More than the Sum of its Parts: Designing Learning Formats from Core Components

Niels Heller
Institute for Informatics, Ludwig Maximilian University of Munich
Munich, Germany
niels.heller@ifi.lmu.de

Sebastian Mader
Institute for Informatics, Ludwig Maximilian University of Munich
Munich, Germany
sebastian.mader@ifi.lmu.de

François Bry
Institute for Informatics, Ludwig Maximilian University of Munich
Munich, Germany
bry@lmu.de

ABSTRACT

With increasing numbers of students in tertiary STEM education and stagnating numbers of available teaching staff, large class lectures often remain the last resort. Lectures are not inherently bad, but they tend to foster negative learning attitudes among students like passivity and a feeling of isolation. Furthermore, some topics are better taught using other formats than lectures. Technology in the form of educational software enables a more appropriate learning and various teaching formats deployable in large classes. This article first identifies core components of educational software based on today's information technology and second demonstrates how these components can be combined in different manners resulting in various learning and teaching formats. The core components are: document management, workflow management, content enrichment, input interactions, learning analytics, and system messaging. The contribution of this article is threefold: Core components of educational software are proposed and motivated, four teaching methods and four learning and teaching formats are proposed that build upon the aforementioned core components, and field evaluations of three of these formats are reported about.

CCS CONCEPTS

• **Human-centered computing → Collaborative and social computing systems and tools**; • **Applied computing → Computer-assisted instruction**; **Collaborative learning**; **Learning management systems**; **E-learning**; **Computer-managed instruction**;

KEYWORDS

Learning Management Systems, Learning and Teaching Formats Computer-supported Collaborative Learning, Conceptual Framework

ACM Reference Format:

Niels Heller, Sebastian Mader, and François Bry. 2019. More than the Sum of its Parts:, Designing Learning Formats from Core Components. In *The 34th ACM/SIGAPP Symposium on Applied Computing (SAC '19), April 8–12, 2019, Limassol, Cyprus.* ACM, New York, NY, USA, Article 4, 4 pages. https://doi.org/10.1145/3297280.3297638

SAC '19, April 8–12, 2019, Limassol, Cyprus

ACM ISBN 978-1-4503-5933-7/19/04.
https://doi.org/10.1145/3297280.3297638

1 INTRODUCTION

Teaching in higher education often benefits from different teaching and learning formats, such as flipped classrooms or jigsaw teaching that can be easily implemented for small class sizes. Yet, with increasing number of students [1] and a high student-to-teacher ratio (142 students to one professor as of 2014 and 212 as of 2018 at the authors' institute), many formats appropriate for small classes become unpractical, often leaving the lecture as the last resort.

While large class lectures are not inherently bad, they tend to foster negative learning attitudes among students [4] and negatively affect the learning outcomes [15]. Increasing staff numbers to counteract this problem is not always feasible due to organizational obstacles, but with educational software there is an alternative approach to tackling the problem: Instructors are provided with means to delegate tasks to software and students are supported by software in their learning.

While there is a multitude of learning management systems (LMS) which allow to conduct some kind of learning and teaching, these often seem to be restricted to few learning formats. In order to easily create and evaluate novel learning and teaching formats, a toolbox of reusable core components with well defined interfaces would be of great use. During the implementation of Backstage[1], it became evident that many different formats can be built from a small set of components – a toolbox for creating said formats.

The benefit of such a toolbox would be twofold: First, it can help developing new, or improving existing learning management *systems* by providing a shared conceptual space and a shared vocabulary to software developers and researchers. Second, it can be used to develop and describe learning and teaching *formats* a learning management system can offer and well support by describing how and to what purposes the components are used.

The original contributions of this article are threefold, first, it introduces a principled proposal of six core components of learning management systems that are sufficient to cover a manifold of learning formats and identifies uses of these components in existing LMSs; second, real-live examples of learning formats built using the introduced components are presented; third, evaluations of these formats with the educational software Backstage are reported about.

2 RELATED WORK

This article is a contribution to LMS frameworks, as it defines core components provided by LMSs that can be used to define learning formats. Together, those components constitute a constructive

[1] https://backstage2.pms.ifi.lmu.de:8080/about

framework that focusses on the technical functionality, but not on their pedagogical purpose. The following section reflects on similarities and differences to existing frameworks in this research field.

