Automated MOOC/SPOC Learning Design Verification based on Instructional Design Theories

Chi-Un Lei, Xiangyu Hou, Jiaqi Wang, Yanxiang Guo
Technology-Enriched Learning Initiative, University of Hong Kong
Email: culei@hku.hk, hxiangyu@hku.hk, wjq1015@hku.hk, yxguo@hku.hk

ABSTRACT: Teachers often work with course development teams to implement MOOCs and SPOCs. However, existing MOOC instructional quality analysis often requires manual effort and is not supported by instructional design theories. In this paper, we propose an automated MOOC/SPOC learning design verification mechanism based on instructional design theories. The mechanism can quickly visualize the courseware with faulty or at-risk designs that may cause obstacles for learners, which allows just-in-time revisions. The mechanism can facilitate the process of verifying the course design and assessing the quality of the course, and eventually minimize learning hurdles encountered by learners.

Keywords: instructional design, verification, visualization, MOOC, SPOC

1 INTRODUCTION

Plenty of massive open online courses (MOOCs) and small private online courses (SPOCs) have been recently developed for enriching learning experiences (Lei et al., 2015; Guo et al., 2014). In order to rigidly incorporate multifaceted contents in MOOCs and SPOCs, teachers often intensively work with other colleagues to develop their courses. For example, a course development team had spent 4045 working hours for producing three MOOCs, and 22% and 24% of the production effort (in terms of working hours) was contributed by the course teacher and project manager, respectively (Hollands and Tirthali, 2014). E-learning technologists and multimedia professionals were also involved.

In practice, course quality assurance (QA) takes a significant amount of time and effort in the course development process. However, discussions on MOOC instructional quality and QA are mainly about manually analyzing MOOCs (Gamage et al. 2015; Lowenthal and Hodges 2015; Stracke 2017; Margaryan 2015). Among these frameworks, Margaryan's framework is supported by instructional design theories. However, no detailed evaluation scheme was proposed by the team. Therefore, due to the tight production schedule in reality, these frameworks are not practically helpful for adoption to analyze and rectify the design of the course. Currently, instructional designers have not yet fully explored using tools to minimize the effort and time needed for the quality assurance process.

In this paper, we aim to propose an automated MOOC/SPOC learning design verification mechanism. Based on instructional design theories gathered by the literature, the mechanism can identify and visualize faulty or at-risk courseware designs in the actually implemented courseware, from course structure level to learning object level. Such weak designs often cause obstacles for learners in participating learning activities in the course. As a result, learners either ask for peers' support, skip the problematic learning section, or even drop out of the course. The proposed mechanism can facilitate the process of self-verifying the course design and self-assessing the quality of the courses for instructional designers. In other words, the mechanism can minimize learning hurdles encountered by learners and prevent undesirable outcomes (e.g. leading to ineffective learning) (Davies, 1999).

This paper describes how the proposed verification mechanism can be used for MOOC and SPOC designs. Faulty and at-risk designs based on instructional design theories are illustrated in Section 2. The technical implementation of the proposed mechanism is described in Section 3. The mechanism has been evaluated through identifying faulty and at-risk designs of MOOCs and SPOCs. The analyzed result is presented in Section 4. Based on the analyzed result, course instructional designers were agreed for further course design revisions. Further development and adoption of the proposed mechanism are presented in Section 5.

2 TEACHING DESIGN BASED ON ANALYTICS AND LEARNING THEORIES

2.1 Analytics-informed Teaching Design Pattern

Standardized learning design patterns (Laurillard 2013) have been proposed for modeling the learning journey, such that learning design patterns can be shared in the teaching community. An automated learning design synthesizing mechanism has been recently proposed for clustering teaching and learning design patterns in MOOCs (Davis et al., 2018). However, the team has not explored how these clustered learning design patterns could be described by exisiting instructional design theories or could be used for course design or verification. Meanwhile, a “teacher inquiry into student learning” model has been proposed for combining learning analytics and learning design (Alhadad and Thompson, 2017). Based on the model, a learning design studio (Law et al., 2017) has been recently developed for guiding the development of courseware designs. However, this studio requires manual course structure modeling, which is effort-demanding.

