Overcoming Challenges to the Adoption of Learning Analytics at the Practitioner Level: A Critical Analysis of 18 Learning Analytics Frameworks

Rogers Kaliisa[1], Anders Kluge[2] and Anders I. Mørch[3]

[123]*Faculty of Educational Sciences, Department of Education, University of Oslo, Oslo, Norway*

Abstract

Learning analytics (LA) is a fast-growing field but adoption by teachers remain limited. This paper presents the results of a review of 18 LA frameworks and discusses how they have tried to address prominent challenges in LA adoption. The results show that researchers have made significant advances in developing appropriate frameworks to conceptualize LA adoption among teachers, and have advanced considerably in connecting LA and learning theory. However, few frameworks are concretized into technological artefacts and concrete data streams. Moreover, there is a need to empirically validate and put into use the most promising existing frameworks. We hope that this review will be informative for teachers who have little LA experience but are interested in adopting LA in authentic practice.

Keywords: Learning analytics, frameworks, models, guidelines, teacher, adoption, challenges, orchestration

Introduction

Due to the emergence of big data and the increased use of technology in higher education, a field of learning analytics (LA) has emerged since 2011 that aims to explore how data generated from students' interactions with digital applications can be analysed and utilised to offer personalised experiences to students and effective learning design (Mor, Ferguson, & Wasson, 2015). LA is concerned with the measurement, collection, analysis and reporting of data about learners and their contexts for the purposes of understanding and optimising learning and the environments in which it occurs (Siemens & Long, 2011). These kinds of data, if suitably collected and analysed, can stimulate teaching and learning processes by providing immediate feedback and proactive evaluations of students' learning (Persico & Pozzi, 2015), particularly in online-based learning environments. For example, Herodotou et al (2019) evaluated the impact of predictive LA, when provided to teachers in a distance learning higher education institution. The key finding was that teachers could positively affect students' performance when engaged with predictive LA. Moreover, Kaliisa, Mørch and Kluge (2019) employed social learning analytics (SLA) approaches (e.g., network and content analysis) to analyse students' online course discussion forums. The results identified and highlighted important insights about students' cognitive learning processes (e.g., the quality and type of contributions made by students) and social learning processes (e.g., students' interaction dynamics). More recently, Vezzoli et al (2020) in a design based LA project with teachers reported that teachers identified LA as a mechanism through which to obtain feedback on their practices (e.g., assessment and teaching styles) in a data-driven way. Accordingly, such insights can raise teachers' awareness and reflection, which could provide a good basis for teachers to make timely, informed educational decisions.

However, just like other educational technologies that higher education has been slow to adopt (Gunn, McDonald, Donald, Nichols, Milne, & Blumenstein, 2017), best practice examples of LA use by teachers at the classroom level remain limited, and those teachers making systematic and pedagogically informed decisions using LA are a small group of early adopters (Persico & Pozzi, 2015). Yet teachers are considered the key users of LA as they are constantly engaged in a reflective cycle of exploring student learning processes to inform their teaching practice. Moreover, teachers are the engine of innovation in

1

education, and any development that fails to consider their needs is bound to fail (Ferguson, Brasher, Clow, Cooper, Hillaire, Mittelmeier, & Vuorikari, 2016). Therefore, it is necessary that teachers are empowered and supported to effectively adopt LA in their practice (Rienties, Boroowa, Cross, Kubiak, Mayles, & Murphy, 2016). This paper attempts to build further on this observation by examining the challenges to LA adoption by teachers, and how the different LA adoption frameworks relevant for teachers have contributed towards overcoming such challenges. Our intention is to provide insights that frame the adoption of LA in teachers' practice.

Background

The slow adoption of technology in higher education is a key challenge that is not particularly unique to LA, but to all fields within the learning sciences (Becker et al., 2018). Among the many barriers deterring teachers from integrating LA into their everyday practice may be the technical, pedagogical, perceptive and ethical challenges (Wasson, Hanson, & Mor, 2016), as well as the unanswered questions with respect to the effectiveness and usefulness of LA towards teacher practice (Dawson, Joksimovic, Poquet & Siemens, 2019). Prompted by the need to look into the challenges facing teachers when adopting technology, a new strand of research often referred to as 'orchestration' has emerged. Orchestration is an approach to technology-enhanced learning that addresses the challenges of technology use in the classroom (Prieto, Dlab, Gutiérrez, Abdulwahed, & Balid, 2011; Roschelle, Dimitriadis, & Hoppe, 2013). Orchestration is a way to approach classroom activities that empowers teachers and advocates for the use of simple technologies and tools to form a totality for the students (Prieto, Rodríguez-Triana, Martínez-Maldonado, Dimitriadis, & Gasevic, 2018). Thus, guided by the principles of orchestration (e.g., design and planning; adaptation and intervention; awareness and assessment; and intervention, regulation and management), the LA research community has devoted considerable efforts to develop strategies to overcome teachers' challenges while using LA in their everyday practice in order to encourage them to favour adoption (Prieto, Rodríguez-Triana, Martínez-Maldonado, Dimitriadis, & Gasevic, 2018).

Part of this effort has been developing frameworks and models, driven by a belief that they will offer practical guidance to teachers in the use of LA (Ferguson et al., 2016). One of the early frameworks is checkpoint and process analytics proposed by Lockyer et al (2013). The framework considers two dimensions of LA: (I) checkpoint analytics-which highlights students' access to the course content and (2) process analytics, which captures students' interaction processes. More recently, aiming to support teachers in making informed learning design decisions, Hernandez-Leo, Martínez-Maldonado, Pardo, Munoz-Cristobal and Rodríguez-Triana (2018) presented a framework (analytics layers for learning design) that articulates three layers of data analytics—learning analytics, design analytics and community analytics.

Study aim and research questions

Although many frameworks have been created to support LA adoption at practitioner level, their application is not widespread. Their effectiveness in encouraging teachers to adopt LA has not yet been conclusively demonstrated, and is therefore largely speculative (Ferguson et al., 2016). Moreover, the frameworks are currently fragmented, which makes it difficult for teachers to choose between them and select those that will provide solutions to their problems. To the best of our knowledge, and through a search of the relevant literature, there has been no study to date that has attempted to examine the different frameworks meant to guide teachers' adoption of LA, to identify the main issues they address and common overlaps among them and to explore how these issues and overlaps are productively conceptualised to address the challenges teachers face in LA adoption. Colvin, Dawson, Wade and Gašević (2017), who explored various models informing LA adoption, have conducted research that is comparable to the present study. The focus of Colvin et al (2017), however, was on institutional LA adoption, rather than on micro-level adoption at the course or teacher level.