Essential functionalities of LMS are content management, delivery, and exchange. To describe these functionalities, the terms "learning object" (LO) and "learning object repository" (LOR) are often used in the literature. A learning object is a "digital object that is used in order to achieve the desired learning outcomes or educational objectives" [14, p. 87] with a LOR being a web-hosted collection of LOs [18].

Service-based LMS architectures are of special interest in the literature. For instance, Chu et al. [2] model LMSs as a composition of 7 services: "a tracking service; a delivery service; a learner profile service; a course management service; a content management service; a test/assessment service; and a sequencing service." [2, p. 157]. In Chu et al.'s framework, the course and content management services are similar to the document management component proposed below. The sequencing service selects "appropriate content" for the learners during the learning process, and can hence be seen as a specialisation of the workflow management component. The learner profile service provides learner information such as learning status. In the framework described in this article, such information would be provided by the learning analytics component.

Another service oriented framework, named TELOS, is proposed by Paquette et. al [16]. It employs a strong role management (like Learners, Learner Facilitators, and Administrators) and defines for each role which services may be used. A "Learner Facilitator" could for instance use the evaluation service to evaluate a learner's competence, while this is not possible for other learners. TELOS offers learners the possibility to add new resources, a resource annotation service, and a commenting service that broadly follows the definition of the content enrichment component defined below.

Ismail [9] proposes a conceptual framework by identifying three subsystems of LMSs: The learning content management system, the learning design system, and the learning support system [9]. The learning content management system is similar to the document management component defined below while laying a strong focus on collaborative content creation. The learning support system offers teachers means to organise learning activities and material (resembling the workflow management component), learners functionalities for collaborative learning (broadly resembling the content enrichment component), and tests and assessments (similar to the input interaction component).

Kazi [11] a framework focussed on learner personalization consisting of four modules: A communication module used to display content and to receive user inputs, an expert module analyzing student responses and producing appropriate feedback, a student module gathering performance data, and a pedagogical module which provides the next content to be addressed by the learner [11].

More recently, authors have focussed on collaborative frameworks and practical applications. Šimko et al. propose the ALEF framework [19] which offers rich collaborative annotation and tagging possibilities.

3 CORE COMPONENTS

In order to define LMS components that support a large number of learning formats, two features were considered: First, components should be defined for versatility, and not for a specific use case. Second, components should not share responsibilities. In this section, six LMS core components are defined by these guidelines and then evaluated in a structured LMS survey.

Most learning in tertiary education is based on documents. Therefore, LMSs have to implement a *Document Management and Document Organization* component.

Learning is typically guided: A *Workflow Management* component provides users with guidance in what task to address next. Workflow management encompasses for example collaborative scripts [12].

A *Content Enrichment* component allows users to add new information to a LMS. This can be either done by adding new documents, or by enriching existing material for example with annotations.

An *Input interaction* component gives users the ability to learn the topics in an active way, for example through multiple-choice quizzes, code editors, or interactive geometry software.

A *Learning Analytics* component generates reports by interpreting data collected from other components of a LMS. They can be used by other components for providing feedback or for adapting their behaviours to a learner's needs.

A *System Messaging* component forwards messages generated by other components of a LMS to learners or groups of learners. Examples of system messaging are notifications on actions to be taken, on tasks to fulfil, or information on actions or tasks that have taken place.

3.1 How Existing LMSs are Composed

In order to evaluate whether the six components listed in the previous section are sufficient to describe LMSs, a survey of existing LMSs has been conducted. Searches were performed using Google (in English language) with the following keywords: *learning management system*, *virtual learning environment*, and their plural forms. Every LMS found on the first two result pages was considered; in case of a collection, the first twenty were considered.

Only the information available on the LMS' official website has been used for classification; a demo was used when no registration was required. Each LMS was classified by two judges, who discussed their classification until consensus was reached.

A total of 86 LMSs were identified, 26 of which were discarded for various reasons such as service discontinuation, the platform not being an LMS, or the information publicly available on the LMS' website being insufficient for an assessment of its functionalities.

