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ORIGINAL PAPER

Visualizing Course Structure: Using Course Composition Diagrams to Reflect on Design

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Abstract
We explore an innovative approach to learning design representations called course composition diagrams, which consist of interactive digital icons representing course elements, such as videos and quizzes. Course composition diagrams present a visual overview of course structure, including the placement and sequence of individual elements within a course. We hypothesize that providing design teams with such representations creates opportunities for reflection that may not exist otherwise, thereby potentially leading to improved design outcomes. We present a case study where design teams of Massive Open Online Courses used course composition diagrams to reflect on courses they had recently developed. Six themes emerged from our qualitative analysis: 1) affordances of representation, 2) limitations of representation, 3) opportunities for comparison, 4) congruence, 5) reflection on design choices, and 6) utility of representation. We argue that this approach holds promise for providing designers with meaningful opportunities to reflect on learning design.

Keywords Course structure · Curriculum visualization · Design patterns · Design representation · Design teams · Instructional design · MOOCs · Reflection

As Massive Open Online Courses (MOOCs) increase in popularity and prominence, researchers are increasingly focusing on the process and experience of those who create and teach MOOCs (Blackmon 2018; Lin and Cantoni 2018). Understanding the MOOC design processes and the experiences of those involved will provide a strong and useful foundation for designers and instructors who engage in this complex work. Further, as effective methods and approaches that support design teams are identified and developed, the potential to improve the learning experience for online learners grows.

While there may be many benefits and rewards tied to the design and development of MOOCs such as high enrollments and wide reach (Blackmon 2018), the challenges of designing and developing MOOCs are also well-described (Alario-Hoyos et al. 2014; Demaree et al. 2014). As many scholars have noted, the MOOC design process is time-consuming, highly complex, and challenging (c.f., Kolowich 2013). Further, MOOCs themselves can be structurally complex because they consist of a variety of different types of activities and resources that can be arranged in a range of sequences (Quintana 2018). MOOCs are composed of various course elements, such as instructional videos, machine-graded quizzes, peer-graded assignments, and threaded discussions (Conole 2014; Margaryan et al. 2015).

Although a MOOC instructor might be seen as the primary author of the course, in reality, many MOOCs are developed in collaboration with multiple stakeholders (Najafi et al. 2015). This reality increases the need for shared representations that can serve as a catalyst for developing shared understandings related to pedagogical goals for a course. As teams engage in MOOC design work, they may find themselves challenged to grasp the overall structure of a course, including the sequence and arrangements of various course elements. A visual representation that provides a holistic course overview can assuage the difficulties associated with conceptualizing learning goals, content structure, and course difficulty. To address these challenges, we consider the efficacy of a MOOC visualization approach that we call "course composition diagrams" (CCDs).

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These digital representations use interactive icons to represent course element types, such as videos and assessments. In their totality, CCDs present a structural overview of a course. By utilizing interactive icons within a holistic course structure, we hope that CCDs can be used to help MOOC designers better attend to the complexities of their work.

MOOC design teams may have limited and infrequent opportunities to reflect on the course structures that they create, and could therefore bypass an important step in the design process, although there is limited research about self-reflection during the MOOC design process (Bartoletti 2016). Reflection on design has been shown to improve the effectiveness of the design process (Reymen 2003) by bringing "unconscious aspects of experience to conscious awareness, thereby making them available for conscious choice" (Sengers et al. 2005, p. 50). We hypothesize that providing course design teams with CCDs will afford more opportunities for reflection, which will result in improved design outcomes.

We begin by reviewing the MOOC design process as described in the literature, we introduce the field of learning design and its connection to design patterns and design representations, and we explore the role of reflection in the design process. Next we present a detailed description of how we created CCDs using two cloud-based tools, Google Sheets and Plotly. Finally, we present an exploratory case study of how one design team used CCDs to reflect on the design of MOOCs that they had recently designed. An exploratory case study (Yin 1994) is an appropriate choice of methodology because it allows us to explore the use of a tool within a design context that is fairly new (i.e., that of MOOCs). This methodology also permits us to examine the outcomes of our hypothesis, namely that interaction with CCDs will create meaningful opportunities for design teams to reflect on design. The outcome of this work can lead to the investigation of further questions about the specific characteristics of CCDs that might best support design teams in the practice of reflection. However, the goal of this initial exploration is to understand what design teams perceive about the utility of CCDs for representing course design and promoting reflection on design.

The following questions guide our inquiry into the efficacy of CCDs for use by course designers and facilitators:

- Research question 1: What do course composition diagrams reveal to course design teams about the structure of an online course?
- Research question 2: What do course composition diagrams obscure about the structure of an online course?
- Research question 3: Do course composition diagrams allow a course team to reflect on the design of an online course? If so, how?

Related Work

MOOC Design Process

Designing and developing a MOOC is a demanding task (Alario-Hoyos et al. 2014; Demaree et al. 2014). First, it requires a significant amount of time on the part of those involved, with some estimates suggesting that it typically requires the lead instructor to invest at least 100 h of effort to prepare materials, such as online lecture videos, before a MOOC is set to launch (Kolowich 2013). Hollands and Tirthali (2014) stated that tasks that MOOC instructors usually do could include repurposing "traditional" course materials (e.g., readings and quizzes), practicing for lecture recordings, recording videos, and reviewing and finalizing videos. Participants in Hollands and Tirthali (2014)'s study likened the experience to developing a textbook.

Developing a MOOC is an extremely complex process that requires the efforts and input of a coordinated team (Demaree et al. 2014). In addition to a MOOC instructor or team of instructors, a group of experts who assume a range of roles are needed. Examples of core roles include learning experience designers to offer research-informed design recommendations, project managers to coordinate development work, media designers to record and edit instructional videos, and video production managers to keep track of video assets (Doherty et al. 2015). Individuals assuming these roles are responsible for designing the course structure and materials, and coordinating the design process as a whole (Law et al. 2017). The input of other experts may also be required, such as copyright specialists, accessibility specialists, legal professionals, and marketing specialists. Given that the process is complex and includes many actors, "A clear workflow is essential to keep on track" (Doherty et al. 2015, p. 178). To add to the complexity, MOOC platforms are in a constant state of flux, with new technical features being added to platforms on a nearly weekly basis, thereby altering the kind of learning experience that can be designed. For this reason, it is essential that the design process include professionals who are up to date on the latest developments in platform functionality.

