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Designing Learning Analytics Tools for Teachers with Teachers

A Design-Based Research Study in a Blended Higher Education Context

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Abstract

Learning analytics (LA) is a research field that has attracted the attention of various stakeholders in higher education, including teachers, administrators, learning designers, policymakers, and technology developers. One of its key aims is to support teachers in orchestrating their teaching activities in technology-enhanced learning environments by visualizing students' learning activities through dashboards. The expectation is that teachers will use the feedback provided by LA to enable the proactive evaluation of their students' learning through monitoring, reflection, designing, and regulating the teaching and learning process. Unfortunately, empirical evidence regarding the impact of LA on teachers' everyday practice remains limited. Challenges that deter teachers from integrating LA into their everyday practice include the teachers' limited involvement in the planning, design, and implementation of LA tools and interventions, and the lack of alignment of LA tools with theory and the teachers' pedagogical needs.

The overall aim of this doctoral thesis is to explore how LA uptake by and relevance to teachers can be improved by their engagement in the planning, design, and implementation of theoretically grounded LA tools and interventions in authentic teaching practices. The questions addressed in this thesis are as follows:

> RQ1: What is the current practice of learning design among teachers, and what is the state of teachers' awareness, acceptance, needs, challenges, and beliefs regarding applying LA to support their learning design decisions?
> RQ2: What is the potential for different forms of analytics to provide insights into students' learning that teachers can then use to make pedagogical decisions?
> RQ3: How can we design and implement empirical and theoretically based LA tools together with teachers to meet teachers' pedagogical expectations?

These questions are investigated in the context of two Norwegian higher education institutions and seven courses using teachers' experiences, learning designs, and data from students' online collaborative activities (online discussions). Guided by design-based research (DBR) and a sociocultural perspective, the empirical work that included teachers and students was conducted through four iterative design stages, which are reported in the four articles that compose this thesis. Article 1 explores the challenges facing teachers' adoption of LA and the existing strategies to overcome them. The findings show that teachers struggle to make sense of analytics, and analytics systems are usually atheoretical and not aligned with their pedagogical practice. Article 1 also reveals a number of frameworks that aim to support the adoption of LA by teachers, even though these are not empirically tested against actual LA adoption in teachers' everyday practice and are not concretized into technological artifacts or concrete data streams. Article 2 explores teachers' course design practices and their perceptions of LA as a potential tool for supporting their practice. The findings show that a number of factors, including situational factors, summative and formative assessments, and teachers' intuition and experience, underpins teachers' course design practices. Teachers also appreciate the formative and normative value of LA in providing more objective evidence of students' learning patterns and shaping learning processes. The findings from this study were synthesized to form a bi-directional LA course design conceptual framework. Article 3 examines the potential of different forms of analytics (checklist and process analytics) to support teachers' learning design decisions. The findings show that if shared in a simple and timely manner and integrated within the same teaching environment, LA visualizations can provide insights into students' online learning processes, which teachers can use to make learning design changes. Moreover,

the different data sources and analytical techniques used in this article show how researchers can move from low levels of abstraction (such as counting page views) toward higher-level constructs (such as identifying discourse patterns). Article 4 is an intervention in seven courses using the Canvas Analytics Dashboard (CADA), which was designed by the researcher together with the teachers. The findings reveal that engaging teachers in the design of and giving them control over LA tools can favor teachers' adoption of LA in their everyday practice. The findings further show that teachers are able to make timely learning design changes based on the insights they gain from the dashboard.

The four articles make theoretical, empirical, practical, and methodological, contributions to technology-enhanced learning and the LA literature. They contribute theoretically and conceptually by proposing an LA course design conceptual framework that highlights the key factors that need to be considered to connect LA and learning design. Using the sociocultural theoretical perspective to guide the analysis and interpretation of students' data and select the features of the teacher-facing dashboard (participation and discourse), this thesis improves our understanding of how learning theories can guide the design and adoption of LA tools. Empirically, this thesis produces guidelines that can be utilized by researchers, institutional leaders, teachers, and technology developers to guide future processes of designing and adopting LA tools. From a practical point of view, the thesis makes an artifact contribution in the form of a teacher-facing LA dashboard (CADA) designed to help teachers gain insights into students' participation and discourse patterns during asynchronous online discussions. This dashboard has value within the immediate context of the study, where teachers have already started using the dashboard in their everyday teaching practice. Lastly, the thesis makes a methodological contribution to the LA research by combining multiple approaches and providing a demonstrable and successful process using DBR and the human-centred LA (HCLA) approach over two iterations with key stakeholders (teachers) to improve the value and uptake of LA systems.