Table 1 shows that a third of the LMSs implement all of the aforementioned six components, with LMSs implementing less than five components making only a third of all examined systems. Table 2 shows that system messaging and content enrichment functionality are the two components left out by most LMSs, with the remaining four being implemented in most systems.

A limitation of the survey is that a LMS might implement one the six components considered without mentioning it on its website.

While most LMSs have content enrichment and system messaging functionalities, these components are implemented by fewer

Table 1: Percentage of LMS implementing several components.

Number of Components	1	2	3	4	5	6
Percentage	0%	2%	10%	22%	35%	33%

Table 2: Percentage of LMS implementing each component.

Component	Percentage of Platforms
Document Management	100%
Workflow Management	88%
Content Enrichment	65%
Input Interactions	92%
Learning Analytics	85%
System Messaging	55%

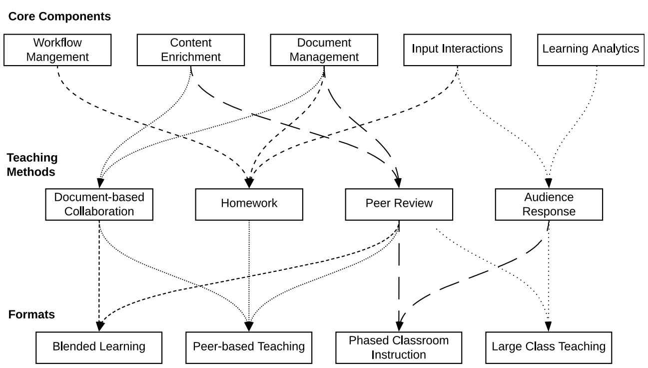

Figure 1: The composition of core components into teaching methods and the composition of teaching methods into learning and teaching formats.

LMSs than the other components. This is worth stressing because content enrichment and system messaging are the main enablers of social and collaborative learning in this framework.

Since most of the six components defined in Section 3 can be identified in most LMSs, it is fair to conclude that this set of components is an appropriate a basis for conceiving a LMS.

Whether the six components listed above are sufficient to describe all, or at least almost all, features of an LMS has to be further evaluated. Yet, such an evaluation is a hardly possible task in light of missing demonstration and potentially incomplete documentation. Nonetheless, with theses six components, a variety of different learning and teaching formats can be conceived which is discussed in the next section.

4 LEARNING AND TEACHING FORMATS

In this section, the core components are now first composed into teaching methods, which are "a set of principles, procedures or strategies to be implemented by teachers to achieve desired learning in students." [22, p. v] These teaching methods are then again composed into learning and teaching formats. This was done to allow reuse of teaching methods in different teaching formats.

Figure 1 shows a non-exhaustive overview of compositions of core components into first teaching methods and then into learning teaching formats. System messaging is omitted, as this component does not enable but improve teaching methods.

4.1 Teaching Methods

This section briefly describes four teaching methods, peer review, document-based collaboration, homework, and quizzes.

Peer Review. Peer review or peer assessment has been defined as "an arrangement in which individuals consider the amount, level, value, worth, quality, or success of the products or outcomes of learning of peers of similar status" [20, p. 250]. Its positive effects have been described in literature [5, 23].

Two components are needed for implementing peer review: document management and content enrichment. Document management provides access to the content to be reviewed, and content enrichment provides the means for creating peer reviews. As of content enrichment for peer reviews, various forms are imaginable: From annotations directly on the reviewed document, to the creation of an independent document containing the feedback.

Document-based Collaboration. By providing a document management system as well as content enrichment functionalities, various forms of collaboration on documents are possible: students can author a document together, or create comments on their peers' work.

Backchannels allow a special form of document-based collaboration: A backchannel provides a shared communication channel for student and lecturer alike that allows for communication besides a running lecture [24].

Homework. The teaching method homework can be realised by combining document management (to store submissions), input interactions (to create submissions), and workflow management (to assign tasks).

While the effects of homework on learning outcomes are still debated [3, 21], homework is mostly considered beneficial because it can mediate self-efficacy [25] and because it allows teachers to give feedback which is known to be beneficial for learning [6].