In the present paper, we take a first step in closing these identified gaps. The goal of this descriptive review is twofold. First, we aim to critically analyse teachers' potential challenges when adopting LA based on a review of the relevant literature. Second, we contextualise teachers' adoption of LA with theoretical insight into the existing LA frameworks and critically assess their relevance in helping teachers overcome

existing LA adoption challenges. Consequently, the study highlights the strengths and weaknesses of the different frameworks, thus providing a frame of reference for teachers on what framework and strategies to use during LA adoption. The paper is guided by the following questions.

RQ1. What are teachers' challenges in adopting LA in everyday practice?
RQ2. What are the features of existing LA frameworks, and how do they help teachers to overcome the challenges of LA adoption?

In the context of this paper, 'LA framework' and 'LA model' are used synonymously to mean a set of guidelines meant to guide and support the practice of LA adoption. This paper uses the term 'LA adoption' to describe the act of teachers beginning to use LA tools to support their everyday practice, such as in course and module design, planning, assessment, adaptation and student feedback. Although the frameworks discussed in this article can be applied across different educational levels and used by different stakeholders (e.g. administrators and policy makers), the primary focus is on higher education (both online and blended-learning structures) and teachers as primary stakeholders, which concur with the focus of the frameworks analysed.

The following section presents the methodology adopted in the study. Afterwards, results are reported organised in two sections: teachers' LA adoption challenges, and existing LA adoption frameworks and how they attempt to address the identified challenges. The last section presents a discussion and a conclusion with several remarks that reinforce the critical points and challenges that require attention to enable LA adoption by teachers.

Methodology

To identify teachers' challenges in adopting LA and the existing LA frameworks designed to address these challenges, we conducted a descriptive qualitative review following the five stages proposed by Whittemore and Knafl (2005): (1) problem identification, (2) literature search, (3) data evaluation, (4) data analysis and (5) presentation.

Literature search

Well-defined literature-search strategies are critical for enhancing the rigour of any type of review (Cooper, 1998). To ensure rigour in this study, the literature search was exclusively conducted using electronic databases such as Google Scholar, ERIC and SCOPUS. In addition to these databases, we manually searched for relevant papers in the proceedings of the International Learning Analytics and Knowledge (LAK) conferences and the *Journal of Learning Analytics*. These sources were selected because they serve as the main forums for LA research. The searches were conducted to include papers and frameworks published from January 1, 2011 through April 30, 2019, when the search was completed. Since we aimed to review the challenges and frameworks related to LA adoption in the same study, the literature search was conducted in two stages.

Stage 1: Searching for LA adoption challenges: To find relevant studies presenting teachers' challenges with LA adoption, we searched for relevant literature using key terms such as 'learning analytics' AND 'challenges'; 'learning analytics' AND 'teachers'; 'learning analytics' AND 'teacher adoption'; and 'orchestration' AND 'learning analytics'. Table 1 gives an overview of the inclusion and exclusion criteria for this first stage of the review.

Stage 2: Searching LA frameworks: To find relevant frameworks, we used search terms such as 'learning analytics frameworks'; 'learning analytics models'; 'learning analytics' AND 'learning design frameworks' OR 'learning analytics' AND 'learning design models'; and 'guidelines for teacher adoption of learning analytics'. To be included in the analysis, the framework had to meet several criteria (Table 2).

Table 1. Inclusion and exclusion criteria (LA adoption challenges)

Inclusion	Exclusion
• The paper identifies a challenge facing the adoption of LA in higher education contexts • The challenge is specific to teachers' adoption of LA • The paper is published in a peer-reviewed journal or conference proceedings	• Papers not directly discussing LA adoption challenges/ focusing on other levels of education other than higher education • Challenges not specific to teachers' adoption of LA • Non-scholarly peer reviewed journal/conference proceedings

Table 2. Inclusion and exclusion criteria (LA frameworks)

Inclusion	Exclusion
• The framework is focusing on LA and specifically, LA adoption at a course/ classroom level • The framework is published in a peer-reviewed journal or conference proceedings	• Frameworks with general reference to LA with no specific reference to LA adoption by teachers • Frameworks not published in peer-reviewed scholarly journals/conference proceedings

Data evaluation

Based on the sets of criteria outlined in Tables 1 and 2, the studies were filtered by the first author based on the titles and abstracts and later verified by all the authors. During the first stage of the review, from an initial pool of 578 studies filtered from the databases, 276 titles and abstracts were screened. In the first screening, 198 papers were discarded because they did not report on an empirical study. Next, 78 full-text papers were assessed by the authors, of which 63 were discarded because they reported on general challenges of LA adoption (i.e. at an institutional level) rather than at the teacher level or because they duplicated the findings of other conference and journal papers. After this step, we were left with 15 papers for the final analysis of teachers' challenges in adopting LA (Indicated by '*' in the reference list).

In the second stage of the review, which focused on frameworks, the initial search strategy resulted in 1,058 hits. The first author conducted the first screening process by reading through titles, abstracts and key words. At this stage, a number of studies were discarded because they were focused on disciplines other than LA (i.e. data mining or learning design), or because they used titles with the term 'LA frameworks' but proposed no actual frameworks. Finally, 29 papers describing LA frameworks were retrieved. Guided by the inclusion and exclusion criteria reported in Table 2, the three researchers further assessed these frameworks. Following this process, 11 papers were discarded, either because they reported on frameworks for LA implementation at the institutional level (7) or because they evaluated LA interventions (4). This left 18 papers (see Appendix A, also indicated by '*' in the reference list) that focused on LA frameworks relevant to the adoption of LA at the practitioner level.