Sammendrag

Læringsanalyse (LA) er et forskningsfelt som har fått oppmerksomhet fra ulike interessenter innen høyere utdanning, som lærere, administratorer, læringsdesignere, beslutningstakere og teknologiutviklere. Et av hovedmålene ved LA er å støtte lærere i å orkestrere undervisning ved å visualisere aktivitetene til studenter og elever. Såkalte "dashboards" gir samlede fremstillinger av elevenes interaksjoner med teknologien. Målet med dette er å gi lærere støtte for evaluering av elevenes læringsprosesser, noe som igjen kan bidra til endring og regulering av undervisnings- og læringsprosessen. Likevel er erfaringer fra virkningen av LA og dashbords fortsatt begrenset. Utfordringer som hindrer at lærere tar i bruk denne teknologien i sin hverdag er at lærere i liten grad har vært involvert i planlegging, utforming og implementering av LA-verktøy, samt begrenset tilpasning av LA-verktøy til læringsteori og til lærernes pedagogiske behov i sitt daglige virke.

Det overordnede målet med denne doktorgradsavhandlingen er å studere hvordan LA-teknologi kan gjøres mer attraktiv ved å trekke lærere inn i planlegging, design og implementering av LA-verktøy med et tydelig utgangspunkt i læringsteori samt å undersøke dette ved intervensjoner i autentisk undervisningspraksis. Forskningsspørsmålene som tas opp i denne oppgaven er som følger:

> RQ1: Hvordan er dagens praksis når det gjelder læringsdesign blant lærere, og hva er status når det gjelder aksept, behov, utfordringer og forventninger til å bruke LA til å støtte for deres vurderinger når det gjelder læringsdesign?
> RQ2: Hva er potensialet til ulike former for LA for å gi innsikt i elevenes læring som kan brukes til å ta pedagogiske beslutninger i lærernes arbeid?
> RQ3: Hvordan kan vi designe og implementere LA-verktøy basert på pedagogisk teori sammen med lærere for å møte lærernes pedagogiske forventninger?

Disse spørsmålene er i denne avhandlingen studert ved to norske høyere utdanningsinstitusjoner og i syv kurs. Dataene ble samlet inn ved hjelp av intervjuer med lærere, læringsdesign og data fra elevenes nettbaserte samarbeidsaktiviteter (nettdiskusjoner). Basert på designbasert forskning (DBR) og med et sosiokulturelt perspektiv, går det empiriske arbeidet i denne avhandlingen gjennom fire deler av DBR-syklusen, og disse er rapportert i de fire artiklene som utgjør denne oppgaven. Artikkel 1 utforsker de utfordringene lærerne står overfor ved innføring av LA og de strategiene de gjør bruk av for å håndtere dem. Funnene viser at lærere har vansker med å ta til seg de automatiserte analysene som kommer fra LA-verktøyene, blant annet fordi de er for langt unna deres pedagogiske praksis og har en svak kobling til læringsteori. Artikkel 1 presenterer også en rekke rammeverk som tar sikte på å støtte innføring av LA for lærere, men de er i liten grad empirisk testet i lærernes hverdagspraksis og har lite konkretisering mot teknologi og konkrete datastrømmer. Artikkel 2 undersøker lærernes praksis for kursdesign og deres oppfatning av LA som et mulig verktøy for å støtte den. Funnene viser at lærernes designpraksis er basert på en rekke faktorer, både kursspesifikke og lærernes mer generelle intuisjon og erfaring. Lærere er positive til den formative og normative verdien til LA ved å gi mer objektive indikasjoner på elevenes læringsmønstre og prosesser. Funnene fra denne studien ble overført til et toveis konseptuelt rammeverk for LA-kursdesign. Artikkel 3 vurderer potensialet til ulike former for analyser (sjekklister og prosessanalyser) for å støtte lærernes beslutninger om læringsdesign. Funnene viser at hvis analysene er lett tilgjengelige og integrert med teknologien som brukes til læring og undervisning, kan LA-visualiseringer gi innsikt i elevenes online læringsprosesser, noe som lærere igjen kan bruke til å gjøre endringer i læringsdesignet. Dessuten viser de forskjellige datakildene og analyseteknikkene som brukes i denne artikkelen hvordan forskere kan gå fra lave abstraksjonsnivåer (som å telle sidevisninger) til høyere

abstraksjonsnivåer (som å identifisere diskursmønstre). Artikkel 4 er en intervensjonsstudie i syv kurs ved hjelp av Canvas Analytics Dashboard (CADA), som er designet av forskere og lærerne i samarbeid. Funnene viser at det å engasjere lærere i utforming og gi dem kontroll over LA-verktøy øker lærernes integrering av LA i sin hverdag. Funnene viser videre at lærere løpende kan tilpasse læringsdesignet basert på innsikten de får fra dashbordet.