Yet, even within the context of working with a team, creating and developing a MOOC can be an isolating experience for instructors. Because the instructional environment is new to most MOOC instructors, they may find platform features of MOOCs to be unintuitive and difficult to utilize. Instructors may struggle to realize their vision for a course, including effectively engaging large and diverse audiences of learners and fostering learning communities within the constraints of platforms that do not necessarily support these goals (Adair et al. 2014). Throughout the facilitation of a course, instructors may feel pressure from learners to be visible and responsive, but because of the scale involved, this is not feasible or practical. Furthermore, their institutions may not provide compensation for time (i.e., course release) or formal recognition for their efforts, increasing the burden instructors may feel (Watson et al. 2016). The relationship between the instructor of the MOOC and the instructional team who supports the design and development of the course is a complicated one, with all parties involved feeling ownership and responsibility for the project. But ultimately, the instructor may bear the greatest share of responsibility, having to attend to learner enrollment incentives and their corresponding needs (Watson et al. 2016). Although the representations that we describe here may not directly address these issues, they can provide greater transparency concerning course design within a process that can be somewhat opaque to instructors.

Learning Design, Design Patterns, and Design Representations

As MOOC design processes regularly include instructional design support (Najafi et al. 2015), it is important to consider the approaches and methods that are used by learning designers within these design processes. Learning design consists of two dimensions: process and product (Conole and Wills 2013). The process dimension involves developing a plan for a learning design that specifies the necessary resources and environmental conditions that are needed to support learners in meeting the learning goals that have been articulated (Law et al. 2017). Within this dimension a learning designer may consider various designs through an iterative (and sometimes messy) process (Conole 2009). Learning designers may draw on *design patterns* which, at their most basic level, are a pairing of a pedagogical problem with a pedagogical solution (Laurillard 2012). The process dimension focuses on coordinating various communication and collaboration mechanisms, and developing assessment strategies and activity designs (Law et al. 2017). These designs may be enacted by various stakeholders within a particular sequence, all of which must be specified in advance. The product dimension, which results from the design process, is often a *design representation* of the outcome of the educational design processes, which allows these processes to be made more explicit and shareable (Conole 2009). This product captures a particular moment in time within the design process, usually the "final" version of a design that has been implemented within the wild.

Design Patterns As part of the process dimension of learning design, Laurillard (2012) surfaced the idea of design patterns. Encompassed within an educational design pattern is learning context, a pedagogical problem, and a pedagogical solution. Design patterns are rooted in the field of architecture and originate with Christopher Alexander's (1977) work on town planning where he recognized that patterns can be used to describe a frequently recurring problem and a corresponding core solution to the problem. The goal is to present solutions in such a way that the pattern can be used "a million times over, without ever doing it the same way twice" (Alexander 1977, p. x). The basic components of a design pattern are the 'problem', the 'context', and a description of the solution. Such patterns can be used to guide architects by describing the components of a design along with the rationale and motivation for their use, the context in which they should be used, and the user behavior that results from their implementation.

Design patterns are not intended to be used prescriptively; rather, they are meant to provide the learning designer with "rules of thumb" as they develop a collection of resources, tools, and materials to be considered when they identify a pedagogical need (McAndrew et al. 2006). In the context of the design of educational technologies, Quintana et al. (2003) used the notion of design patterns from architecture as inspiration to develop a "scaffolding pattern" to describe scaffolding approaches in a more systematic, structured manner. Such patterns can be used when a learner need has been identified (e.g., learners may require support with sense-making and need support to analyze and make sense of their work products) to inform the type of scaffold that is used within the software (e.g., a graphic organizer). Design patterns can capture three important aspects of teaching: (i) contextual information, such as summary, rationale, and learning outcomes, (ii) pedagogical information, such as sequence of activities, roles, methods of assessment, and (iii) reflections on teaching, such as an evaluation of how well the pattern worked and a proposal for how the pattern could be improved (Laurillard 2012). Formalized pedagogical patterns can represent design decisions and facilitate the transfer of useful pedagogical ideas. These patterns are of use to the original creators of the pattern and to learning designers who desire to re-use or adapt them (McAndrew et al. 2006). As Law et al. (2017) emphasized, the need for formalizing representations of pedagogical design patterns is greater than ever, because much of the work done in the design of online learning experiences (e.g., MOOCs) is done by course design teams (rather than individual instructors). Of particular interest to the present study, is creating design representations that encapsulate the second aspect of teaching that Laurillard (2012) outlines, that of pedagogical information, such as sequence of activities, roles, and methods of assessment.

Design Representations Design representations allow MOOC design teams to represent the outcome of the design process and share practices that exist within the design process. Design representations describe and represent pedagogical processes and outcomes at varying levels of granularity, including discrete learning activities, entire activity sequences, and whole curricula (Conole 2010; Conole and Wills 2013). Design representations portray an abstraction of course elements and sequences, these representations can range from a formal structure to a semi-formal design. An example of a formal structure is as a completely computer-runnable design. An example of a semi-formal structure is a visual or textual depiction of a plan (Conole and Wills 2013). Using design representations, it is possible to codify learning activities—tasks that learners engage in to make progress on and meet learning goals—and make them available for review and critique to stakeholders and teams. Teachers have used various approaches to documenting teaching plans, such as concept maps, diagrammatic sequential representations, storyboards, and matrices that map learning activities along a timescale (Conole and Wills 2013). Different kinds of design representations may have unique strengths and may be well-suited for a particular purpose, serving to foreground particular aspects of the learning design (Conole 2009). For instance, Conole (2010) suggested that the "swim-lane" format (c.f., Garcia-Solorzano et al. 2011) is particularly useful for representing curriculum at the activity level during the course design phase. Diagrammatic or iconic representations of curriculum designs can be valuable, because they can highlight relationships among learning activities, and can give the viewer a sense of flow and movement (Conole 2009).