Data analysis (coding and categorisation)

In this phase, we developed a set of criteria to guide the selection of relevant information and to ensure methodological rigour (Cooper, 1998). Consequently, following the screening process, we proceeded with ordering, coding and categorising the final selected papers according to several dimensions (Appendix B) based on the two research questions. To answer the first research question, the analysis and coding focused on whether the paper highlighted the challenges of LA adoption for teachers at the classroom or course level. The categorisation of challenges was performed through a bottom-up approach whereby four categories of challenges (e.g. pedagogical, technical, institutional and ethical) were generated after common challenges

were identified from the literature. To answer the second research question, the analysis and categorisation of the identified frameworks was based on the Orchestrating Learning Analytics framework (OrLA) (Prieto et al., 2018). This framework identifies four aspects to which LA tools and frameworks should provide support (e.g. design and planning; adaptation and intervention; awareness and assessment; and intervention, regulation and management). The detailed explanation of each aspect is provided in appendix B. We used this analysis framework to characterise the different frameworks and discuss their utility in helping teachers overcome the challenges of LA adoption in a manner that supports their translation into practice. The papers were manually coded by the first author, and were later crosschecked by the two other authors. All differences in coding were discussed and reconciled.

Results

RQ1: Teachers' challenges in adopting LA

The review identified five key challenges teachers face when adopting LA in classroom environments: (1) difficulties integrating technical and pedagogical expertise in LA use; (2) lack of connection between LA and educational theories or pedagogies; (3) failure to align LA with teachers' practice; (4) ethical and privacy concerns; and (5) additional workload and lack of time.

Challenge 1: Integration of technical and pedagogical expertise in LA use

One of the critical challenges highlighted across the LA literature is teachers' limited technological-pedagogical expertise in connecting LA with their everyday teaching practices. Teachers find it difficult to make connections between the heterogeneity of the goals they define before and during the learning process and the variety of possible actions suggested by LA tools. Van Leeuwen (2018) confirms this assertion in a study of teachers' perceptions of LA usability. She found that the challenge teachers mentioned most frequently was the transition from diagnosis to intervention, since they lacked the technical expertise necessary to manipulate and act upon LA outputs. The explanation provided in many studies is that teachers lacking the necessary expertise to utilise LA could shy away from using LA in their practice, thus leaving LA to more skilled and technically savvy users (Dyckhoff, Zielke, Bültmann, Chatti, & Schroeder, 2012; West et al., 2015; Schmitz, Van Limbeek, Greller, Sloep, & Drachsler, 2017). Studies have suggested that for teachers to adopt LA effectively at the classroom level, it will require a higher level of digital literacy (e.g. data interpretation and critical evaluation) (Greller & Drachsler, 2012; Ferguson et al., 2016). This is because most LA tools are complex, with most of their features going beyond what a teacher might have a need for, in particular in view of the notion of orchestration.

Consequently, if LA is to move towards classroom-level application, it is imperative that teachers are supported with easy-to-use analytics tools to act and understand analytics approaches with confidence (Arnold et al., 2014; Kaliisa, Kluge, Mørch, 2020). In their generic framework for LA, Greller and Drachsler (2012) identified some of the required skills and competences (e.g. numeric, interpretative and critical evaluation) that make meaningful use of LA data possible by teachers, although it is unclear how the different competences were identified.

Challenge 2: Lack of connection between LA and educational theories or pedagogies

Although proponents claim the purpose of LA is to understand and optimise learning, the connection between LA and pedagogical approaches remains uncertain, which affects teachers' attempts to use LA results in meaningful ways. For example, Knight et al. (2014) argue that many pedagogical models in the field of LA are implicit (e.g. they do not clearly explain their epistemological assumptions), which could lead to failed attempts to interpret LA results due to lack of context. Essentially, as noted by Bakharia et al. (2016), there is a knowledge gap for teachers in attempting to bridge the divide between the information provided by LA and the types of pedagogical actions designed by teachers to support student learning. The above studies highlight the need to design relevant LA frameworks and tools that provide a more explicit theorisation and contextual LA interpretation by teachers (e.g., how LA correlate with learning behaviours and outcomes).

Challenge 3: Failure to align LA with teachers' practice

Choosing pedagogically meaningful data from LA systems logs and helping teachers use them efficiently to improve students' learning are known concerns for LA adoption (Greller & Drachsler, 2012; Wise et al., 2013). Rogers et al. (2016) shared the same concern by stating that LA in some instances provide summative data (e.g. total page views), which are insufficient to reflect a clear picture of students' academic performance and learning processes (e.g. formative data). This shortcoming could partly be caused by the existing communication gap between LA researchers and end-users (e.g. teachers), who use different languages and have different expectations and intentions regarding LA (Gunn et al., 2017). The aforementioned studies reveal that the use of inaccurate proxies for tracking and measuring academic performance could potentially become an obstacle to teachers' use of LA. To address this challenge, Michos et al. (2020) stress that the design of LA tools to resolve teacher-identified problems with LA is critical. In line with this suggestion, Shibani, Knight and Buckingham Shum (2020) responded to teachers' questions and concerns by involving them in the design of transferable tasks in a writing analytics intervention. While this study explored the perspectives of only three teachers who had been early adopters of the LA technology, it provides a proof of concept for how to engage teachers as co-designers of LA tools to support pedagogically relevant analytics with a shared language.

Challenge 4: Ethical and privacy concerns

While learning institutions have regulations concerning the data use, ambiguous approaches towards ethical issues, particularly for LA-specific practice, have made teachers' adoption of LA very difficult (Tsai & Gasevic, 2017). For example, in their study examining higher education teachers' knowledge, attitudes and concerns about the use of LA, Howell et al. (2018) found that teachers raised ethical concerns about LA, specifically with regard to the transparency of students' data and informed consent, as well as the impact on student learning and well-being. In this regard, Slade and Prinsloo (2013) argue that 'informed consent, privacy, and anonymisation of data' must be prioritised to advance LA adoption for teaching purposes. However, this is without challenges as the presence of asymmetrical power relationship between students and teachers could compromise the principle of informed consent (Tsai et al., 2020). Teachers are expected to comply with institutional, national and international or regional regulations. For example, the European Union's General Data Protection Regulation (GDPR) requires teachers to make modifications to the data extraction process (e.g., by anonymising student data) before using it for research and development-related purposes. Nonetheless, the lack of clear examples to guide teachers and researchers has left much space for the interpretation of GDPR and other institutional regulations regarding the use of students' data for LA. This calls for clear frameworks and illustrative examples designed to guide teachers in ethical and privacy management for LA adoption purposes.