De fire artiklene gir teoretiske, empiriske, praktiske og metodiske bidrag til teknologibasert læring og til LA-litteraturen. De bidrar teoretisk til feltet ved å foreslå et konseptuelt rammeverk for LA-kursdesign som understreker nøkkelfaktorene ved å koble LA og læringsdesign. Ved å bruke det sosiokulturelle teoretiske perspektivet til å informere analysen og tolkningen av studentenes data og designet til det lærertilpassede dashbordet, demonstrerer denne oppgaven potensialet ved å bruke en teoribasert tilnærming til både LA-forskning og til praksis. Empiriske resultater fra avhandlingen er retningslinjer som kan brukes av forskere, institusjonelle ledere, lærere og teknologiutviklere for å veilede fremtidige prosesser for å designe og ta i bruk LA-verktøy. Fra et praktisk synspunkt gir oppgaven et teknologibidrag i form av et konkret lærertilpasset LA-dashboard (CADA) designet for å gi lærere innsikt i elevenes deltakelse og diskursmønstre i asynkrone nettdiskusjoner. Dette dashbordet har vist sin verdi i denne studien, der lærere har begynt å bruke dashbordet i sin regulære undervisningspraksis. Avslutningsvis gir denne oppgaven et metodologisk bidrag til LA-forskningen ved å kombinere flere tilnærminger og gir empiriske tester ved bruk av DBR og en brukertilpasset LA-tilnærming (HCLA - Human-Centered Learning Analytics) over to iterasjoner med lærere for å forbedre utbytte og verdi av LA-systemene.

List of Abbreviations

CADA	Canvas Analytics Dashboard (developed as part of this thesis)
DBR	Design-based research
HCLA	Human-centered learning analytics
LA	Learning analytics
LAK	Learning analytics and knowledge
LMS	Learning management system
MOOCs	Massive open online courses
SNA	Social network analysis

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Part II: The Articles

Article 1: Kaliisa, R., Kluge, A., & Mørch, A. I. (2021a). Overcoming challenges to the adoption of learning analytics at the practitioner level: A critical analysis of 18 LA frameworks. *Scandinavian Journal of Educational Research*, 1–15. https://doi.org/10.1080/00313831.2020.1869082

Article 2: Kaliisa, R., Mørch, A. I., & Kluge, A. (2021b). 'My point of departure for analytics is extreme skepticism': Implications derived from an investigation of university teachers' learning analytics perspectives and design practices. *Technology, Knowledge and Learning*, 1–22. https://doi.org/10.1007/s10758-020-09488-w

Article 3: 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*, *7*(3), 33–47. https://dx.doi.org/10.18608/jla.2020.73.4

Article 4: Kaliisa, R., & Dolonen, J. A. (2022). CADA: a teacher-facing learning analytics dashboard to foster teachers' awareness of students' participation and discourse patterns in online discussions. *Technology, Knowledge and Learning*, 1-22. https://doi.org/10.1007/s10758-022-09598-7

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Part 1: Extended Abstract

Chapter 1: Introduction

The last few decades have witnessed remarkable changes in the field of higher education. In particular, we have seen a rising number of students in fully online (e.g., massive open online courses [MOOCs] and distance learning institutions) and blended learning institutions (with both face-to-face and online teaching), increasing financial constraints, internationalization, and the demand for more student-centered teaching approaches (Robson & Wihlborg, 2019; Maassen & Stensaker, 2011). These changes, driven partly by economic and competitive forces, have radically affected the pedagogical approaches used by teachers and the ways in which students learn. For example, a growing number of higher education institutions have introduced digital learning tools and platforms, such as learning management systems (LMSs) (Coates et al., 2005), to support innovative, technology-enhanced learning (Sinclair & Aho, 2018).