Due to the convenience of collecting learning data from learning management systems, traditional evidence-based education framework proposed by Davies (Davies, 1999) had been recently revamped by researchers (Ferguson, 2017). For example, DAPER framework (Ogata et al., 2018) had been proposed to systematically collect data, identify teaching and learning problems through statistical computations and visualizations, measure adopted interventions for producing evidence-based teaching-learning cases (TLCs), and finally reflect on aggregated TLCs for deriving good teaching and learning practices. Some of the research challenges proposed by DAPER include i) how to evaluate evidences, and ii) how to support teachers and learners to apply evidence-informed teaching and learning practices.

2.2 Faulty and At-risk Designs based on Instructional Theories and Practices

A collection of high-level design principles (corollaries) for effective and efficient instructions can be found in Merrill’s “First Principles of Instruction” study (Merrill, 2002). These principles are grouped into five big categories: problem-centered, activation, demonstration, application, and integration. Studies showed that there may be a decrement in learning when the learning design process violates or fails to implement one or more of these principles. After analyzing the courseware through these principles, in order to remove learning hurdles (i.e., prevent undesirable outcomes), revisions may include i) re-organizing learning objects for a coherent learning sequence, ii) changing problematic settings of the learning object, and iii) adding new contents and objects according to the learning design principles.

Selected principles for implementation are shown in Table 1. The selection is based on whether the principle can i) rapidly identify the quality (or "health") of the course for just-in-time learning design interventions, and ii) directly and automatically analyze the courseware source file package (See Section 3). For example, principles related to the "Demonstration" category requires understanding of context inside the object, which is usually course dependent and cannot be generalized. Therefore, we have not modeled principles related to the "Demonstration" category. For illustrations, we have modeled 4 out of 15 principles in the Merrill's study (Merrill, 2002).

Table 1: High-level Instructional design principles essential for promoting students' learning

Principles	Corresponding category	Description
Show tasks	Problem-centered	Learners are shown the problem that they will be able to solve after completing a module. (Van Merriënboer et al. 1997)
Structure	Activation	Learning is promoted when learners are provided or encouraged to recall a structure that can be used to organize the new knowledge. (Dijkstra et al. 2012)
Coaching	Application	Learners are guided in their problem solving by appropriate feedback and coaching. (Dijkstra et al. 2012) [Simplified version]
Reflection	Reflection	Learners can reflect on, discuss & defend their new knowledge or skill. (Laurillard 2002)
Adequate contents	N/A	Contents in the learning object are adequate.
Relevant parameters	N/A	Parameters in the learning object are relevant and within a reasonable range.

For ease of identification, we claim that a courseware has a "faulty" (Critically pedagogically problematic: Students cannot proceed to learn) or "at-risk" (Potentially pedagogically problematic: Students can proceed to learn, but students learn in-effectively) design if one of the following situations is true: i) The amount of learning objects in the learning journey is not in an appropriate proportion; ii) The content is pedagogically insufficient for learning; and iii) The learning object cannot convey the message clearly due to problematic technical settings in the learning object.

3 AUTOMATED LEARNING DESIGN VERIFICATION AND VISUALIZATION

The proposed mechanism can help i) identify problematic settings in learning objects through course-level and object-level verification, and ii) visualize the course design with identified problematic learning objects through course-level visualizations. The mechanism can be adopted in any learning management systems that can export courseware design packages (e.g. (Open) edX, Moodle and Canvas). For other LMSs, course developers can also manually analyze the course and import data based on principles shown in Table 1. In this paper, we used Open edX courseware packages for illustrations. In Open edX, the course design is represented by a zipped package of courseware XML files which specify course objects, including Chapters, Sections, Subsections, Units, and Components/Learning objects, course structure, course assets and course settings.

3.1 Course-level and Object-level Verification

Verification is to ensure the implemented learning design does not violate pre-defined learning design rules. Learning design rules specify restrictions to ensure all learning components function correctly. Table 2 shows detailed design rules for edX/Open edX courses with their corresponding pedagogical problem severity as well as violations of learning design principles listed in Table 1. In the verification process, learning design and course object design parameters are first extracted from XML files. Parameters are then automatically checked for faulty or at-risk designs. If there is no violation, then the learning design passes the inspection. If any faulty or at-risk designs are identified, they will be reported through visualizations, for revision of the courseware design.