Design Representations within the MOOC Design Processes

Educational research that reports on the practice of using design representations within the MOOC design process is fairly nascent, although it does exist. Alario-Hoyos et al. (2014) presented a visual framework to guide MOOC designers to focus on important dimensions such as target learners, objectives and competencies, and pedagogical approaches. Demaree et al. (2014) described their use of tabbed spreadsheets to detail instructional design decisions and to track course assets. Seaton (2016) developed methods that use iconic representations of MOOC elements (e.g., videos and textual readings) to depict the final structure and sequence of activities within a MOOC, allowing researchers and designers to see similarities and differences in MOOC designs. Garcia-Solorzano et al. (2011) visualized the structure of an online course to provide wayfinding support for learners, by visually mapping learning goals to specific elements within the course. Powers (2015) visualized the course structure of MOOCs as a tree diagram, to expose course layout to students in order to enable self-regulation. These representations can represent designs in progress (e.g., Alario-Hoyos et al. 2014; Demaree et al. 2014) or depict finalized designs (e.g., Garcia-Solorzano et al. 2011; Seaton 2016). MOOC design representations are also intended to be used by various audiences, such as MOOC design teams (Alario-Holyes et al.; Demaree et al. 2014), researchers (Seaton 2016), and learners (Garcia-Solorzano et al. 2011; Powers 2015).

Given that the MOOC design process requires the coordinated efforts of a large team, we posit that it is vitally important for MOOC design teams—including instructors, learning designers, media designers, and other professionals who are involved in the design of MOOCs—to understand the structure of the individual MOOCs that they create. CCDs, one form of design representation, are a product of the learning design process. It is our assertion that understanding the composition of courses will allow design teams to fine-tune their structures, potentially leading to an improved design and learning outcomes (Freeman et al. 2011) and increased student satisfaction (Laverty et al. 2012).

Supporting Reflection on Design throughout the MOOC Design Process

Design research literature has emphasized the importance of adopting reflective practices and has underscored the potential for these practices to positively influence design outcomes (Ishii and Miwa 2005). This work is largely premised on Donald Schön's notion of the "reflective practitioner" where he differentiates between reflection "on-action" and reflection "in-action" (Schön 1983, 1987). Schön describes reflection "on-action" as a cognitive process that takes place *after* a design activity is complete. In this explicit act (rather than a tacit process), designers formally reflect on their design process, on decisions that they made, and on designed artifacts. In this way they are assessing outcomes from a completed project. By adopting this approach, designers are able to understand design outcomes in a more abstract and metacognitive way (Ishii and Miwa 2005), with the eventual outcome of improving their own design processes and designerly judgment (Gray and Siegel 2014). Reflection "on-action" contrasts with reflection "in-action," which involves the designer considering and evaluating available information *during* the design process in order to make a decision in the moment. Design researchers have primarily focused on supporting reflection "in-action," which has led to the development of a variety of tools that support reflective practices within current design practices (e.g., Klemmer et al. 2002; Lin et al. 2000).

Design representations hold promise for supporting reflection "on-action," although they are used throughout the entire design process. Design representations can serve as mediating artifacts to communicate and facilitate shared understandings, such as facilitating professional discourse around pedagogical patterns (Law et al. 2017). They can also stimulate "design conversations" between a designer and their materials (Fischer and Ostwald 2005).Without a mediational tool or aid, it can be a challenge for designers to get a sense of the "big picture" (Arias et al. 1997). Sharmin and Bailey (2013) presented ReflectionSpace, an interactive visualization tool for supporting reflection "on-action" in design. The tool used file meta-data and naming conventions to map real design artifacts to appropriate design phases, allowing the designer to navigate the representation at varying levels of detail. Bartoletti (2016) described a MOOC design process that included reflection "in-action" and "on-action" through group collaboration and discussion, using an online textual collaboration tool. Our project uses CCDs (a tool that focuses on design representations) to promote and stimulate reflection "on-action," making it one of the few examples of a tool that is designed to support this type of designerly reflection.

Methods

This case study is situated within the context of a large midwestern public university which has produced over 150 MOOCs from 2016 to 2020. All MOOCs that are created by the University's faculty are developed on site within the University's MOOC production center.

Participants

We recruited staff at the University's MOOC production center and one faculty member who had a lot of MOOC design experience to participate. Participants ($n = 16$) held various job titles and took on different roles within the design teams, see Table 1. Our participant pool was roughly representative of the role to role ratios within the academic unit (e.g., there were twice as many project managers as learning experience designers at that time).

Materials

We invited participants to interact with at least one CCD from a MOOC they had previously designed. We chose ten MOOCs that had been developed at the University's production unit within the previous year, believing that participants' experiences would be recent enough that the course design process would be easy to recall. We selected MOOCs that were hosted on the Coursera (Coursera n.d.) platform because the form of the CCD was most congruent with the linear structure that is apparent on the Coursera interface. Courses ranged in topic, including three data science courses, three social impact courses, and four professional development courses. Courses varied in length, from 4 to 7 modules, with each week including 1–3 lessons (i.e., related groupings of resources and activities).

We used the approach demonstrated by Seaton (2016) as the basis for our method, using the open source files provided through Seaton's blog post as a guide. We created the CCDs using two cloud-based tools that are available for users who have signed up for an account: Google Sheets (Google Sheets n.d.) and Plotly (Plotly n.d.). We used Google Sheets as a database to store the course component information, which allowed us to create the file format (i.e., a CSV file) that is needed to create interactive visualizations in Plotly. The added benefit of Google Sheets was that it was cloud-based and therefore supported multiple researchers co-editing the document, synchronously and asynchronously. There are no subscription fees associated with tools in the Google suite. We used Plotly to create interactive data visualizations (i.e., the CCDs). Our rationale for choosing this tool was that it allows users to choose and modify representational symbols and customize interactive visualizations.