These systems, which became popular in the late 1990s (Watson & Watson, 2007), support the creation of virtual learning environments for traditional campus-based students and are even used to expand educational offerings by developing fully online and distance learning universities (Coates et al., 2005). At the same time, with the increased focus on the scholarship of teaching and learning (Hutchings et al., 2011) and student-centered teaching pedagogies (Damşa et al., 2015), teachers, particularly in blended learning institutions, have leveraged LMS-specific features, such as discussion forums and peer assessments, to introduce more student-centered pedagogies that support student engagement and participation (Børte et al., 2020). This trend has become prominent since the start of the COVID-19 pandemic, which affected higher education institutions in different ways (for instance, by reducing face-to-face contact), forcing institutions to move all their courses online.

The transition to technology-enhanced learning and student-centered pedagogies might increase the pressure and workload of higher education teachers, who already face time constraints in their everyday practice characterized by juggling between core tasks, such as research, teaching, dissemination, and administrative duties (Børte et al., 2020). For example, teachers are expected to design for physical, online and blended-based teaching and assessments, and to reflect on the effectiveness of the enacted activities for timely design changes and future iterations (Bennett et al., 2017; Wasson & Kirschner, 2020). Moreover, teachers are expected to monitor students' learning processes and provide them with the necessary feedback and guidance to stimulate the actions necessary for learning (Van Leeuwen et al., 2019). Due to the large number of students enrolled in online courses and conventional face-to-face and blended learning programs, teachers are faced with a high level of busyness, which affects the quality and amount of pedagogical support they provide to their students (Pardo et al., 2017).

In the face of continuous changes being made in higher education and the increased number of responsibilities that such changes bring to teachers with limited support structures (Børte et al., 2020), strategies to support teachers' everyday practice are necessary. One potential strategy is to use proactive, automated, and timely approaches to information gathering to inform and empower teachers with prompt insights into students' participation, engagement, and performance. With higher education becoming increasingly digitalized, institutions have access to a higher volume of student (learning and demographic) data, creating opportunities for collecting and analyzing this data, and sharing it with teachers to offer timely and data-informed teaching and student support. This context is the catalyst for the research described in this thesis, which explores how data-supported approaches, particularly learning analytics (LA), a field that strives to employ algorithmic

techniques of data mining and analysis (Williamson, 2017), can be leveraged to support teachers in blended and technology-enhanced learning environments.

1.1 Learning analytics: An overview

The LA field emerged in 2011 in response to the emergence of big data, the increased use of technology in higher education, the development of computational tools that can turn large amounts of data into actionable insights (Clow, 2013), and the increasing pressure on institutions to improve quality and performance (Ferguson, 2012; Siemens, 2013). LA is concerned with the "measurement, collection, analysis, and reporting of data about learners and their contexts for the purposes of understanding and optimizing learning and the environments in which it occurs" (Siemens & Long, 2011, p. 34). LA as a multidisciplinary field of research embraces methods and approaches from disciplines such as data mining, computer science, machine learning, natural language processing, and human–computer interaction (HCI) (Piety & Pea, 2018).

Since its inception in 2011, LA has matured significantly as a field of both research and practice. It has been featured in educational horizon reports (see Brown et al., 2020) and publications and policy documents concerned with technology, such as the UK Joint Information Systems Committee (Sclater et al., 2016), and it has also received attention from policymakers (Williamson, 2017). Moreover, education technology vendors, such as Instructure, have integrated analytics tools into their platforms to provide users with different analytics about students' learning behaviors (Williamson, 2017). There is also a growing research community around the topic, with an annual conference (the Learning Analytics and Knowledge [LAK] Conference) since 2011, professional LA associations (e.g., the Society for LA Research [SoLAR]; https://www.solaresearch.org/), and an official journal on the topic (the Journal of Learning Analytics; https://learning-analytics.info/index.php/JLA).

A key component of the LA field is exploring how data generated from student interactions and activities in digital and physical environments can be analyzed and utilized to "open the black box" of learning processes (Clow, 2013). For example, student interactions with course content can be captured, stored, analyzed, and used as indicators of teaching quality. The assumption behind LA is that the collection and analysis of student data can reveal the truth about students' learning processes, which teachers and educational institutions can then use to improve teaching and learning outcomes (Beer, 2018; Williamson, 2017).

To achieve this, LA researchers have designed a number of systems and visual representations in the form of early warning systems (Arnold & Pistilli, 2012) and dashboards that visualize information for teachers and students based on student learning patterns and interactions (Verbert et al., 2013). Figure 1 shows an example of an LA dashboard from The Open University (OU) (Herodotou et al., 2019), illustrating key information about students' course access, participation, and performance at a glance.