Table 2: Detailed design rules for edX/Open edX courses, based on principles shown in Table 1.

Course Structure					
Item description	Severity	Violation	Item description	Severity	Violation
There is no course image or course overview on the landing page.	At-risk	Learner guidance	Number of assessment objects is different from the assessment setting.	Faulty	Relevant parameters
Section, Subsection or Unit is empty.	Faulty	Adequate contents	There is no forum in the course.	At-risk (SPOC) Faulty (MOOC)	Reflection
There is no problem in a Section.	At-risk	Show tasks	There is no introduction for first-time learners.	At-risk	Learner guidance
Learning Object					
Item description	Severity	Violation	Item description	Severity	Violation
The transcript is not available for videos.	At-risk	Learner guidance	The provided link is broken.	Faulty	Adequate contents
The video, images or iframe objects cannot be loaded.	Faulty	Adequate contents	Forum category and subcategory have not been named.	At-risk	Structure
Video, HTML, question, third-party object or forum has not been named.	At-risk	Structure	There is no Learning Tools Interoperability (LTI) ID, LTI URL for third-party objects connected by LTI.	Faulty	Relevant parameters
There is no correct answer in the question.	Faulty	Relevant parameters	There is no hint/feedback for questions.	At-risk	Feedback
There are no pedagogical settings for the assessment question, including the number of maximum attempts, the time required between attempts, the selection of the option for answer retrieval and question resetting.				At-risk	Feedback

3.2 Course-level Visualization

To facilitate instructional designers and teachers analyzing the course design, the tool will visualize the overview of the courseware design, including the number of sections, subsections, units, learning objects and their corresponding locations. The overview can help instructional designers estimate the workload of each section and re-structure contents in sections if contents among sections are not balanced or aligned. Furthermore, identified faulty and at-risk designs, based on instructional design rules shown in Table 2, will also be shown in the visualization. Based on the verification results, problematic components identified in the verification process will be labeled in a subsection level. Based on the visualization, instructional designers can identify faulty/at-risk objects and decide on possible revisions of the courseware.

4 EVALUATION OF THE PROPOSED MECHANISM

4.1 Adoption for Analyzing the Design of a Launched On-Campus SPOC

Figure 1: The verified SPOC design: course structure. The middle bottom figure is a zoomed figure showing the structure of Chapter 7 Sections 1 and 2.

We have adopted the proposed mechanism in a 13-week on-campus general education SPOC. The course was delivered using the flipped classroom approach: students remotely learned concepts of algorithmic design via online videos and quizzes in advance followed by face-to-face learning activities. As shown in the course structure visualization (Fig. 1), each block represents a Section in the course. Its horizontal location is the index of the Chapter, and the vertical position is the index of the Section. The stacked bars in the block show the structure of Section inside. To be specific, the number of bars means the number of subsections in each section, where each bar describes units (contents) inside the Subsection. Colors of the bar indicate different types of contents (e.g. Green: Logistics-related; Purple: Assessment-related; Blue: Content-related). The figure shows that the contents are unevenly distributed among chapters, however, it is typical since contents are arranged according to topics rather teaching weeks. Videos have been heavily used for online activities (Chapters 2-16) except the logistic announcements section (Chapter 1). Google Docs have also been used for online collaborative writing, which is shown to be effective as a pre-class activity.

The instruction for visualization of warnings (Fig. 2) is similar with the course structure, substituting the component type with the issue type (e.g. Red: Faulty; Gray: At-risk), with Section 0 indicating chapter-level issues. The figure shows that questions in chapters can have a better design, such as including more hints or providing concept clarification sessions during the classwork session.

