently and iterating based upon the results. The diversity theme emphasizes the integration of a diverse array of perspectives in the design process. This includes forming an experientially diverse team and seeking a variety of outside perspectives, as well as ensuring these diverse perspectives contribute to the process.

Carlgren and colleagues [10] also describe each of the five themes across three dimensions: principles/mindsets, practices, and techniques. These dimensions describe how each theme is enacted with the design process. Principles/mindsets represent values, beliefs, and orientations embodied by designers or design entities. They guide a designer's approach and inform their actions and decisions. Practices represent the key activities in which designers engage throughout the process. Techniques represent specific tools or approaches that can guide activities within the practices. While specific mindsets, practices, and techniques may be aligned with specific themes, many overlap several themes.

Applying the Lens to Course Design Objects

The themes and dimensions of design thinking do not explicitly state what a design object is. Instead, they describe the context within which a design object is created, and thus represent properties that inform a design object. Several of these properties offer unique implications for an engineering course that might be designed through a design thinking frame, especially when considered against "traditional" methods.

The user focus theme represents three key concepts: designers seek to understand users and their needs, user needs drive the design process, and designers must involve users in the design process in some way. If we consider educators in the role of designers and students in the role of users, these concepts have important implications for considering a course as a design object. First, the focus on meeting user needs positions a course not necessarily as a vehicle for delivering some specific content or molding future engineers, but rather as a vehicle for meeting some unmet need(s) in the students' experiences. The needs could be related to learning some specific content or developing some specific engineering skills or mindsets. However, the needs might also be affective or related to improving students' experiences in the course, department, or university. Second, the interaction between the designer and user, the teacher and student, that informs the development of the design object is likely to take place, at least in some substantive part, during the course itself. Thus, a design thinking lens positions the enactment of the design object as part of its development and suggests the substantive role students have in shaping the design object, both in development and practice.

Design thinking also emphasizes the open-ended nature of design problems. The problem that a design object is intended to address is not static; it is subject to change based on designers' evolving understanding of the context and users' needs therein. Whether by personal practice or contextual characteristics, engineering courses are often thought to address, in part at least, static problems. For example, each course contributes to accreditation and degree requirements. From this perspective, a course solves the problem of helping students develop knowledge, skills, and mindsets that are consistent with an engineering degree in a particular discipline (from a department, college, and university) and contributes to student outcomes agreed upon by an accrediting organization. These problems (as topics and/or student outcomes covered) are even codified beforehand in course catalogs and accreditation reports. The reframable nature of design problems in design thinking would suggest less rigidity in defining the problem a course addresses as a design object, and thus a more malleable design object in its own right. In fact, the concept of co-evolution [16] suggests that the design problem and solution evolve together and that the designers' understanding of the design problem is actually part of the solution. Thus, understanding the problem a course addresses as a design object is intrinsically part of the design object itself.

Like its view of design problems, design solutions are also emphasized as open-ended. Some of this open-ended nature follows from the open-ended nature of design problems and the concept that design solutions are driven by design problems and not vice versa. However, design thinking also emphasizes divergence in generating design ideas, fluidity in developing rapid prototypes, and multi-modality of more developed prototypes. In other words, when visualizing what a course might be, ideas (1) need not conform to any preconceived forms and (2) should be considered in a great variety of forms. This challenges some contextual factors and personal expectations that might be considered well-defined. This could include, but is not limited to, course location (i.e., in a classroom), instruction formats (e.g., lecture, problem-based learning), topic- or outcome-based instruction plans, duration and timing, etc. In fact, the open-ended nature of design solutions suggests that a course itself may not be the ideal solution to address a design problem. Alternatively, it may suggest that course designers and instructors should expand consideration of the features, environments, interactions, and objects that are part of the design object. For example, a course might not just be a collection of content, assessments, and instructional strategies that occur in finite points of time and space, but also a variety of tangential aspects including interactions, experiences, connections that extend beyond a semester or other term.