Course Composition Diagram Creation

The creation of a CCD consisted of two phases: 1) spreadsheet creation, where course component data was organized into a spreadsheet and 2) Plotly configuration, where the spreadsheet created in Phase 1 was configured in Plotly to generate an interactive diagram (i.e., CCD). We describe our process as a set of structured guidelines to make it possible for the reader to replicate our process.

Table 1 Summary of participants' roles and numbers

Role name	Description of role	Number of participants
Project manager	Coordinates the efforts of all design team members to keep project on track	6
Learning experience designer	Works closely with faculty to design learning goals, assessments, learner-centered activities, and instructional content	3
Course advocate	Interacts with learners once the MOOC is "live" to support and monitor discussion fora, and to act as a liaison between learners and faculty	3
Media designer	Works closely with faculty to produce instructional videos for the course	2
Marketing specialist	Works with course team to develop strategies for marketing the course to a global audience	1
Faculty	Leads the development of curriculum materials; subject matter expert	1

Phase 1: Spreadsheet creation (preliminary and final). To format a final spreadsheet required by Plotly, we first prepared a preliminary spreadsheet (see Fig. 1).

Preliminary Spreadsheet Creation We created a two column spreadsheet to describe the order of all course components. For the first column (called "Number"), we assigned an ordinal number to each component to describe the component's position relative to all other components. For the second column (called "Metadata"), we described each item by component type, title, and additional descriptive metadata (see Table 2 for more detail).

Once all course items were numbered and described, we sorted the preliminary spreadsheet by the "Metadata" column, which allowed us to group course components by type (e.g., assessment, discussion prompt, and section heading).

Final Spreadsheet Creation We used the sorted preliminary spreadsheet as the basis for the final spreadsheet (one per MOOC) to specify the position of *each component* in the course according to three dimensions: 1) its horizontal position (x-axis) within the interactive diagram; 2) its vertical position (y axis) within the interactive diagram; 3) its descriptive metadata, which was used as the "hover" text within the interactive diagram (Fig. 2).

Respectively, for each component, we assigned its value found in the "Number" column of the preliminary spreadsheet as its x-axis position; we followed Seaton (2016) and assigned a value of "1" as y-axis position to all components to ensure that they are plotted on a single horizontal line; we also matched each component with its descriptive metadata, i.e., "hover" text. Lastly, we downloaded the final spreadsheet as a CSV file.

If you imagine the CCDs as a beaded necklace, the final spreadsheet describes the pattern of the necklace, identifying the type, position, and description of each bead. Our CCDs contained five component types: i) assessment, ii) video, iii) reading, iv) section (i.e., to indicate the start of a new lesson or module), and v) discussion prompt. In our example, each final spreadsheet contained 15 columns because we were representing the position (on the x and y axes) and metadata for five types of components (i.e., 5 components multiplied by 3).

Phase 2: Plotly configuration. In phase two, we uploaded the CSV file produced in phase one to Plotly. We chose "Scatter Trace Type" as the chart type. We created a new trace for each component type (i.e., five traces) and mapped the x, y, and hover text to the x-axis, y-axis, and metadata columns respectively. We selected abstract icons to replace the default dots, one for each component type. We chose icons that had semantic similarity to the course components. For example, we used a triangle shape for the video component type, because triangles resemble the play button of a video player; we used a circle for the discussion component type, because circles reminded us of seated conversation circles. Please refer to Table 3 for more details of customizable aspects of CCDs.

Data Collection

We created a web-based task and accompanying open-ended survey to send to participants to elicit their experiences and reflections on interacting with a CCD for a MOOC that they had recently worked on. The web-based task allowed participants to interact with CCDs in a self-paced manner. The survey allowed participants to submit responses anonymously. We sent one or more customized versions of the task to each participant ($n = 16$) in which we provided 1) a statement of the research goal (i.e., "to understand the utility of course composition diagrams for allowing course design teams to reflect on design") 2) a hyperlink to the CCD for a MOOC in which the participant had recently participated in the design process 3) several open-ended reflection prompts (see Table 4). We sent out 23 tasks with reflection prompts to all 16 participants

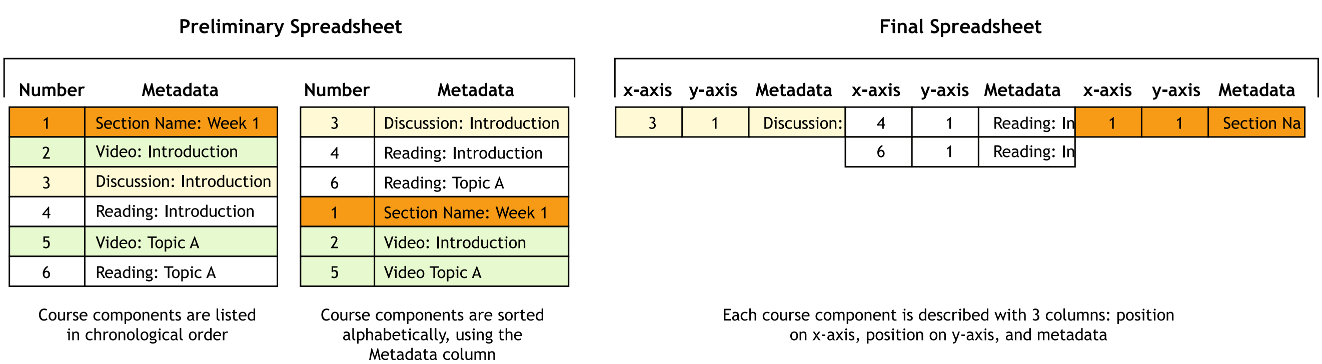

Fig. 1 Overview of preliminary and final spreadsheet creation process

Table 2 Metadata example of each course component type

Component type	Metadata example
Assessment	Assessment: Week 1 Quiz Questions: 10 First attempt average score: 79% Last attempt average score: 85%
Discussion prompt	Discussion prompt: Introduce yourself
Reading	Reading: Background knowledge
Section heading	Section heading: Week 1
Video	Video: Introduction Length: 11 min Type: Lecture In video questions: 2

initially, and sent 13 additional tasks to those who had responded to the first task and who had worked on another MOOC in our sample courses ($n = 10$). Overall, we received 24 completed open-ended surveys completed by 16 participants from the 36 tasks we sent out.