Figure 1

The OU Analyse Dashboard

Note. This dashboard shows data specific to the individual students and their online activity (e.g., predictions as to whether they will submit their next assignment).

Despite increasing interest in the LA field, studies and large-scale systematic reviews on LA (e.g., Viberg et al., 2018) have demonstrated that, as a developing research domain, LA has not yet asserted itself as a regular part of teachers' practice and thus requires more scrutiny. This thesis focuses on two main gaps in this area of research, which I will briefly describe below and explain in more detail in the literature review section.

First, despite a growing consensus within the LA community to increase stakeholder participation in the conception, design, deployment, and sustaining of LA systems (Buckingham Shum et al., 2019), work that targets teachers within blended learning institutions remains. As I discuss in detail in Chapter 2, promising efforts have been made to engage teachers in the design process. For example, Dollinger et al. (2019) presented a large-scale study involving several Australian universities and teachers to develop the Student Relationship Engagement System (SRES). Other examples include the development of the OU Analyse dashboard at the OU in the United Kingdom (UK), where several teachers engaged in hands-on workshops (Analytics4Action) to explore their LA needs before deploying a dashboard in authentic practice (Rienties et al., 2018). Chatti et al. (2020) used a human-centered LA (HCLA) approach to engage teachers using a novel technique called the indicator specification card (ISC). Despite these efforts, the adoption of LA systems by teachers, especially in blended learning institutions, remains minimal (Kaliisa et al., 2021a). More work in this area is needed to develop theoretical knowledge and principles that will guide researchers and designers in engaging teachers in the design process (Martinez-Maldonado et al., 2020). As observed by Van Harmelen and Workman (2012), "LA systems are socio-technical systems where human decision-making and consequent actions are much a

part of any successful analytics solution as the technical components" (p. 4). This implies that considering teachers' needs and experiences prior to the design of LA systems is vital, since doing so could favor such systems' use in everyday practice.

Another contention within the field of LA is the lack of theoretical support from the learning sciences, which makes it difficult for users to make sense of the analytics presented in LA systems and to inform their everyday practices (Gašević et al., 2016). Researchers have argued that the analytics element has received more attention, particularly among researchers who take an empiricist data-driven approach and consider data to be the starting point and endpoint without relying on theoretical preconceptions (Tansley & Tolle, 2009; Kitchin, 2014). Meanwhile, some scholars have argued that the full potential of LA will only be achieved if LA researchers leverage theory-driven approaches to provide context for the interpretation of LA outputs and design systems that align with stakeholders' needs (Wise & Shaffer, 2015).

1.2 Thesis aims and research questions

Considering the research gaps described above, the aim of this thesis is to study how LA's uptake by and relevance to teachers can be improved by engaging them in the planning, design, and implementation of theoretically grounded LA tools in authentic teaching practices. Throughout this thesis, I rely on a design-based research (DBR) approach (Barab, 2006) and a sociocultural perspective (Vygotsky, 1978; Säljö, 2002) to explore how teachers can be engaged in the design of an LA system that is both based on their needs and informed by theory. A DBR inspired approach was regarded as appropriate to (a) support the development of principles to guide future processes of LA adoption and design through interactive and iterative design cycles with teachers, and (b) to increase understanding of how learning theories (e.g. a sociocultural perspective) can guide the development of LA tools and be improved based on the evidence generated during the design process. To achieve the thesis aims, three general research questions were set.

> RQ1: What is the current practice of learning design among teachers, and what is the state of teachers' awareness, acceptance, needs, challenges, and beliefs regarding applying LA to support their learning design decisions?

This research question sought to (a) gain preliminary insights into the topic at hand by exploring the challenges teachers face while attempting to use LA and the efforts they make to overcome them (Article 1) and (b) establish teachers' current learning design practices and awareness of LA as a potential tool to support their practice (Article 2). By addressing this research question, a strong conceptual and empirical foundation was established on which appropriate LA solutions that align with teachers' pedagogical needs could be designed.

> RQ2: What is the potential for different forms of analytics to provide insights into students' learning that teachers can then use to make pedagogical decisions?

This research question is answered by examining different LA data sources and techniques, and sharing the outputs with teachers to assess whether the insights gained could offer them a more nuanced description of students' learning (Article 3).

> RQ3: How can we design and implement empirical and theoretically based LA tools together with teachers to meet teachers' pedagogical expectations?

This research question sought to generate lessons and recommendations for the design and implementation of empirically and theoretically based LA tools through the active involvement of teachers (Article 4).