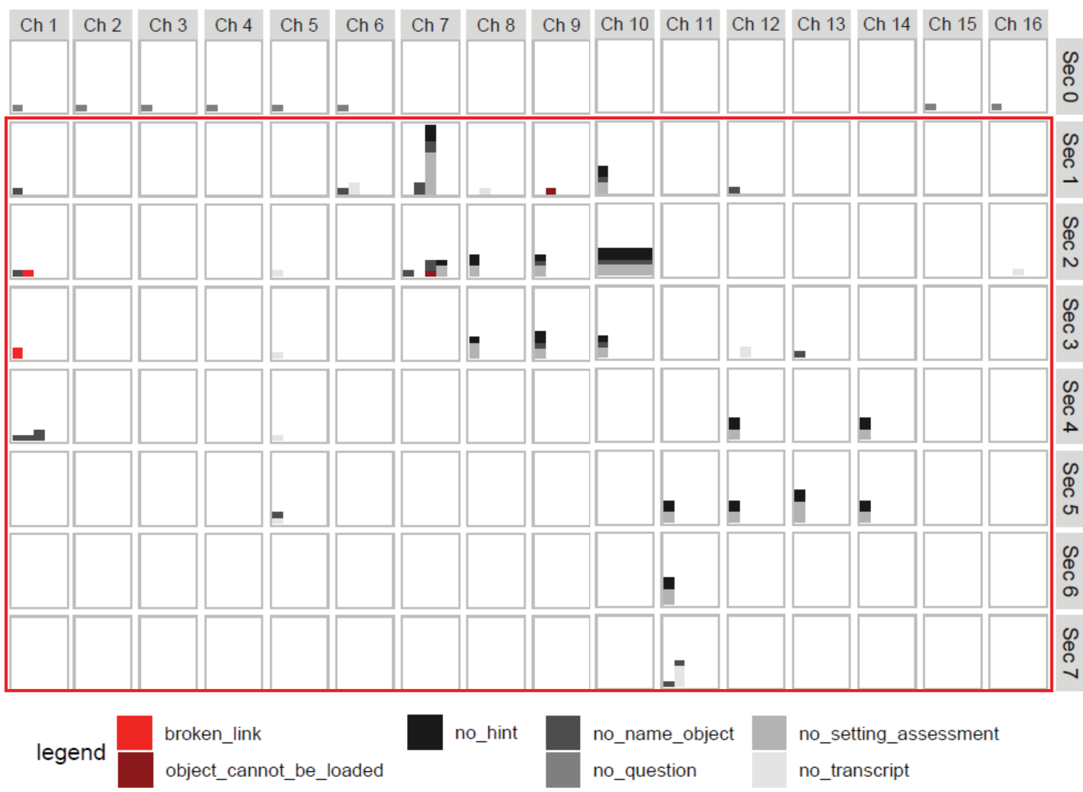

Figure 2: The verified SPOC design: faulty/at-risk components.

The analyzed results had been sent to the course teacher for reflections. She reflected that the analyzed results listed the learning elements with real-time insights on the pedagogical strength, for prompt revisions. She was agreed for revising the course design next cohort, based on generated insights. She reported that it was common that some learning materials were not updated in time, especially when there were multiple offerings of one course in the same academic year. The mechanism addresses these issues with a design of not allowing faulty content to be published and flagging the content that is at risk. She recommended the mechanism can offer in-depth pedagogical guidance through aggregating (sub-)section-level content, since the pedagogy is manifested in not only a single learning activity, but also a series of learning objects arranged in particular sequences.

4.2 Adoption in Analyzing the Design of a Work-In-Progress MOOC

We adopted the proposed mechanism to analyze a MOOC that is in the development stage. The course is about calculus and differential equations and is taught by two teachers. The structure visualization (Fig. 3) shows that there are many interactive learning components which provide a variety of learning experiences for learners that could not be experienced in face-to-face sessions. However, the course still has faulty and at-risk designs (Fig. 4), and thus is not ready for launch. For example, the assessment tasks are not yet well designed, without feedback or learner's guidance provided for questions. Furthermore, the learning design for the first part of the content (Chapters 2-8) is different from the second part of the content (Chapters 9-14) (e.g. how assessments are arranged in the Section level). This is caused by the difference of teaching rationales of the two teachers. After exploring the design, the learning designer decided to redesign the course by i) including more assessment tasks with informative feedback and hints, ii) simplifying contents shown in Chapters 3 and 4, iv) introducing more contents for Chapters 5-8, and iii) revise the contents of chapters for minimizing faulty and at-risk design issues.