Audience Response. Audience response systems (ARS) are software that provide means for submission, aggregation, and display of an audiences' responses to a lecturer's prompts [10].

Input interactions provide an ARS with the means to provide a variety of quizzes, that is, an input interaction available on a system can be used for quizzes. Learning analytics aggregate students' answers and provide visualizations.

4.2 Learning and Teaching Formats

This section describes four learning and teaching formats designed by combining the teaching methods discussed above in Section 4.1.

Peer-based Teaching. In this format, students are tasked to study learning material, deliver homework submissions, and review each other's submissions afterwards. The course format is suitable for situations where there is a shortage of teaching staff as many of the lecturer's duties are realized by software or by students [7].

This format has been used and evaluated in a course on functional programming with 45 participants in [7]. Exercises in this course were practical programming tasks and theoretical questions on functional programming. To facilitate practical tasks, the platform provided students a code editor with compilation functionality. Students showed a positive attitude towards the course format. The use of the code editor correlated positively with examination results but not with the mere participation in the course.

Blended Learning. This format encompasses students collaboratively collecting content, writing a larger body of text, and finally reviewing other students' submissions. This format is applicable in contexts where students work on different (but related) topics independently, while they should gain knowledge of all topics [13].

This format was used and evaluated in a seminar on job applications for computer scientists. Students collected content about how to write a job application, wrote an application referring to a mock job advert, and reviewed other students' applications. The students' attitude towards the seminar was positive, collaborative content collection was received well, especially the peer review and the access to all job applications and to all peer reviews [13].

Large Class Teaching. Large classes are usually taught in form of lectures, where interactivity is often impeded by the audience's social inhibition. Additionally, over the course of a lecture, the audience's attention drops. Document-based collaboration in form of a backchannel can be used to reduce social inhibition; an audience response system makes a change of medium, here in form of quizzes, possible with large classes [17].

The format has been evaluated in four classes with varying numbers of students. The students' attitude towards the use of the format was generally positive [17].

Phased Classroom Instruction. Learning formal languages requires application, something that is hardly possible in larger classes. This format proposes alternating mini-lectures of about 20 to 25 minutes, with larger exercises of about 45 minutes. The format can be supported by an audience response system with appropriate input interactions. The format was initially introduced in [8].

5 SUMMARY AND PERSPECTIVES

Technology has the potential for tackling one of education's most impending problems: the steadily rising number of enrolments with stagnating numbers of teaching staff. Technology-enhanced formats provide teachers and students with means to teach and learn – even if the audience size is larger than suitable for the corresponding traditional format.

Driven by the goal of reusing an existing technology for novel learning and teaching formats, this article has introduced a constructive framework, describing a format as a composition of teaching methods, which are in turn composed of core components. Six core components of LMSs were identified and later validated with a structured survey, and and their applications demonstrated by means of four learning and teaching formats.

The proposed "toolbox" of core components enables "format designers" to easily create new formats using a set of tools only implemented once. This allows for faster development and deployment of new formats, and opens avenues for a more experimental approach to learning and teaching: New formats can be tried out without having to fear that, in case of failure, a software system becomes obsolete.