1.3 Empirical basis

The studies that comprise this thesis were conducted within the context of two Norwegian higher education institutions. The data sources used in this thesis included log data, online discussion posts from students' course activities in the Canvas LMS, learning designs for specific courses, a mini-survey, and interviews with the teachers who participated in the baseline and intervention phases of the project. To achieve the goals of this study, a DBR approach that emphasizes the interaction between theory and practice, as well as active collaboration between researchers and practitioners, was employed (Barab, 2006). The thesis was guided by the following four DBR phases: (1) *Problem analysis and requirements identification:* This phase involved two studies that aimed to gain preliminary insights into the current state of the art by (a) exploring the challenges facing teachers' adoption of LA and existing strategies to overcome them *(Article 1)*, and (b) gaining a better understanding of teachers' course design practices and perceptions/level of awareness of LA *(Article 2)*. This phase contributed to answering RQ1. (2) *Development of solutions:* Based on the insights gained from phase one, the second phase involved creating prototype solutions together with the teachers by exploring a range of LA data types, techniques, and visualizations that could provide insights into students' learning processes *(Article 3)*. This phase contributed to answering RQ2. (3) *Intervention, evaluation, and testing of solutions:* This phase involved the development of an actual solution in the form of a dashboard, which was later piloted with seven teachers and seven authentic university courses *(Article 4)*. (4*) Reflection to produce design and adoption principles:* This phase involved the documentation of and reflection on the DBR process to generate LA design and adoption principles to guide researchers, technology developers, teachers, and higher education managers in the design and adoption of LA tools *(Article 4)*. The third and fourth phases both contributed to answering RQ3. Figure 2 illustrates the DBR process followed in this thesis, how the four articles were linked to the different DBR phases, and the study's research questions.

1.4 Thesis outline

This thesis is structured into two parts: an extended abstract (Part 1) and articles (Part 2). Part 1 consists of six chapters. Chapter 1 provides a general introduction to, background of, and motivations behind the thesis. In particular, I provide a brief background regarding ongoing changes within higher education, and the challenges they bring to higher education teachers. I then provide an overview of the field of LA and its potential as a supporting tool for teachers within technology-enhanced learning environments. The end of the chapter outlines the thesis's overall aim, research questions, and empirical focus. Chapter 2 provides a detailed account of the relevant conceptual and empirical literature on learning design practices and studies on LA, and it highlights the current research gaps that provided the basis for the studies included in the thesis. Chapter 3 explains the theoretical grounding of the thesis by highlighting the philosophical and theoretical perspectives that guided the different studies included in it. Chapter 4 details the thesis's overall framework, research design, and empirical settings, as well as the methodological choices made in the four studies. Details regarding the study's reliability, validity, and ethical considerations are also provided. Chapter 5 provides a brief summary of the four articles included in the thesis. Chapter 6 synthesizes the findings from the four articles, with special reference to how they address the thesis's overall research questions. The findings are then discussed in terms of their theoretical, empirical, practical, and methodological contributions to the field of LA and technology-

enhanced learning. This chapter ends with the limitations of the thesis and implications for further research.

Part II presents the four articles that comprise this thesis. The articles are presented chronologically in the order in which they were written.

Article 1: Kaliisa, R., Kluge, A., & Mørch, A. I. (2021). Overcoming challenges to the adoption of learning analytics at the practitioner level: A critical analysis of 18 LA frameworks. *Scandinavian Journal of Educational Research*, 1–15. https://doi.org/10.1080/00313831.2020.1869082