Design thinking emphasizes a variety of lo-fi prototypes that can be frequently tested by and with users to gain an understanding of their acceptance and experience. This would seem to challenge the traditional model of course development, where a course is ideally well-defined and planned prior to the term in which it is implemented. Instead, one might think about each course implementation itself as a prototype and even specific elements thereof as shorter-term prototypes. Yet, this also challenges educators to consider what might be a prototype that they can test with students outside the confines of implementation and connects to the above discussion in terms of what form a course really takes or can be described by. For example, what components are part of the prototype? What role does the "performance" of a course play in it as a design object compared to the planning artifacts (e.g., syllabus, lesson plans, assignments)? From a procedural standpoint, this suggests that a course is ever-changing, both term to term and within the term. Thus, a course is not a static object but is instead constantly in flux, both in terms of its manifestation and the components that are even considered part of it.

Design thinking also emphasizes *who* is creating the design. From a personnel standpoint, design thinking emphasizes both diversity of perspectives within a design team and the fuzzy boundary between designers and users. From an individual standpoint, design thinking also emphasizes the importance of understanding the mindsets and tools that inform an individual's practice and contributions to the development of the design. Collectively, a design object is the product of who creates it and what principles they've used to create it. In contrast with a traditional narrative of the lone engineering educator enacting a targeted course that fits a departmental and university need, that remains stable from term to term, instructor to instructor, and student population to student population, the multivocal and personal nature of design thinking suggests that (1) designers themselves are "part" of the design object and (2) these parts should be many and varied.

Comparison Across Models

In comparing the three models, we identified three themes, each with two sub-themes, related to courses as design objects in each of the three models: bounds of the problem and solution spaces, the role of designers and users, and course evolution over time. We explicate these themes and sub-themes below.

Theme 1: Bounds of the Problem and Solution Spaces

Each of the three models places different bounds on the problem a course might address and the form a solution might take (Table 1). Both engineering design and backward design offer structuring techniques to make the problem more approachable or solvable. In backward design, these techniques are meant to guide decisions related to three course pillars: content, assessment, and pedagogy, and their alignment. Not only must courses address these pillars; they are guided to do so by the educational philosophy undergirding backward design. For example, content is guided toward enduring understanding and telling a connected story. In engineering design, problem framing involves identifying distinct criteria a design solution must address, constraints it must work within, and functions it must achieve. These aspects could be translated into the pillars that guide backward design, but they need not do so. Thus, course designers are freer to explore the ambiguous space of what a course should do and how it might do so. Design thinking, conversely, resists some of this front-heavy structuring and assumptions about the core components of what a design object should entail. Instead, design thinking asks what core user needs should be addressed and allows the solution to follow from there. This raises questions about whether a 'course' is the optimal object to be designed or another learning experience may be a better fit. Further, it suggests, along with engineering design, that learning may not be the sole target of a course (or other learning activity).

Table 1: Sub-themes related to *Bounds of the Problem and Solution Spaces*

Sub-Theme	**Engineering Design**	**Design Thinking**	**Backward Design**
Structure of design object and components	Criteria it should meet, constraints it must address, functions it needs to perform	Rejects nature of predefined structure. Focus is on user needs. Structure of the object follows from the needs and problem statement.	Learning outcomes, assessments, and pedagogy or delivery of learning. Aligned so each piece feeds into the next, in a stepwise fashion
Problem-solution space	Problem space is defined (e.g., problem statement), given key criteria and constraints in order to identify potential solutions. Solutions are tested to see if they meet key criteria and constraints and perform needed functions or compared across alternatives (e.g., tradeoff matrix) to see if some alternatives perform better than others.	Problem is consistently reframed during the process based on outcomes of experimentation and new perspectives. The goal is not to develop a solution but to understand the problem.	Understanding of the problem and form of the solution may evolve throughout the process and between implementations, especially as knowledge and perspectives change. However, the problem is well-defined as helping students learn some content, developing systems to evaluate that learning, and support learning through relevant and aligned pedagogy.

Theme 2: Role of Users and Designers

Each of the three models considers the role of both designers and users, including how they shape the design object, but differs in what those roles are (Table 2). In engineering design and backward design, users or stakeholders are sought to give feedback, provide criteria, and inform the design process. However, the designer is primarily responsible for furthering the design process. However, in design thinking, users are defined more broadly and are more fully integrated into the design process, both in terms of where they contribute and the depth of their contributions. Role of the designer in engineering design and backward design is an expert. They have the fundamental technical knowledge and skills to create the design object. Users or stakeholders act as informants, not co-designers. The distinction between designer and user is less hierarchical in design thinking; users are more involved in the process and have unique expertise to share.