Approach to Analysis

We performed a *content analysis* to develop an understanding of our topic of interest, which was how members of MOOC design teams perceived the utility of CCDs for promoting reflection on design. According to Hsieh and Shannon (2005), content analysis is a systematic method for "the subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns" (p. 1278). For this study, textual data was obtained in electronic form from open-ended surveys. The goal of content analysis is to "provide knowledge and understanding of the phenomenon under study" (Hsieh & Shannon, p. 1278, 2005).

We chose to use a qualitative approach to analyze the open-ended survey data, following a *conventional* approach to analysis (Hsieh and Shannon 2005), where coding categories are directly and inductively derived from the data (Thomas 2006). This approach is well-suited to situations where research on a phenomenon of interest is limited (i.e., our topic). Other approaches to data analysis begin with a theory or relevant research findings to guide the generation of initial codes (i.e., a directed approach).

We followed the content analysis approach described by Creswell (2015):

- Read through the textual responses (i.e., responses to open-ended questions taken from 24 surveys) and recorded our initial thoughts as "memos"
- Divided the text into discrete segments of information or "excerpts" ($n = 174$) that appeared to capture key thoughts or concepts which addressed the research questions (Thomas 2006)
- Created descriptive labels (i.e., codes) to describe related segments of content
- Worked through an iterative process of grouping excerpts and refining labels ($n = 32$) to reduce redundancy
- Derived themes or major ideas from groups of codes ($n = 6$)

We took care to review the whole data corpus before creating excerpts and assigning codes, moving back and forth between the data and our research questions. The initial thoughts or "memos" captured our first impressions and informed the codes that we created in subsequent phases. We created labels (i.e., codes) to capture the essence of each code,

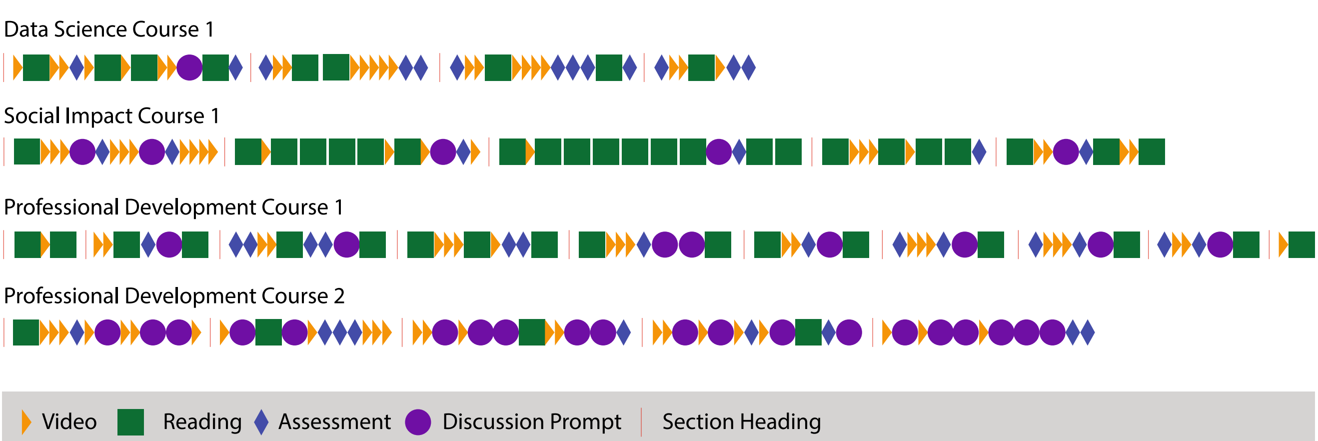

Fig. 2 Course composition for one MOOC. The orange box shows additional information that is visible when users hover over a video element

Table 3 Customizable aspects of CCDs

Customizable aspect	Our approach	Variability
Component type	We chose to abstract our course design to 5 components: assessment, video, reading, section heading, discussion prompt	If a course had additional components (e.g., live office hours), these could be added to accurately reflect the composition of the course. Further, designers could choose to create variations of components (e.g., different assessment types - practice or summative)
Descriptive metadata	We chose to add descriptive metadata to two components: video and assessment. For videos we added the type (e.g., lecture), length, and number of embedded in video questions. For assessment, we added type (e.g., multiple choice), number of questions, and first and last attempt scores (i.e., drawing from learner data).	The type and quantity of descriptive metadata is almost limitless. Researchers can decide what data are most useful to course design teams. Some possibilities include number of discussion posts to a prompt and number of replies to a discussion post.
Icon shape and color	We chose icons in Plotly that were visually related to each component (e.g., a triangle for a video, because it resembled a play button). We chose 5 colors that contrasted with each other.	Designers could customize the look of icons to achieve desired outcomes. For instance, if a course contained different video types, designers could create a range of fill types for the triangle shape to differentiate among them.

often taking words directly from the data itself. We applied the same labels to excerpts that shared similar concepts or ideas, and began to sort these codes into categories according to their relationships relative to each other. When two or more labels appeared to describe the same concept, we consolidated these labels into a single code to avoid overlap among codes. Once we confirmed that there were no further codes to be derived from the data, we grouped related codes into meaningful clusters which formed the basis of our themes. We used Dedoose (n.d.), a web-based application that allows researchers to analyze data using qualitative or mixed methods approaches, to analyze the data, using the inductive approach described above.