Challenge 5: Additional workload and lack of time

The use of LA to improve teaching and learning processes involves a number of stages (e.g., collecting, integrating and analysing raw data from log files) which may require teachers to devote extra time to learn and implement the necessary tools (King, 2017). The analysed studies reported that teachers have no time for additional workload resulting from LA adoption, because they have to observe and react to many different events at once in the classroom (Greller, Ebner, & Schön, 2014). The issue of time is further corroborated by a study conducted by Macfadyen et al. (2012), who found that teachers wanted a clear picture about students' activities, but they reported having no time to review visualisations or statistics about students' progress. Shibani et al. (2020) made the same observation in their study of teachers who had introduced an automated writing feedback tool into their classrooms over the course of three years. The teachers reported that the work related to setting up the intervention took a lot of time and effort and increased the preparations they needed to make before, during and after the delivery of the intervention. These findings highlight that frameworks and tools must provide teachers with guidelines supplemented with automated or semi-automated tasks so that LA does not overwhelm teachers with extra workload.

RQ2: LA adoption frameworks and their relevance to LA adoption challenges

The second research question sought to explore the features of existing LA frameworks and the ways they attempt to address teachers' challenges with LA adoption. The literature review identified 18 frameworks of relevance to teachers' adoption of LA (see full details in Appendix A). In this section, we present the features of the frameworks with respect to the orchestration aspects (e.g., the kinds of tasks teachers should perform) reported in Table 3. The aspects include design and planning; awareness, adaptation and intervention; and regulation and management (Prieto et al., 2018). In this paper, we assume that the identified LA adoption frameworks should provide the necessary guidelines and tools to support teachers in performing these orchestration aspects from an LA perspective and in overcoming the challenges of LA adoption. An overview of these frameworks as well as their conceptual and practical contributions follows below.

Design and planning

This orchestration aspect defines the role of teachers in structuring the course objectives and activities (e.g. scripts, assessments and resources) that students and teachers undertake in the context of a unit of learning (Conole, 2012). To support this orchestration aspect, the review identified 11 frameworks that have grounded themselves practically and implicitly through learning design to help teachers design and plan activities using LA (e.g. Bakharia et al., 2016; Echeverria et al., 2018; Emin-Martínez et al., 2014; Greller & Drachsler, 2012; Gunn et al., 2017; Hernandez-Leo et al., 2018; Koh et al., 2016; Lockyer et al., 2013; Martinez-Maldonado et al., 2016; Rienties et al., 2016). For example, Bakharia et al. (2016), drawing upon a sample of 12 teachers from three Australian universities, presented an LA conceptual framework supporting teachers with an enquiry-based evaluation of learning designs. The framework's main idea is for teachers to adjust and make sense of their enacted pedagogical plans using LA outputs. In addition, the analytics layers for the learning design (AL4LD) framework uses layers to define logical partitions associated with the functions that analytics can offer to support teachers as designers of learning experiences (Hernandez-Leo et al., 2018). Lockyer et al. (2013) developed a process and checkpoint analytics framework to describe how teachers can map the learning process supported by their planned design, pre-identify learning patterns towards the desired learning outcomes and then use LA to track learner progression. An example of this framework in action is presented by Kaliisa et al. (2020), who looked into teachers' adaptations of course activities based on social network and discourse analysis visualisations created from students' online discussion activities.

Such a development is a step forward towards overcoming the lack of connection between LA and educational theories and pedagogies. The frameworks provide guidelines and a benchmark to teachers to help them bridge the divide between pedagogical objectives and the information provided by LA systems. By bridging this divide, teachers are empowered to articulate the design and intent of learning activities, and this gives them the agency to effectively make LA decisions informed by data to reach the intended learning objectives.

Awareness, adaptation and intervention

Orchestration is used to enhance teachers' awareness of what is happening in the classroom (both online and face to face), and it is intended to help them change and adapt the course design and implement relevant interventions in line with the classroom context and emergent behaviours during the enactment of learning activities (Prieto et al., 2011). To address the inherent challenges teachers could face in doing this from an LA perspective, the review identified eight frameworks (e.g., Dyckhoff et al., 2012; Echeverria et al., 2018; Hernandez-Leo et al., 2018; Martinez-Maldonado et al., 2016; Rienties, et al., 2016; Verbert et al., 2013) that aim to provide teachers with clear guidelines and user-friendly information about students' learning behaviours (either formative or summative). Use of these frameworks allows evidence-based interventions based on a menu of potential response actions, as illustrated by Rienties et al. (2016) in their Analytics4Action framework. In addition, Dyckhoff et al. (2012) developed the Exploratory Learning Analytics Toolkit (eLAT) to support teachers' awareness of students' learning processes by helping them explore user behaviour and assessment results based on individually selected graphical indicators. Echeverria et al. (2018) proposed a conceptual model for using data storytelling (DS) principles to support the meaningful interpretation of questions in teacher- and student-facing dashboards and to translate these interpretations into direct actions.

In the same vein, Vezzoli, Mavrikis and Vasalou (2020) used inspiration cards and found initial evidence to support the hypothesis that analytics use would support teachers' awareness and interventions.

These recent studies show that teachers can use analytics in real time as a form of orchestration, thereby increasing their awareness of students' learning progress and consequently being better able to identify opportunities for interventions and improvements. At the same time, by providing automated and user-friendly information about students' learning processes, these frameworks could support teachers in dealing with issues of workload and encourage adaptation and timely classroom interventions.

Regulation and management

This orchestration aspect refers to the role teachers play in dealing with ethical and privacy concerns and coordinating the ongoing teaching process (e.g., helping students access course elements and manage their time and workflow) (Prieto et al., 2011). The review identified seven frameworks that support teachers' regulation and management of classroom activities by suggesting strategies to enable teachers to access meaningful data about students' workflow, while addressing privacy and ethical concerns. One notable example is the LA-LD framework developed by Gunn et al. (2015), which emphasises bottom-up LA that empowers teachers to gain actionable insights from their own local data (e.g., resource use, interim grades, student interactions) instead of receiving LA from centrally controlled services. The authors of this framework suggest the Student Relationship Engagement System (SRES) tool, which allows a teacher to use data collected through learning management systems (LMSs) and other context-specific sources to target students efficiently based on their individual progress. In addition, to support the management of ethical concerns, Greller and Drachsler (2012) created a generic LA framework to facilitate ethical adoption of LA, while Dyckhoff (2012) suggested a tool (eLAT) to anonymise students' sensitive data prior to analysis.

Discussion

In this paper, we have presented five key challenges facing teachers as they attempt to adopt LA and 18 frameworks for LA adoption by teachers that attempt to address the identified challenges. Based on these findings, we can make several conclusions and recommendations to better support teachers' LA adoption.