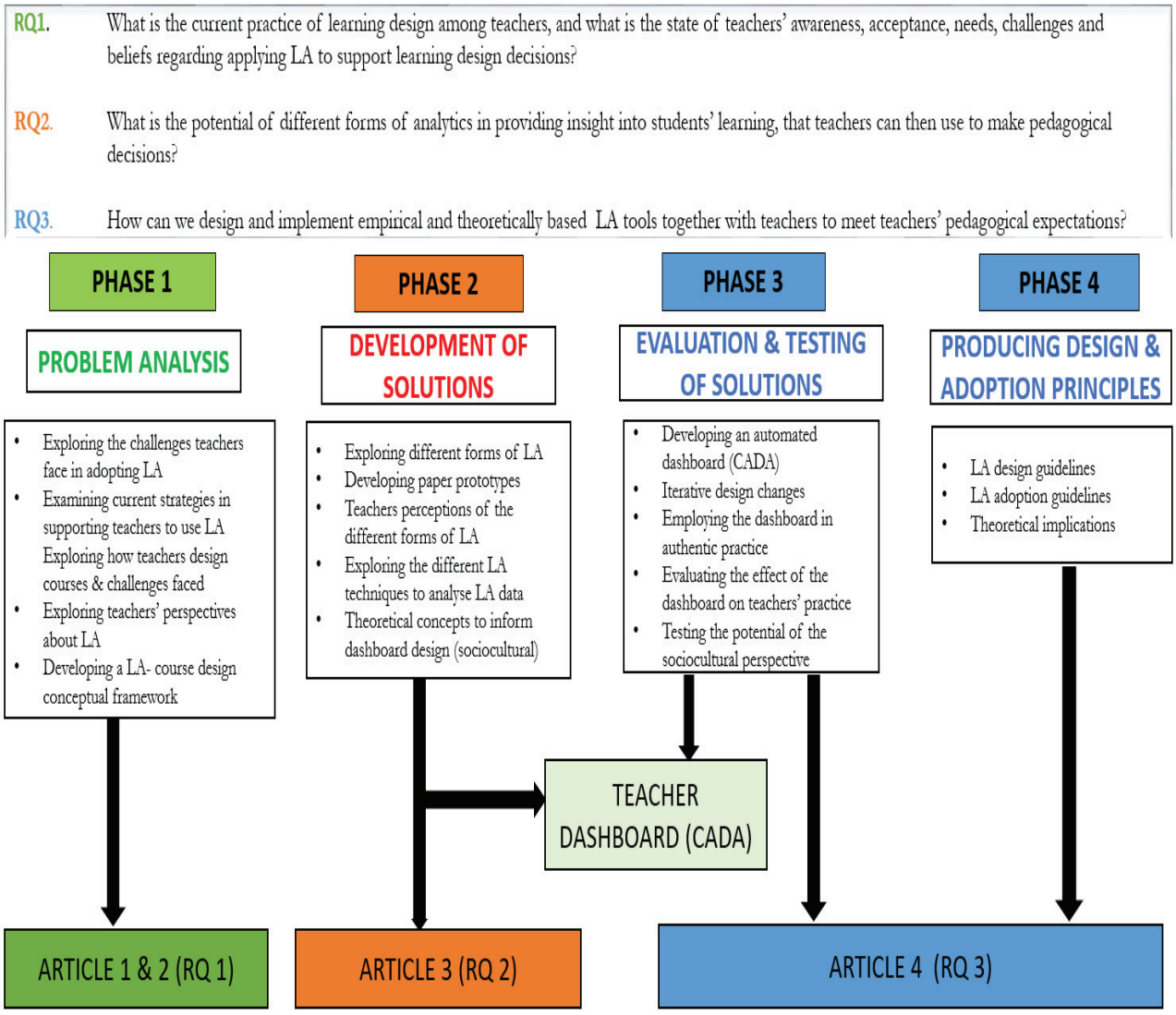
Article 2: Kaliisa, R., Mørch, A. I., & Kluge, A. (2021). 'My point of departure for analytics is extreme skepticism': Implications derived from an investigation of university teachers' learning analytics perspectives and design practices. *Technology, Knowledge and Learning*, 1–22. https://doi.org/10.1007/s10758-020-09488-w

Article 3: 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*, *7*(3), 33–47. https://dx.doi.org/10.18608/jla.2020.73.4

Article 4: Kaliisa, R., & Dolonen, J. A. (2022). CADA: a teacher-facing learning analytics dashboard to foster teachers' awareness of students' participation and discourse patterns in online discussions. *Technology, Knowledge and Learning*, 1-22. https://doi.org/10.1007/s10758-022-09598-7

Figure 2

A DBR Workflow



Note. This workflow illustrates the four phases of the Ph.D. project and how the four articles are linked to these stages and the study's research questions.

Chapter 2: Related Literature

The purpose of this review is to present relevant empirical literature on the two main themes of learning design and LA to contextualize the research problem. Thus, the aim of this chapter is not to give a broad and exhaustive overview of research on learning design and LA, but to present relevant literature that justifies the thematic and methodological focus of this thesis, and creates a basis for the discussion of the findings. The reviewed areas included studies on learning design in higher education (Section 1) and studies on LA in higher education (Section 2). Since the focus of this thesis is LA, the second section is more detailed, focusing particularly on general LA studies in higher education and the three strands of LA research relevant to this thesis: studies on the synergy between LA and learning design, studies on LA dashboards, and studies on the human-centered and participatory design of LA systems.