Findings

Our analysis of the survey data revealed six themes: 1) affordances of representation, 2) limitations of representation, 3) opportunities for comparison, 4) congruence, 5) reflection on design choices and 6) utility of representation.

Theme 1: Affordances of Representation

Participants noted how CCDs surfaced quantitative aspects of the course, including the quantity of one element type (especially when it existed in high or low numbers), the length of a course, and the length of modules in relation to other modules. Participants described how CCDs provided a high-level overview of course structure, which revealed the proportion of one element type to another. Participants appreciated that CCDs allowed them to retrieve additional details about each course element through interactivity.

Participants described the way that course elements related to each other (see Table 5):

- Balance – even distribution of course elements
- Variety – mix of course elements across the course
- Repetition – recurrence of a single element at various points in the course
- Pattern –repetition of a sequence of elements
- Rhythm – repetition of a sequence of elements, with some variation
- Emphasis – impression of prominence of one or more elements
- Movement – relates to the progression or flow through a sequence of elements

Theme 2: Limitations of Representation

Participants reported three major limitations of CCDs: 1) lack of differentiation within element types, 2) lack of precision in the display of quantitative information, and 3) lack of precision in qualitative information (see Table 6). Participants wanted to see more precise differences within an element type (e.g., representing quiz types – formative or summative – instead of simply seeing an assessment icon in a CCD). Participants also wanted quantitative aspects of course elements to be represented visually (even though they were available by hovering over an element). For example, videos ranged from 5 to 30 min, but this difference was not shown in the representation (i.e., by icon width). Similarly, several participants noted that qualitative dimensions such as difficulty level and required effort were not represented.

Table 4 Initial open-ended survey questions and follow-up survey questions

Initial survey questions	Follow-up survey questions
1. Describe your experience using the interactive timeline graphic. What did you enjoy about the approach? 2. What aspects of using the interactive timeline did you find challenging? 3. What did you notice about the flow and sequence of instructional content?	1.1.1. What were the similarities and/or differences between the first course you viewed a timeline for and this course, in terms of structure, patterns, or elements within the course?
4. What did you notice about the types of content contained within the course? 5. What were the patterns you observed? 6. How does the final course design relate to your experience of working on the course? (For example, were elements missing that you expected to be there? Were elements present that you did not expect? Did assessment results align with your expectations?) 7. Do you have any final thoughts concerning the interactive timeline approach?	1.1.1.2. Do you have any further observations or comments about the interactive timeline approach? (e.g., was the timeline more useful for one course vs. another?)

Theme 3: Opportunities for Comparison

Participants reported that CCDs allowed them to make comparisons between courses, such as comparing quantitative dimensions among courses, and comparing the number of an element type or the length of two or more courses (see Table 7). Participants also made comparisons from CCDs to the course outline view available in Coursera.

Table 5 Overview of themes and codes associated with the first research question

Q1: What do course composition diagrams reveal to course design teams about the structure of an online course?

Theme	Code	# of excerpts	Code description	Exemplar quote
Theme 1: Affordances of representation	Quantitative aspects	27	Number of different element types or length of grouping of elements	"It allows us to get a much more quantitative view of the content."
	Bird's eye view	13	High level overview of course structure	"I could get a feel for the distribution of various elements in the course."
	Additional details	3	Additional information and detail	"I enjoyed the 'interactive' element, and being able to see additional information by hovering over each element."
Affordances of representation – related to principles of design	Balance	20	Distribution of one or more element	"Each module was relatively 'even' in terms of the number of content types."
			Balance with respect to weight, or a preponderance of an element type within a specific part of the course	"I see a similar trend of very heavy reading modules in the middle/end of the course."
	Variety	15	Diversity of elements	"I observed the diversity of content type."
	Rhythm	13	Repeating pattern with some variation	"Each module has a relatively familiar flow, even if they're not identical to each other."
	Pattern	11	Repeating sequence of elements	"Each section of the course is structured almost like a sentence."
	Emphasis	12	Impression of prominence	"There was a heavy representation of discussion prompt activities/content types."
	Repetition	7	Regular recurrence one element	"I like that I'm able to isolate the different components (assessments, videos, etc.) to see how they are distributed across the course."
	Movement	6	Suggestion of direction, flow, and progression	"I was easily able to see the content mix and progression."

Table 6 Overview of theme and codes associated with the second research question

Q2: What do course composition diagrams obscure about the structure of an online course?

Theme	Code	# of excerpts	Code description	Exemplar quote
Theme 2: Limitations of representation	Lack of differentiation within element type	6	Lack of differentiation within an element type obscured information about some elements	"I know from working on the course that a lot of 'readings' are actually videos from external sources that we couldn't embed and so they're linked from readings. That skews a little bit of the perception of the amount of text vs. videos."
	Lack of precision in display of quantitative information	4	Lack of precision in display of quantitative information (i.e., all icons to represent videos are the same width, regardless of video length)	"If I were comparing these side by side I don't think I could say which was longer (in minutes)."
	Lack of precision in display of qualitative information	3	Lack of precision in representation in display of qualitative information (e.g., required effort, or difficulty level)	"It was difficult to get a sense of required effort over a module."

Theme 4: Congruence

Participants spoke about the congruency of the CCDs with the "actual" course and how it impacted their reflection on the course. Some participants stated that CCDs provided confirmation of expected outcomes (i.e., congruence) (see Table 7). Others stated that CCDs helped them see that the course structures that they had

Table 7 Overview of themes and codes associated with the third research question

Q3: Do course composition diagrams allow a course team to reflect on the design of an online course? If so, how?