First, in relation to the challenges facing teachers' use of LA (RQ1), our analysis shows that much of the literature revolves around teachers' technical challenges in adopting LA (e.g. data literacy and access) with challenges related to pedagogy (e.g. how to translate LA terminology into actual practice) remaining overshadowed. One possible explanation for this is that LA researchers with technological backgrounds tend to focus more on the tools' technical aspects while neglecting the educational and pedagogical aspects. Yet, as van Harmelen and Workman (2012, p. 4) argue, 'LA exist as part of a socio-technical system, and for LA implementation to be successful, the technical, social and pedagogical dimensions all require consideration'. However, it is clear to us that the pedagogical challenges are considerable, and the limited focus on challenges such as connecting LA with pedagogy can be considered a gap in the LA field. Therefore, LA researchers and technology developers need to consider the pedagogical challenges more seriously by developing relevant tools and guidelines to match teachers' practical requirements.

Second, in response to RQ2, the synthesis revealed a large body of research that has attempted to develop relevant frameworks and tools to help teachers adopt LA in their everyday practice. For example, scholars have developed frameworks to support teachers in collecting, representing, analysing, interpreting and acting upon LA outputs (Bakharia et al., 2016, Lockyer et al., 2013; Verbert et al., 2013) and to map the different types of learner and course data obtained from LMSs (Gunn et al.,

2017). In particular, a number of authors have made efforts to bridge the gap between LA theory and pedagogy, by suggesting relevant frameworks that are grounded in learning theories. These efforts align with Knight et al. (2014), who argue that no LA design can exist without pedagogical and epistemological assumptions. Moreover, the effort to connect LA and learning design is one way to give agency to teachers to align their practice with LA. Such agency could give teachers a genuine voice in the design of relevant LA tools, as Buckingham Shum et al. (2019) assert. Nevertheless, the diversity of the learning theories and pedagogical assumptions highlighted by the different frameworks (Table 3) imply that LA could support different pedagogical purposes to a lesser or greater extent (i.e., by predicting learner behaviour, connectedness and self-reflection). Certainly, as Greller and Drachsler (2012) highlight, a critical point is establishing which pedagogic theories and assumptions are reflected and supported by which particular frameworks and tools.

However, even though the increasing number of frameworks is a positive sign, it is apparent that these frameworks and tools differ in the kinds of orchestration roles they support. For example, some of the frameworks and associated tools (e.g. the LA conceptual framework by Verbert et al. [2013]) support the awareness orchestration aspect by providing analytics about students' learning to the teacher (e.g. through dashboards that visualise learning traces). However, even though such tools can provide insight into students' learning processes, they do not provide support for the intervention roles. Thus, the framework leaves the interpretation to teachers without providing any guidance. A reason for this lack of support seems to be that most of these tools are still not developed for use by teachers in everyday practice.

Moreover, as Greller and Drachsler (2012) note, the simplicity and attractive display of data information provided by some of the LA tools suggested by the frameworks may delude teachers, distracting them from the full pedagogic reality (i.e. what the displayed data mean for learning). In other words, most of the tools suggested by framework developers maximise technological possibilities at the cost of usability for teaching purposes. Consequently, the frameworks and related tools do not directly indicate the specific actions that need to be taken or how and when these actions should occur (Wise & Vytasek, 2017, p. 150). As Koh, Shibani, Tan and Hong (2016) note, explicit guidance is needed about when and how teachers should work with analytics as a tool to support their practice. Otherwise, teachers with limited expertise translating analytics into actual interventions may not benefit from such outputs. One possible solution is the use of multi-functional LA tools that provide teachers with customised insights to support their orchestration of LA in their everyday practice.

Similarly, while a number of frameworks suggest guidelines that teachers could follow to support the adoption of LA in their everyday practice, the suggested guidelines are not empirically tested against actual LA adoption in teachers' everyday practice. Those guidelines that are empirically tested are based on relatively small samples from very context-specific environments. This naturally limits their ability to present teachers with the insights they require to adopt LA successfully. However, as highlighted in the previous section, there is increasing progress among LA researchers in the validation of identified frameworks, and this provides hope that these different frameworks will soon become more applicable in actual practice. Moreover, as illustrated by the given examples, the aggregation of different frameworks and the discussion of their potential roles and the issues they address provide a comprehensive view of the issues that teachers need to take into account to gain the full advantages of using LA.

Table 4. Theories and pedagogical assumptions informing existing frameworks

Theories and/or pedagogical assumptions	Frameworks
Constructivist: Constructivist models focus on those forms of learning that occur in the learner's guided exploration of and experimentation with the world, typically in classrooms or online environments. Constructivist models are likely to measure success as quality of construction, with learners experimenting with their environment, and being capable of using tools that are appropriate for their given age.	Lockyer et al., 2013; Koh et al., 2016
Pragmatic, socio-cultural approaches (building on, for example, Dewey, 1998) hold that learning occurs in the development and negotiation of a mutually shared perspective between learners. Pragmatists suggest that, as human knowers, our conception of some given thing is bound up in our understanding of its practical application — and that is all.	Verbert et al., 2013 ; Clow, 2012 ; Echeverria et al., 2018 ; Prieto et al., 2018: Rienties et al., 2016
Transactional/Instructions: Transactional approaches hold that learning entails the transfer of knowledge from the knower (teacher) to the learner (student). Learning analytics based on transactional approaches will tend to focus on simple metrics such as test scores, not requiring deeper analysis of more complex artefacts, or the processes by which they were derived.	Greller & Drachsler, 2012
Pedagogical/epistemological assumptions	Ifenthaler et al., 2014; Gunn et al., 2017; Hernandez-Leo et al., 2018; Emin-Martínez et al., 2014; Dyckhoff et al., 2012; Martinez-Maldonado et al., 2016; Bakharia et al., 2016
No theory	Chatti et al., 2012; Ali et al., 2013; Siemens, 2013

Study limitations

One limitation of this study is that it may not represent all existing LA adoption frameworks due to possible errors during the search and selection processes. The researchers limited the literature review to specific keywords, journals and databases; thus, papers that did not explicitly state the key words or publish in these specific sources could have been missed. However, while it is not assumed that this paper presents all scholarly LA frameworks with relevance to teachers' adoption of LA, the 18 frameworks analysed constitute a reasonable sample with which to analyse the other frameworks in the field. Moreover, the primary goal of the analysis was not to provide a comprehensive account of all LA frameworks, but rather to draw insights from the existing frameworks and identify the ways in which they attempt to deal with the challenges of LA adoption.