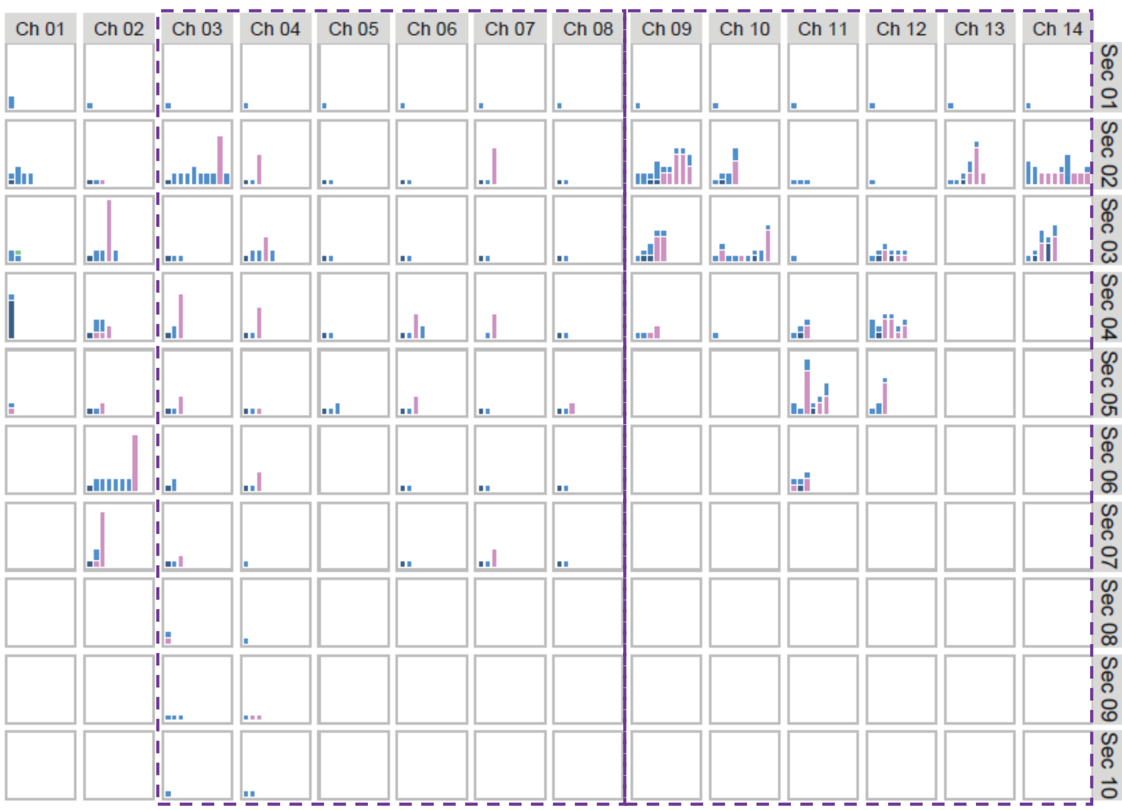

Figure 3: The verified MOOC design: course structure.

4.3 Analyzing the Learning Design of MOOCs and SPOCs

To furthermore illustrate the performance of the proposed mechanism, the course structure of another ten MOOCs and SPOCs were also analyzed. Table 3 describes the analyzed results. In summary, MOOCs tend to have more learning components (e.g. forum discussions and assessments). This is because blended SPOC learners usually have both online and on-campus learning and assessment experiences, but not for MOOC learners. In total, there are with 393 faulty and 2731 at-risk instructional design warnings on these courses, which may be difficult and effort-demanding to be identified manually. This indicates the needs for automatic verifications. For example, pages in HKU03x contain insecure links to external resources, leading to a high number of faulty warnings. It also does not design questions with correct pedagogical settings, leading to a high number of at-risk warnings. The tool provides an efficient way for estimating learners' workload.