Theme	Code	# of excerpts	Description of code	Exemplar quote
Theme 3: Opportunities for comparison	Comparison	20	Comparison to other courses or representations	"This course, like the first one, still only has one discussion prompt."
Theme 4: Congruence	Congruence	7	Representation was consistent with expectations	"This outline reinforces my expectations/knowledge of the course."
	Incongruence	11	Representation was inconsistent with expectations	"Since [pre-lecture reflections] fall under the 'assessment' symbol, it seems like students are being quizzed more than they really are and in spots in the course that do not necessarily make sense for quizzes."
			Incongruence was also associated with new perspectives that emerged by viewing CCD	"It allowed me to realize that this was a very reading-light course (and I think we knew this all along), but it's even more clear that that's the case when I use this visualization."
Theme 5: Reflection on design choices	Affirming design choices	2	Evaluative statements that affirm design choices	"I would say that this course has a good amount of interactive activities."
	Questioning design choices	6	Tentative statements that question design choices	"I'm worried about having a peer review in the first week of a course."
	Speculating about design choices	8	Speculative statements that hypothesize about the impact of design choices	"Each unit has its signature beginning and ending so your surroundings in the course might stay familiar."
Theme 6: Utility of representation	Potential for future use	7	Consideration of how approach could be used in future processes	"I think this would be most useful when I have additional data, including data from the platform and potentially conversations from learners within the course."
	Reservations about future use	5	Expression of uncertainty of meaning, interpretation, significance, and utility of visualization	"I don't know which is 'better' or which just "looks better" so I am not really sure what I would do with the information."

developed were incongruent with what they had originally envisioned.

Theme 5: Reflection on Design Choices

Participants used CCDs to reflect on their course design choices in three ways: by providing: 1) evaluative statements that affirmed design decisions, 2) tentative statements that questioned design choices, and 3) speculative statements that hypothesized about the impact of design decisions (see Table 7).

Theme 6: Utility of Representation

Participants considered how CCDs could be used in future course design processes, such as to complement other data sources, to inform evaluation and iteration processes, in conversation with faculty, and as a tool for answering research questions (see Table 7). Some participants questioned the utility of the representation and had reservations about its future use, including expressions of uncertainty of meaning, interpretation, and significance.

Discussion

The first two themes that emerged from our analysis address our research questions on CCDs as tools to represent course structure, including what CCDs *reveal* and *obscure* about MOOCs to their design teams: the affordances and limitations of the representations. These findings relate most closely to the literature on design representations, and how they have the potential to foreground certain aspects of a design, bringing various dimensions into clearer focus (Conole 2010). Similarly, they also echo the challenge that Conole (2009) articulates, that of balancing readability with utility.

Participants commented that one of the affordances of the CCD design representation was that it allowed them to perceive the entire course at a glance. This finding is consistent with Conole's (2009) view that diagrammatic or iconic representations are particularly useful for providing a quick overview or "bird's eye view" of a course. Quantitative aspects of individual elements were also immediately apparent, especially when there was extreme variation in the quantity of an element, such as "a lot" or "a little" of one element type (e.g., videos). Surfacing quantitative aspects of a course design could allow designers to see how their pedagogical design relates to MOOC typologies. For instance, MOOCs associated with typologies that relate to the orientation to knowledge (e.g., content acquisition), might have CCDs with a high proportion of elements such as videos and readings.

Participants also remarked that they could see how course elements related to each other. Participants used descriptive language that had semantic connections to the visual language of design. They used terms and phrases that very closely mapped to the principles of design: balance, variety, rhythm, pattern, emphasis, repetition, and movement. In visual art, the principles of design describe the way that the individual elements of design (such as line, color, and shape) are arranged and their relationship to each other (Dewitte et al. 2015; Ragans 2005). CCDs not only enabled members of course design teams to see "what was there" from an objective point of view, they allowed participants to see the relationship of individual elements to the whole course "composition." This finding suggests that participants were able to comprehend course structure in a nuanced way. The CCD provided a visual means of representing pedagogical patterns (Laurillard 2012) and allowed participants to identify when these patterns were quite regular and when there was some variance within the pattern.

With respect to the limitations of the design representation, many participants wanted to see differentiation of elements through specialized icons, such as showing the difference in video length visually. This finding is interesting, because participants could have obtained additional information (such as video length) by hovering over an element, but it appears that they wanted to be able to obtain this information without performing the hovering action. This finding reveals an important tension, that of wanting to provide design practitioners with a representation that is easily understood, without creating a representation that is so simplistic that it ceases to be useful (Conole 2009). These findings suggest possible future directions for CCDs, but we should proceed with caution: if we further differentiate element types, we risk increasing the visual noise and could potentially obscure the representation's meaning. Participants were able to identify patterns in the CCDs used in this study. The addition of more icons could make this task more challenging. One participant remarked that the representation was already "visually noisy" and that it took them some time to *"acclimate to the different icons being used, especially since they didn't intuitively signify the element they represented."*

The remaining four themes address our research question about how CCDs might serve as reflective supports for MOOC design teams: comparison among courses, congruence of representation with experience, reflection on design choices, and utility of the design representation. In reviewing these themes, we saw evidence of reflection when participants referred to CCDs in relation to other CCDs. We also saw evidence of reflection related to participants' design experiences.

The variation in the designs of individual MOOCs in this study is apparent when the CCDs are viewed side by side (see Fig. 3). Participants who viewed multiple CCDs (i.e., those who were involved in more than one design process and were shown two or more CCDs) noted that the CCDs allowed them

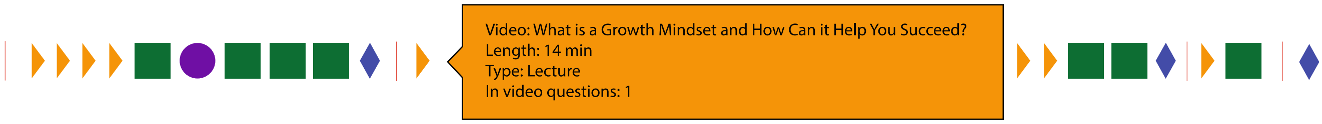

Fig. 3 Course composition diagrams for four MOOCs, including legend for icons

to make comparisons between courses. Although comparison was not central to our methodology, this finding resonates with Blackmon and Major's (2017) assertion that the differences among MOOCs may be as important as their similarities. It also gives credence to the claim that xMOOCs are not monolithic entities (Blackmon and Major 2017). Following Conole's (2014) call for methods and tools that give a more nuanced view of MOOC design, the findings of this study show that CCDs can expose variation in the design of MOOCs.