Table 2: Sub-themes related to *Role of Users and Designers*

Sub-Theme	**Engineering Design**	**Design Thinking**	**Backward Design**
View of user	Users may interact with an intermediate developed design object, may give feedback, check that the design object meets key criteria. Ultimately the view is to get the user a finalized design object.	Users are central to the process. Student is the user. Students may contribute to design in various ways. Overarching goal is to meet user needs.	Users or stakeholders are in part the school or administration for which the course is being built. There is recognition of students needs and how they also should be considered in course design
Inherent expertise of designer	Technical understanding of the topic, how to create appropriate functions, limits and constraints on different technical or physical properties shape designer's ability to identify possible solutions and achieve key criteria.	Design thinking is guided by mindsets, practices, and techniques. A designer's mindsets guide their behavior and choices. Knowledge of practices and techniques, but how and when to use them informs the process. Designers also emphasize both leveraging their relevant expertise and relaxing their perspectives and biases to ensure they most adaptably meet user needs.	Knowledge and beliefs about the discipline or topic guide design decisions, e.g., enduring understanding that is prioritized or types of pedagogy used. Knowledge of how and when to use the tools affects the effectiveness of their use.

Theme 3: Course Evolution

Each of the three lenses allows for iteration, demonstrating that a course as a design object is malleable, not permanent. Yet, the lenses emphasize different levels and scope of iteration. Engineering design allows for iteration within the design process, with prototypes serving as tests of feasibility and viability. However, this model carries the assumption that a design will be delivered within a timeline, ending iteration. The end-product may be carried through another design cycle eventually, but that might be considered a separate design object (e.g., a course changing from semester to semester). Backward design suggests a high degree of iteration within the process. For example, Streveler and colleagues [5] presented the example of how an instructor's conceptualization of the course content evolved through multiple iterations of a concept map and substantive thought work. This model may suggest a concrete end point for iteration, like engineering design, however, as it acknowledges the degree to which instructor perspectives and sensibilities affect the design object and how their changing perspectives and sensibilities over time (e.g., new understanding of the content, teaching professional development) will cause natural iterations in a course. At the furthest end of the spectrum, design thinking implies an ongoing, continuous evolution of the course depending on user needs and changes. Many of these changes may occur as the course is in progress based on dynamic user needs and changing designer awareness of those needs, thus rejecting the notion of permanence of a design object at the beginning of a term.

Table 3: Sub-themes related to *Course Evolution*

Sub-Theme	**Engineering Design**	**Design Thinking**	**Backward Design**
Nature of design object over time	Goes through iterative loops and settles to a final design that is robust, largely unchanging. May engage in a new development cycle, though would be considered a different object.	Frequent iteration, including lo-fi prototypes. The object itself is a part of the design process, thus it is continually dynamic. Course may change term to term, but it may also change within term.	Design object changes through both micro-iterations in process and macro-iterations between course implementations. By engaging in backward design, the designer develops new understandings of the course object that inform further design choices and iterations.
Nature of iterations	Technical iterations based on working toward feasibility and functionality.	Iterations based on evolving understanding of user needs and reframing of the design problem based on frequent testing of rapid prototypes, user research/interactions, and other design work.	Iterations based on designer's evolving understanding of key content and aligning assessment and pedagogy with that evolving understanding.

Instructional Implications

Exploration of the three design models revealed three key themes and substantive differences between the models across those themes. In the following section, we explore instructional implications of creating a course within each of the models. While we do not suggest these are the only three ways to create a course, we argue that the differences in the models and the consideration of the three themes represent generative considerations for engineering educators and scholars. We present these implications as questions instructors might ask themselves and how they might address these questions in the context of each model.

Who Am I as a Course Designer?