Second, even though the authors endeavoured to categorise the frameworks based on the developed criteria, this process cannot be considered conclusive or without error. For example, some frameworks did not explicitly highlight some of the evaluated aspects (i.e. theory), and therefore, it is possible that some of the elements were not captured during the analysis. It should also be noted that due to space limitations, details about each framework could not be thoroughly presented. However,

the researchers sought to capture sufficient details for each framework (see appendix A), which readers can examine to gain a more comprehensive understanding of all the features. Third, since the majority of the frameworks examined have only recently been formulated, it may still be too early to assess their validity based on the analysed papers; further evidence of their utility and validity may be ascertained in follow-up studies that are not captured in the present analysis. These gaps could be explored in future studies.

Conclusion and further directions

This paper has taken initial steps to analyse the challenges teachers face in adopting LA. We have investigated how existing LA frameworks can guide teachers to overcome such challenges by supporting the orchestration of LA adoption at the classroom level. The review shows that existing LA adoption frameworks have established valuable theoretical and pedagogical guidelines that can be referenced, specifically by teachers with limited LA experience who are interested in adopting LA in their everyday practice. In addition, some frameworks suggest the use of technological tools to aid teachers in the collection, analysis and interpretation of LA outputs to address challenges such as limited data literacy among teachers, which has been widely reported in LA adoption literature. As such, they provide a useful starting point for further analysis of the strategies needed for effective LA adoption by teachers.

However, although the frameworks are intended to provide important insights to address the LA adoption challenges faced by teachers, this review shows that there is a need for caution when applying some frameworks due to conceptual and operational limitations. For instance, some of the frameworks have still not considered the pedagogical and epistemological requirements of LA adoption, with some frameworks silent or less explicit about their pedagogical assumptions. The few frameworks that involve teachers and support learning design are not clear on how and when teachers should be involved in the selection of relevant analytics or on the influence, teachers should have on relevant tools. Even though frameworks are designed to be general and high level, not to address implementation details, detailed elaborations of the guidelines is needed to support their application in practice (e.g. how teachers can deal with implicit GDPR guidelines). Furthermore, the large number of frameworks not concretised into technological artefacts and concrete data streams could make it hard for teachers to use them in making pedagogically informed learning and teaching decisions based on the analytics.

Moreover, while we acknowledge that the actual provision, training and validation of mature tools based on the frameworks take time, there is a need for empirical validation of the existing frameworks to provide a deeper understanding of how LA frameworks can contribute to the quality and efficiency of LA initiatives. The lack of proper empirical examples can explain in part why none of the frameworks has up to now proved capable of becoming a standard to guide teachers in the adoption of LA in their authentic practice.

To sum up, this paper aims to be informative for teachers and LA technology designers who are deciding which LA approaches and tools to develop and want to understand how their choices and context-specific factors (e.g., teacher competency) might affect the potential adoption of LA in everyday practice. More importantly, we hope that this review will act as a benchmark for LA researchers towards developing sound and empirically informed frameworks by identifying the key constructs needed for the orchestration of LA interventions. Specifically, we find Prieto et al.'s (2018) OrLA framework and Rienties et al.'s (2016) Analytics4Action framework, which both emphasise

stakeholder communication and dialogue (e.g.. among administrators, policy makers, technical staff, teachers and students), to be promising approaches to guide the adoption of LA at the practitioner level.

Our main recommendation for ensuring adoption of LA among teachers is to deal with the technical, pedagogical and institutional limitations of LA adoption discussed above and ensure that the LA adoption is bottom-up, with teachers playing central roles in critical conversations about the planning and design of LA tools, approaches and institutional policies. We suggest, following Hansen and Wasson (2015), that effective adoption can only be achieved if teachers are provided with the right competencies, policies and legal structures to support data access. If the challenges are not addressed, LA adoption at the classroom level could bypass the high expectations and proofs of concept voiced in the literature to become another example of technology that failed to fulfil its early promise to positively influence educational practices.

Acknowledgments

Funding

Statements on open data, ethics, and conflict of interest

There were no conflicts of interest in the production of this paper. Ethics approval was not required. Access to the analysis files is available via the online supplementary data section (Appendix A & B).

References

*Arnold, K. E., Lynch, G., Huston, D., Wong, L., Jorn, L., & Olsen, C. W. (2014). *Building institutional capacities and competencies for systemic learning analytics initiatives.* Paper presented at the Proceedings of the Fourth International Conference on Learning Analytics And Knowledge. doi.org/10.1145/2567574.2567593

Ali, L., Asadi, M., Gašević, D., Jovanović, J., & Hatala, M. (2013). Factors influencing beliefs for adoption of a learning analytics tool: An empirical study. *Computers & Education, 62*, 130-148. doi:10.1016/j.compedu.2012.10.023

*Bakharia, A., Corrin, L., de Barba, P., Kennedy, G., Gašević, D., Mulder, R., Lockyer, L. (2016). *A conceptual framework linking learning design with learning analytics.* Paper presented at the Proceedings of the Sixth International Conference on Learning Analytics & Knowledge.

Cooper, H. M. (1998). *Synthesizing research: A guide for literature reviews* (Vol. 2): Sage.

Colvin, Dawson, S., Wade, A., & Gasevic, D. C. (2007). Addressing the challenges of Institutional Adoption. *Handbook of Learning Analytics*, 281-289

Chatti, M. A., Dyckhoff, A. L., Schroeder, U., & Thüs, H. (2012). A reference model for learning analytics. *International Journal of Technology Enhanced Learning*, *4*(56). doi.org/10.1504/IJTEL.2012.051815

*Clow, D. (2012, April). The learning analytics cycle: closing the loop effectively. In *Proceedings of the 2nd international conference on learning analytics and knowledge* (pp. 134-138). ACM. doi>10.1145/2330601.2330636

Conole, G. (2012). *Designing for learning in an open world* (Vol. 4). Springer Science & Business

Media.

**Dyckhoff, A. L., Zielke, D., Bültmann, M., Chatti, M. A., & Schroeder, U. (2012). Design and implementation of a learning analytics toolkit for teachers. *Journal of Educational Technology & Society*, 15(3), 58-76.. https://www.jstor.org/stable/10.2307/jeductechsoci.15.3.58

*Echeverria, V., Martinez-Maldonado, R., Granda, R., Chiluiza, K., Conati, C., & Shum, S. B. (2018, March). Driving data storytelling from learning design. In *Proceedings of the 8th international conference on learning analytics and knowledge* (pp. 131-140). doi.org/10.1145/3170358.3170380.