The CCDs also allowed participants to reflect on their design experience and to evaluate if the representations were congruent with their perception of the course, with some participants declaring that the CCDs provided confirmation and others stating that CCDs surfaced aspects of the design that were previously unknown to them. In this way, the CCDs acted as a mediating artifact, allowing the participants to have a "conversation" with the representation and to listen to the "talk back" of the situation (Fischer and Ostwald 2005). Although mediating artifacts are usually discussed in the context of collaborative design, they can also mediate a design conversation between the designer and their materials (Fischer and Ostwald 2005). Similarly, the CCDs enabled participants to reflect on their design choices, causing participants to affirm, question, or hypothesize. As Sengers et al. (2005) observed, this is an important step in the design process, because by bringing aspects of experience that were previously unconscious to the surface, they become "available for conscious choice" (p. 50) for future processes. In practice, an increase in design experience tends to lead to a decrease in awareness of design decisions, with "informed intuition" replacing specific rules (Gray and Siegel 2014), CCDs could act as a cognitive scaffold for novice designers by decomposing tasks for them (Quintana et al. 2003).

Implications

This study reveals three practical implications of CCDs that can be applied by instructional design teams. First, CCDs can be used as a measure of the extent to which the course design advances instructional goals held by the team. By demonstrating course structure consistency across units, including both across modules within a course and across courses within a series, CCDs can expose potential design flaws about course structure, such as imbalanced learning designs (e.g., an overabundance of readings). Also, with the ease of modifying CCDs in Plotly, when design decisions need to be updated, CCDs can work as a prototyping tool to visualize desired changes of course structures to help design teams understand how newly introduced ideas could influence the overall course design. Second, CCDs can be used to expose the instantiation of particular instructional goals. For example, for course designs that intend to provide active learning experiences for students, design teams can customize CCDs by color coding individual course elements to highlight the differences between instructor-focused interactions (e.g., lecture videos) and learner-focused interaction in a course (e.g., discussion opportunities). Third, in scenarios where some units have introduced MOOC facilitation teams to alleviate burden from instructors, CCDs provide insight to team members who were not part of the original design process, in order to support them as they monitor and facilitate courses. CCDs could be customized to indicate particular types of elements that need higher levels of support once a course has gone live (e.g., peer-graded assignments in courses with lower enrollments).

Limitations

We acknowledge three primary limitations in this study. First, there was an imbalance within our participant pool; project managers outnumbered other types of roles. Although this was roughly representative of the role to role ratios within the MOOC production center we studied, a standard course design team in practice would have a more balanced staff composition. Second, participants held different levels of expertise in learning design and some of them were not trained as learning designers at all. Considering the focus of this study was to understand reflection on *design* specifically, we prioritized the interpretations of those with higher levels of design expertise during analysis. Third, we chose a convenience sample of course design themes that had recently completed ten MOOCs within the production center's project roster. While this allowed participants to accurately recall recent and important details within the design process such as the rationale behind specific decisions, we were constrained to a small number of teams and courses as our sample. Furthermore, we only tested the utility of CCDs on courses that were published on one MOOC platform (Coursera), whose platform affordances lead to course designs that are linear in composition (i.e., without complex branching structures). We chose this approach because the course composition diagram format lends itself to linear representations, but this decision also led to a narrowing of the teams and courses represented in the study.

Future Work

The final theme (utility of the design representation) relates to opportunities we see for building on this work. In our study, participants considered how CCDs could be incorporated within the design processes if they were made an intentional element for reflection. In future work we might consider providing design teams with CCDs as a tool to stimulate discussion with faculty earlier in the design process, thereby potentially opening up "new design spaces" (Sengers et al. 2005). For instance, CCDs could be used to elicit understanding of MOOC typologies (eg., courses oriented towards content acquisition) that are evident within a particular course design. As design teams begin to become familiar with various patterns, they might recognize specific MOOC typologies in relation to these patterns thereby opening up the possibility of engaging in meaningful conversation around course goals and design intent. Although we originally positioned this tool as one that supports reflection "on-action" we also see its potential to support reflection "in-action," allowing design teams to consider and evaluate available information *during* the design process in order to make informed decisions. Furthermore, if CCDs could be automatically generated from existing documentation methods, such as spreadsheet creation, this practice could be more easily integrated into existing workflows, as we recognize that this approach would require additional effort on the part of design teams, including faculty designers. We are interested in pursuing future work that examines design outcomes when CCDs are utilized within the process. In what ways might course designs be influenced by their use and ultimately how might they be improved?

Participants also noted that CCDs could potentially be useful as a tool for answering research questions. While our focus has been on the role of CCDs for use by course design teams, we can see the opportunity for such approaches to be used by educational and design researchers. For instance, researchers might be interested in using CCDs to find commonalities and differences across a group or portfolio of courses. While the representational affordances of CCDs are currently limited to the type of resource or element that can be published on the platform, we see the potential for adding additional information that could become the object of research. Currently, two aspects of design patterns (Laurillard 2012) are not represented 1) contextual information, such as the rationale behind design decisions and 2) reflections on implementation, such as how well a pattern worked and how the pattern could be improved. In future work we could consider how to capture and represent contextual information and reflections in addition to course element data, such as sequence of activities, roles, methods of assessment. Such information could be useful to researchers who want to gain a deeper understanding of design pattern composition and the overall efficacy of these approaches.

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