Each of the models suggests a key role of the designer (often the course instructor) in developing the design object. These roles change from model to model. Prior research has suggested substantive differences in the ways that educators understand and approach the course or instructional design process [17,18]. Visscher-Voerman and Gustafson [17], for example, present four paradigms evidenced by creators of instructional design objects: instrumental, communicative, pragmatic, and artistic. The instrumental paradigm focuses on formulating design goals up front and emphasizes a design object consistent with those goals. This paradigm aligns well with the engineering design and backward design lenses, which emphasize setting criteria and course content, respectively, and working to build a course that meets those criteria. Conversely, design thinking would seem to connect with either the communicative paradigm, which emphasizes negotiation among many users and interested parties in determining and developing the design object, or the pragmatic paradigm, which promotes a process of rapid prototyping and continuous iteration. Consideration of one's expertise and design sensibilities might inform the model within which an instructor might be most successful or comfortable.

How Much Time Can I Dedicate to the Course as an Object?

Educators have many responsibilities and challenges. The distribution of these responsibilities, personal and professional constraints, interest in the course, and current level of success of the course can influence how much time an educator has to invest in developing the design object. Backward design, while not taking a trivial amount of time, has clear guidance and structure and thus may provide a more streamlined approach for those under a time crunch. Design thinking, overall, could take the longest given its fluid structure; i.e., time needs to be continually allocated for future instances of the learning experience. However, given the continuous nature of iteration in design thinking, educators willing to dedicate more time and effort within a semester, and take the risk of unsuccessful early prototypes, may require less lead-time for developing the initial minimum viable product.

How Much Will the Topic or Area I'm Teaching Change?

Each model encourages iteration and suggests courses can change from semester to semester. Thus, each can be responsive to changes in relevant content and innovations in instructional and assessment approaches. Design thinking offers the most fluidity, and thus greatest responsiveness to changes. Backward design, however, with its guiding questions and targeted tools provides the most structure within which to acknowledge changes. Engineering design falls somewhere in the middle. Thus, while design thinking may offer the most responsiveness, backward design might better facilitate responsiveness for those requiring a bit more structure.

What Do Students Bring to the Course? What are their Needs?

If students are largely novices or may struggle with a less structured learning experience it may be useful to use engineering design or backward design, where expertise relies more with the instructor. In particular, backward design may be most useful when the course subject matter is complex and challenging to connect for students, due to its emphasis on enduring understanding and aligned content. In cases where students are more experienced or bring important insights, ideas, and expertise, design thinking may be preferred. Further, students who are more accessible, willing to share perspectives, and apt to co-create their own learning environments may not only prefer a design thinking approach but may require one.

What Is My Institutional Context? How Much Flexibility Do I Have to Make Changes?

Educators find their courses in different contexts. Some may find themselves in highly constrained contexts based on, for example, accreditation requirements, departmental expectations, student expectations, presence of parallel instructors, course inertia, etc. Others may have more flexibility to make changes or course object alterations. While each model has the potential to benefit from a more flexible context, engineering design may be the most useful under more constrained circumstances. Engineering design emphasizes identifying criteria and constraints and working to meet those criteria. Designers can thus navigate within the environmental constraints. Design thinking may require the most flexibility, and may be infeasible, without adaptation, within certain institutional contexts.

Other Considerations

The preceding discussion is by no means comprehensive. However, it aimed to provide generative ability to consider models or aspects of models given educators' contextual factors. Additional factors may also be applicable. We encourage others to consider those factors. Further, we note that other models or hybrids between the presented models may be useful to consider. For example, instructors may be most comfortable within engineering design, but may borrow some tools and principles from the other models to support them. This might involve tactics such as leveraging content-identifying procedures from backward design to illuminating design criteria and applying rapid prototyping methods from design thinking in developing the object to meet those criteria.

Conclusion

Designing a course is a nontrivial task with many considerations such as the scope of the content, key learning outcomes, activities to be used, needs of students and institutional context, and instructor experience and expertise. In this work we took a multiple perspective [7] approach to the design of a course as an "object" and presented three models for developing a course: engineering design, backward design, and design thinking. These models were selected to provide insights into the similarities and differences across models as well as to unearth hidden assumptions associated with each. Detailing these, we argue, allows for a more conscientious consideration and selection of model use, unique to the different design paradigms common in engineering education. In discussion we compare these models and also offer a set of instructional questions to consider when deciding on what frame may be useful for a given instructional context, goal, and student population. Future work may seek to expand this theoretical work to an analysis of the approaches faculty use in practice and seek to develop a more comprehensive set of guiding questions for considering the utility of different lenses when deciding on course design.

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