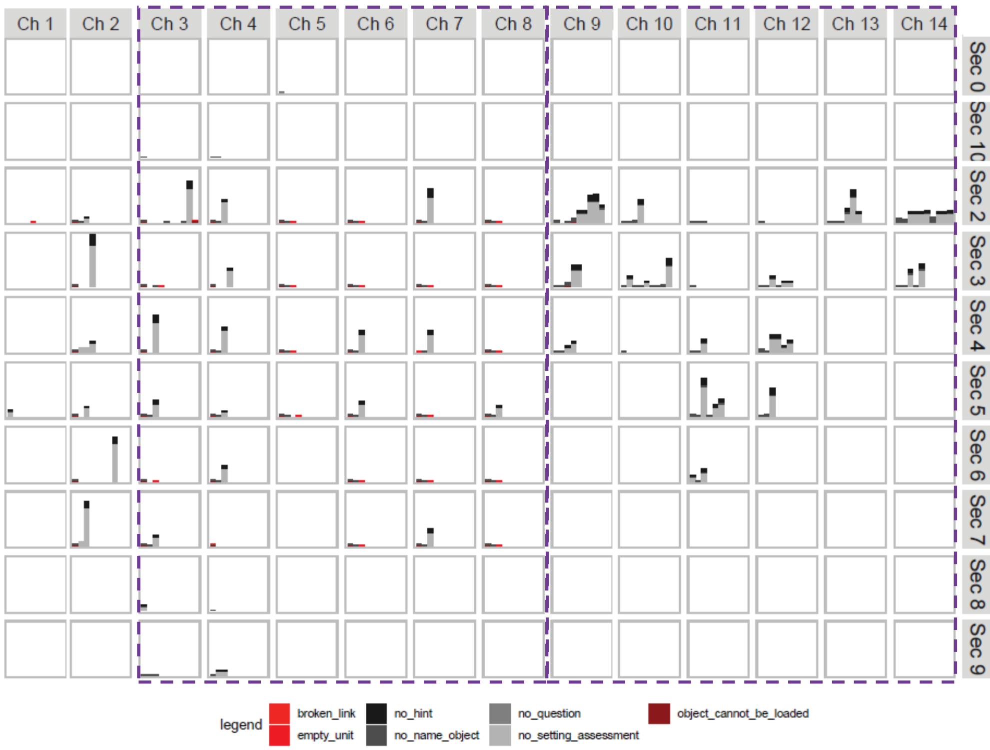

Figure 4: The verified MOOC design: faulty/at-risk components.

Table 3: Summary of the analysis

Course Code	Course Type	Number of Chapters / Sections / Sub-sections	Number of HTML / Video / Problem / Forum / Other components	Number of faulty/at-risk warnings
ARCHx	MOOC	7/59/115	50/80/94/25/9	81/381
HKU01x	MOOC	7/33/131	51/97/124/11/2	24/538
HKU03X	MOOC	14/150/245	117/126/238/8/2	201/961
HKU04x	MOOC	7/36/84	128/63/31/16/3	25/129
HKU06x	MOOC	10/125/219	80/98/78/18/4	13/332
ELEC3542	SPOC (On-campus)	12/28/31	20/26/0/0/4	0/16
CCHU9001	SPOC (On-campus)	13/64/65	83/19/0/0/4	4/32
NURS	SPOC (Training)	7/27/91	147/7/20/0	23/92
IOL	SPOC (Training)	5/9/14	9/7/19/0/0	0/108
ILT	SPOC (Training)	6/23/57	78/35/25/7/0	22/142

Table 4 shows some of the popular issues identified by the mechanism. Most issues are related to URL links shown on the courseware as well as inappropriate design of assessment questions, which may be effort-demanding to be identified manually. This tool can quickly identify issues for revisions, which leads to a more efficient development progress and eventually a more effective learning.

Table 4: Major issues identified by the mechanism (10 MOOCs).

Issues	Severity of the issues	Number of issues
The provided link cannot be loaded.	Faulty	305
The provided link is broken.	Faulty	80
There is no pedagogical settings for the question.	At-risk	1889
There is no hint/feedback for questions.	At-risk	748
The component has not been named.	At-risk	31
There is no problem in a Section.	At-risk	48

5 CONCLUSIONS

An automated course learning design verification mechanism, based on instructional design theories, has been proposed in this paper. Through the mechanism, problematic designs can be identified and revised immediately, for preventing undesirable outcomes (learning obstacles). The mechanism has been evaluated through identifying faulty and at-risk designs of twelve MOOCs and SPOCs. Possible extensions for the mechanism include i) verifying MOOCs/SPOCs implemented in other LMSs, ii) auto-correcting learning design with faults, and iii) auto-identifying good teaching design patterns. Natural language processing techniques could also be introduced to understand the contents in learning objects for a more informative instructional design analysis.