REFERENCES

[1] Philip G Altbach, Liz Reisberg, and Laura E Rumbley. 2009. Trends in global higher education: Tracking an academic revolution.
[2] Chih-Ping Chu, Ching-Pao Chang, Chung-Wei Yeh, and Yu-Fang Yeh. 2004. A web-service oriented framework for building SCORM compatible learning management systems. In *Information Technology: Coding and Computing, 2004. Proceedings. ITCC 2004. International Conference on*, Vol. 1. IEEE, 156–161.
[3] Harris Cooper. 1989. Synthesis of research on homework. *Educational leadership* 47, 3 (1989), 85–91.
[4] Graham Gibbs. 1982. Twenty terrible reasons for lecturing. Standing Conference on Educational Development Services in Polytechnics.
[5] Stephanie J Hanrahan and Geoff Isaacs. 2001. Assessing self-and peer-assessment: The students' views. *Higher Education Research & Development* 20, 1 (2001), 53–70.
[6] John Hattie and Helen Timperley. 2007. The power of feedback. *Review of educational research* 77, 1 (2007), 81–112.
[7] Niels Heller and François Bry. 25-28 September 2018. Peer Teaching in Tertiary STEM Education: A Case Study. In *The Challenges of the Digital Transformation in Education - Proceedings of the 21st International Conference on Interactive Collaborative Learning (ICL2018)*, Vol. 2. Springer, to appear.
[8] Niels Heller, Sebastian Mader, and François Bry. 2018. Backstage: A Versatile Platform Supporting Learning and Teaching Format Composition. In *Proceedings of the 18th Koli Calling International Conference on Computing Education Research.* ACM, 27.
[9] Johan Ismail. 2001. The design of an e-learning system: Beyond the hype. *The internet and higher education* 4, 3-4 (2001), 329–336.
[10] Robin H Kay and Ann LeSage. 2009. Examining the benefits and challenges of using audience response systems: A review of the literature. *Computers & Education* 53, 3 (2009), 819–827.
[11] Sabbir Ahmed Kazi. 2004. A conceptual framework for web-based intelligent learning environments using SCORM-2004. In *Advanced Learning Technologies, 2004. Proceedings. IEEE International Conference on.* IEEE, 12–15.
[12] Lars Kobbe, Armin Weinberger, Pierre Dillenbourg, Andreas Harrer, Raija Hämäläinen, Päivi Häkkinen, and Frank Fischer. 2007. Specifying computer-supported collaboration scripts. *International Journal of Computer-Supported Collaborative Learning* 2, 2-3 (2007), 211–224.
[13] Sebastian Mader and François Bry. 16-19 September 2014. Blending Classroom, Collaborative, and Individual Learning using Backstage 2. In *Methodologies and Intelligent Systems for Technology Enhanced Learning, 8th International Conference.* Springer, to appear.
[14] Rory McGreal. 2004. *Online education using learning objects.* Psychology Press.
[15] James Monks and Robert M Schmidt. 2011. The impact of class size on outcomes in higher education. *The BE Journal of Economic Analysis & Policy* 11, 1 (2011).
[16] Gilbert Paquette, Ioan Rosca, Stefan Mihaila, and Anis Masmoudi. 2007. TELOS: A service-oriented framework to support learning and knowledge management. In *E-Learning Networked Environments and Architectures.* Springer, 79–109.
[17] Alexander Pohl. 2015. *Fostering Awareness and Collaboration in Large-Class Lectures.* Ph.D. thesis. Institute for Informatics, Ludwig Maximilian University of Munich.
[18] Lakshmi Sunil Prakash, Dinesh Kumar Saini, and Narayana Swamy Kutti. 2009. Integrating EduLearn learning content management system (LCMS) with cooperating learning object repositories (LORs) in a peer to peer (P2P) architectural framework. *ACM SIGSOFT Software Engineering Notes* 34, 3 (2009), 1–7.
[19] Marián Šimko, Michal Barla, and Mária Bieliková. 2010. ALEF: A framework for adaptive web-based learning 2.0. In *Key Competencies in the Knowledge Society.* Springer, 367–378.
[20] K. Topping. 1998. Peer Assessment Between Students in Colleges and Universities. *Review of Educational Research* 68, 3 (1998), 249–276. https://doi.org/10.3102/00346543068003249
[21] Ulrich Trautwein and Olaf Köller. 2003. The relationship between homework and achievement – still much of a mystery. *Educational psychology review* 15, 2 (2003), 115–145.
[22] Peter S Westwood. 2008. *What teachers need to know about teaching methods.* Australian Council Educational Research.
[23] Eira Williams. 1992. Student attitudes towards approaches to learning and assessment. *Assessment and evaluation in higher education* 17, 1 (1992), 45–58.
[24] Sarita Yardi. 2006. The role of the backchannel in collaborative learning environments. In *Proceedings of the 7th international conference on Learning sciences.* International Society of the Learning Sciences, 852–858.
[25] Barry J Zimmerman and Anastasia Kitsantas. 2005. Homework practices and academic achievement: The mediating role of self-efficacy and perceived responsibility beliefs. *Contemporary Educational Psychology* 30, 4 (2005), 397–417.