*Emin-Martínez, V., Hansen, C., Triana, R., Jesūs, M., Wasson, B., Mor, Y., & Pernin, J. P. (2014). Towards teacher-led design inquiry of learning. *eLearning Papers*, (36). http://oro.open.ac.uk/39353/1/Teacher%20led%20design%20inquiry.pdf

*Ferguson, R., Brasher, A., Clow, D., Cooper, A., Hillaire, G., Mittelmeier, J., Vuorikari, R. (2016). Research evidence on the use of learning analytics: Implications for education policy. *Joint Research Centre, Seville, Spain.* https://doi.org/10.2791/955210

Ferguson, R., Clow, D., Macfadyen, L., Essa, A., Dawson, S., & Alexander, S. (2014, March). Setting learning analytics in context: Overcoming the barriers to large-scale adoption. In *Proceedings of the Fourth International Conference on Learning Analytics And Knowledge* (pp. 251-253). https://doi.org/10.1145/2567574.2567592

**Greller, W., & Drachsler, H. (2012). Translating learning into numbers: A generic framework for learning analytics. *Educational Technology & Society,* 15 (3), 42–57. https://www.jstor.org/stable/10.2307/jeductechsoci.15.3.42

Greller, W., Ebner, M., & Schön, M. (2014). *Learning analytics: From theory to practice–data support for learning and teaching.* Paper presented at the International Computer Assisted Assessment Conference.

Greller, W., Ebner, M., & Schön, M. (2014, June). Learning analytics: From theory to practice–data support for learning and teaching. In *International Computer Assisted Assessment Conference* (pp. 79-87). Springer, Cham. https://link.springer.com/chapter/10.1007/978-3-319-08657-6_8

*Gunn, C., McDonald, J., Donald, C., Nichols, M., Milne, J., & Blumenstein, M. (2017). Building an evidence base for teaching and learning design using learning analytics. https://ako.ac.nz/assets.

Hansen, C., & Wasson, B. (2015). Data literacy and use for teaching. In *Measuring and Visualizing Learning in the Information-Rich Classroom* (pp. 72-89). Newyork: Routledge.

*Hernández-Leo, D., Martinez-Maldonado, R., Pardo, A., Muñoz-Cristóbal, J. A., & Rodríguez-Triana, M. J. (2019). Analytics for learning design: A layered framework and tools. *British Journal of Educational Technology*, *50* (1), 139-152 doi.org/10.1111/bjet.12645

*Howell, J. A., Roberts, L. D., Seaman, K., & Gibson, D. C. (2018). Are We on Our Way to Becoming a "Helicopter University"? Academics' Views on Learning Analytics. *Technology Knowledge and Learning, 23*(1), 1-20. doi:10.1007/s10758-017-9329-9

Herodotou, C., Rienties, B., Boroowa, A., Zdrahal, Z., & Hlosta, M. (2019). A large-scale implementation of predictive learning analytics in higher education: the teachers' role and perspective. *Educational Technology Research and Development*, *67*(5), 1273-1306. doi.org/10.1007/s11423-019-09685-0

Ifenthaler, D., & Widanapathirana, C. (2014). Development and validation of a learning analytics framework: Two case studies using support vector machines. *Technology, Knowledge and Learning*, *19*(1-2), 221-240. doi. 10.1007/s10758-014-9226-4

*Koh, E., Shibani, A., Tan, J. P. L., & Hong, H. (2016, April). A pedagogical framework for learning analytics in collaborative inquiry tasks: An example from a teamwork competency awareness program. In *Proceedings of the Sixth International Conference on Learning Analytics & Knowledge* (pp. 74-83). doi.org/10.1145/2883851.2883914

Kaendler, C., Wiedmann, M., Rummel, N., & Spada, H. (2015). Teacher competencies for the implementation of collaborative learning in the classroom: A framework and research review. *Educational Psychology Review*, 27(3), 505-536. https://link.springer.com/article/10.1007/s10648-014-9288-9

Kaliisa, R., Mørch, A. I., & Kluge, A. (2019, September). Exploring Social Learning Analytics to Support Teaching and Learning Decisions in Online Learning Environments. In *European Conference on Technology Enhanced Learning* (pp. 187-198). Springer, Cham. doi.org/10.1007/978-3-030-29736-7_14

Kaliisa, R., Kluge, A., & Mørch, A. I. (2020). Combining Checkpoint and Process Learning Analytics to Support Learning Design Decisions in Blended Learning Environments. *Journal of Learning Analytics*.

*King, J. L. (2017). The Nature and Extent of Instructors Use of Learning Analytics in Higher Education to Inform Teaching and Learning. *ProQuest LLC. Ph.D. Dissertation, University of Nevada, Las Vegas*. https://digitalscholarship.unlv.edu/thesesdissertations/2998/

Knight, S., Shum, S. B., & Littleton, K. (2014). Epistemology, assessment, pedagogy: where learning meets analytics in the middle space. *Journal of Learning Analytics, 1*(2), 23-47. doi.org/10.18608/jla.2014.12.3

*Lockyer, L., Heathcote, E., & Dawson, S. (2013). Informing pedagogical action: Aligning learning analytics with learning design. *American Behavioral Scientist*, *57*(10), 1439-1459. doi.org/10.1177/0002764213479367

*Macfadyen, L. P., Dawson, S., Pardo, A., & Gašević, D. (2014). Embracing big data in complex educational systems: The learning analytics imperative and the policy challenge. *Research & Practice in Assessment*, *9*, 17-28. https://eric.ed.gov/?id=EJ1062692

*Martinez-Maldonado, R., Schneider, B., Charleer, S., Shum, S. B., Klerkx, J., & Duval, E. (2016). Interactive surfaces and learning analytics: data, orchestration aspects, pedagogical uses and challenges. *In Proceedings of the Sixth International Conference on Learning Analytics & Knowledge.* (pp. 124-133). doi.org/10.1145/2883851.2883873

Michos, K., Lang, C., Hernández-Leo, D., & Price-Dennis, D. (2020, March). Involving teachers in learning analytics design: lessons learned from two case studies. In *Proceedings of the Tenth International Conference on Learning Analytics & Knowledge* (pp. 94-99). doi.org/10.1145/3375462.3375507