REFERENCES

Alhadad, S. S., & Thompson, K. (2017). Understanding the mediating role of teacher inquiry when connecting learning analytics with design for learning. *Interaction, Design, & Architecture (s)*, 33, 54-74.

Davies, P. (1999). What is evidence-based education?. *British journal of educational studies*, 47(2), 108-121.

Davis, D., Seaton, D., Hauff, C., & Houben, G. J. (2018, June). Toward large-scale learning design: categorizing course designs in service of supporting learning outcomes. In *Proceedings of the Fifth Annual ACM Conference on Learning at Scale* (p. 4). ACM

Dijkstra, S., Schott, F., Seel, N., Tennyson, R. D., & Seel, N. M. (2012). *Instructional Design: International Perspectives: Volume I: Theory, Research, and Models; Volume II: Solving Instructional Design Problems.* Routledge.

Ferguson, R., & Clow, D. (2017, March). Where is the evidence?: a call to action for learning analytics. In *Proceedings of the seventh international learning analytics & knowledge conference* (pp. 56-65). ACM.

Gamage, D., Fernando, S., & Perera, I. (2015, August). Quality of MOOCs: A review of literature on effectiveness and quality aspects. In *Ubi-Media Computing (UMEDIA), 2015 8th International Conference on* (pp. 224-229). IEEE.

Guo, P. J., Kim, J., & Rubin, R. (2014, March). How video production affects student engagement: an empirical study of MOOC videos. In *Proceedings of the first ACM conference on Learning@ scale conference* (pp. 41-50). ACM.

Hollands, F. M., & Tirthali, D. (2014). Resource requirements and costs of developing and delivering MOOCs. *The International Review of Research in Open and Distributed Learning*, 15(5).

Laurillard, D. (2002). *Rethinking university teaching: A conversational framework for the effective use of learning technologies*. Routledge.

Laurillard, D. (2013). *Teaching as a design science: Building pedagogical patterns for learning and technology*. Routledge.

Law, N., Li, L., Herrera, L. F., Chan, A., & Pong, T. C. (2017). A pattern language based learning design studio for an analytics informed inter-professional design community. *Interaction Design and Architecture (s)*, 92.

Lei, C. U., Hou, X., Kwok, T. T., Chan, T. S., Lee, J., Oh, E., ... & Lai, C. (2015, December). Advancing MOOC and SPOC development via a learner decision journey analytic framework. In *Proceedings of the International Conference on Teaching, Assessment, and Learning for Engineering*, (pp. 149-156). IEEE.

Lowenthal, P., & Hodges, C. (2015). In search of quality: Using Quality Matters to analyze the quality of massive, open, online courses (MOOCs). *The International Review of Research in Open and Distributed Learning*, 16(5).

Mayer, R. E. (2002). Multimedia learning. In *Psychology of learning and motivation* (Vol. 41, pp. 85-139). Academic Press.

Margaryan, A., Bianco, M., & Littlejohn, A. (2015). Instructional quality of massive open online courses (MOOCs). *Computers & Education*, 80, 77-83.

Merrill, M. D. (2002). First principles of instruction. *Educational technology research and development*, 50(3), 43-59.

Ogata, H., Majumdar, R., Akçapınar, G., Hasnine, M., & Flanagan, Brendan. (2018). Beyond Learning Analytics: Framework for Technology-Enhanced Evidence-Based Education and Learning. In *Proceedings of the 26th International Conference on Computers in Education*.

Stracke, C. M. (2017, July). The Quality of MOOCs: How to improve the design of open education and online courses for learners? In *International Conference on Learning and Collaboration Technologies* (pp. 285-293). Springer, Cham.

Van Merriënboer, J. J. (1997). Training complex cognitive skills: A four-component instructional design model for technical training. *Educational Technology*.