Persico, D., & Pozzi, F. (2015). Informing learning design with learning analytics to improve teacher inquiry. *British Journal of Educational Technology, 46*(2), 230-248. doi.org/10.1111/bjet.12207

*Prieto, L. P., Rodríguez-Triana, M. J., Martínez-Maldonado, R., Dimitriadis, Y., & Gasevic, D. (2018). Orchestrating Learning Analytics (OrLA): supporting the adoption of learning analytics at the practitioner level. *Preprint*. doi.10.31219/osf.io/y2p7j

Prieto, L. P., Dlab, M. H., Gutiérrez, I., Abdulwahed, M., & Balid, W. (2011). Orchestrating technology enhanced learning: a literature review and a conceptual framework. *International Journal of Technology EnhancedLearning*, *3*(6), 583. doi.org/10.1504/IJTEL.2011.045449

*Rienties, B., & Toetenel, L. (2016). The impact of learning design on student behaviour, satisfaction and performance: A cross-institutional comparison across 151 modules. *Computers in Human Behavior, 60*, 333-341. doi.org/10.1016/j.chb.2016.02.074

*Rienties, B., Boroowa, A., Cross, S., Kubiak, C., Mayles, K., & Murphy, S. (2016). Analytics4Action Evaluation Framework: A Review of Evidence-Based Learning Analytics Interventions at the Open University UK. *Journal of Interactive Media in Education*, *2016*(1). https://eric.ed.gov/?id=EJ1089327

*Rogers, T., Gašević, D., & Dawson, S. (2016). Learning analytics and the imperative for theory driven research. *The SAGE Handbook of E-Learning Research,* 232-250.

Roschelle, J., Dimitriadis, Y., & Hoppe, U. (2013). Classroom orchestration: synthesis. *Computers & Education, 69*, 523-526. doi.org/10.1016/j.compedu.2013.04.010

Schmitz, M., Van Limbeek, E., Greller, W., Sloep, P., & Drachsler, H. (2017). *Opportunities and challenges in using learning analytics in learning design*. In *European Conference on Technology Enhanced Learning*. (pp. 209-223). Springer, Cham. doi: 10.1007/978-3-319-66610-5_16

Siemens, G., & Long, P. (2011). Penetrating the fog: Analytics in learning and education. *EDUCAUSE review, 46*(5), 30. https://eric.ed.gov/?id=EJ950794

*Siemens, G. (2013). Learning analytics: The emergence of a discipline. *American Behavioral Scientist*, *57*(10), 1380-1400. doi.org/10.1177/0002764213498851

*Slade, S., & Prinsloo, P. (2013). Learning analytics: Ethical issues and dilemmas. *American Behavioral Scientist*, *57*(10), 1510-1529. doi.org/10.1177/0002764213479366

*Shibani, A., Knight, S., & Shum, S. B. (2020). Educator perspectives on learning analytics in classroom practice. *The Internet and Higher Education*, *46*, 100730. doi.org/10.1016/j.iheduc.2020.100730

*Tsai, Y.-S., & Gasevic, Dragan. (2017). Learning Analytics in Higher Education- challenges and Policies: A review of Eight Learning Analytics Policies. In *Proceedings of the Seventh International Learning Analytics & Knowledge Conference*, 233-242. doi.org/10.1145/3027385.3027400

Tsai, Y. S., Perrotta, C., & Gašević, D. (2020). Empowering learners with personalised learning approaches? Agency, equity and transparency in the context of learning analytics. *Assessment & Evaluation in Higher Education*, *45*(4), 554-567. doi.org/10.1080/02602938.2019.1676396

*van Leeuwen, A. (2018). Teachers' perceptions of the usability of learning analytics reports in a flipped university course: when and how does information become actionable knowledge? *Educational Technology Research and Development*,, 1-22. doi.org/10.1007/s11423-018-09639

Van Harmelen, M., & Workman, D. (2012). Analytics for learning and teaching. *CETIS Analytics Series*, *1*(3), 1-40. http://publications.cetis.org.uk/wp-content/uploads/2012/11/Analytics-for-Learning-and-Teaching-Vol1-No3.pdf

*Verbert, K., Duval, E., Klerkx, J., Govaerts, S., & Santos, J. L. (2013). Learning analytics dashboard applications. *American Behavioral Scientist, 57*(10), 1500-1509. doi.org/10.1177/0002764213479363

Vezzoli, Y., Mavrikis, M., & Vasalou, A. (2020, March). Inspiration cards workshops with primary teachers in the early co-design stages of learning analytics. In *Proceedings of the Tenth International Conference on Learning Analytics & Knowledge* (pp. 73-82). doi.org/10.1145/3375462.3375537

*Wasson, B., Hanson, C., & Mor, Y. (2016). Grand challenge problem 11: empowering teachers with student data. In *Grand challenge problems in technology-enhanced learning II: MOOCs and beyond* (pp. 55-58): Springer. doi.10.1007/978-3-319-12562-6_12

West, D., Heath, D., & Huijser, H. (2016). Let's Talk Learning Analytics: A Framework for Implementation in Relation to Student Retention. *Online Learning*, *20*(2), 30-50. doi 10.24059/olj.v20i2.792.

Whittemore, R., & Knafl, K. J. (2005). The integrative review: updated methodology. *Journal of advanced nursing*, *52*(5), 546-553. doi.org/10.1111/j.1365-2648.2005.03621.

*Wilson, A., Watson, C., Thompson, T. L., Drew, V., & Doyle, S. J. (2017). Learning analytics: challenges and limitations. *Teaching in Higher Education*, *22*(8), 991-1007. doi.org/10.1080/13562517.2017.1332026

Wise, A. F., Zhao, Y., & Hausknecht, S. N. (2013). Learning analytics for online discussions: a pedagogical model for intervention with embedded and extracted analytics. In *Proceedings of the third international conference on learning analytics and knowledge* (pp. 48-56). https://doi.org/10.1145/2460296.2460308

Wiley, K. J., Dimitriadis, Y., Bradford, A., & Linn, M. C. (2020, March). From theory to action: developing and evaluating learning analytics for learning design. In *Proceedings of the Tenth International Conference on Learning Analytics & Knowledge* (pp. 569-578). doi.org/10.1145/3375462.3375540