I used Scopus and Google Scholar to search for relevant literature. I also checked for relevant studies in specific journals that publish research on teaching in higher education and LA, including *Higher Education*, *Teaching in Higher Education*, *Studies in Higher Education*, *Research in Higher Education*, *Educational Technology in Higher Education*, the *Journal of Learning Analytics, Technology, Knowledge and Learning*, *Computers and Education*, and *Computers in Human Behavior*. In addition, I searched the proceedings from the LA and Knowledge Conference (LAK) over the past 11 years and the first handbook on LA, which provides an overview of the key research areas in LA. Several search terms were used to find articles relevant to the different topics that informed this study. These included learning design AND/OR instructional design and higher education, designing for learning in higher education, learning analytics and learning design, instructional design, learning analytics AND/OR academic analytics AND/OR educational data mining and higher education, learning analytics in higher education, teachers, and learning analytics.

I conducted three systematic reviews on the following three themes: LA challenges and frameworks, social LA, and LA dashboards. Since two of the reviews have been published elsewhere (Kaliisa et al., 2021a; Kaliisa et al., 2022a), I summarize only the key findings from these studies in this thesis. This chapter ends with a summary of the key themes identified in the literature, the research gaps, and a brief explanation of how the four articles included in this thesis fill the research gaps by contributing empirical and methodological evidence.

2.1 Learning design practices in higher education

Learning design is a common task among teachers in higher education. The term is vague and contested, with some scholars wondering whether it should be considered a verb or a noun (Macfadyen et al., 2020). Some researchers define learning design as a product (Koper, 2005). Here, the emphasis is on technological tools and technical specifications that support the design process and the creation of online repositories to share promising design examples and practices (e.g., Agostinho, 2011; Hernández-Leo et al., 2006). Other researchers define learning design as a process or practice that involves the planning, sequencing, and adaptation of teaching activities (Macfadyen et al., 2020).

The concept of learning design in this thesis differs from related fields, such as instructional design, a concept widely used in the United States to refer to the "systematic and reflective process of translating principles of learning and instruction into plans for instructional materials, activities, information resources, and evaluation"

(Ragan & Smith, 1999, p. 4). In this thesis, I conceptualized learning design using the definition from Conole (2012), which describes learning design as a range of activities through which teachers prepare and improve course objectives, activities, assessments, and resources in the context of a course or lesson, with the goal of achieving specific pedagogical objectives. In this thesis, the act of making changes to the designed activities (e.g., the lesson structure) or the classroom activities is also considered part of the learning design process. In this case, the process is considered flexible and continuous, with teachers making regular changes, even during the running of the course. Based on this conceptualization, and as I explain more in Section 2.4, learning design is used to explore how LA can be used as a tool to both examine the quality of teachers' activities (e.g., tasks, assessments, and resources) undertaken as part of the learning design process and support their improvement.

One strand of learning design research has focused on what influences teachers' design decisions. Bennett et al. (2015), for instance, investigated the factors that shape university teachers' course design decisions. Their findings revealed that teachers' perceptions of student characteristics, their own beliefs and experiences, summative assessments, and contextual factors influenced design decisions. These findings changed very little over a 15-year period, as an earlier study by Stark (2000) identified similar factors. More recently, Nguyen et al. (2020) highlighted the challenges of learning design as an educator-led practice within educational institutions. Their findings revealed that teachers face significant challenges in assessing intended and enacted learning designs. The authors also reported that most teachers make design decisions at the end of a course since the main source of feedback that informs their learning decisions is summative assessments; however, these assessments provide only a partial picture of learning design and its effectiveness (Bennett et al., 2017).

Other researchers have investigated how the connection between learning design and classroom observation can support the understanding of students' learning and the effectiveness of teaching practices. For example, Eradze et al. (2019) conducted a systematic review based on 24 studies that connected learning design and classroom observations. The authors found that attempts to connect learning design and classroom observations were dominated by human-mediated observations of the physical learning environment. Although the results from observations provide insights into enacted and intended learning design, it is challenging to apply these insights on a large scale due to the human resources required, yet the results are also not available quickly enough to be used by teachers. One promising way forward, according to the authors, is to leverage modern observational approaches, such as multimodal LA techniques and other ICT tools, to complement manual observation processes and systematize learning design data. This is critical given the "design demands on the twenty-first century teacher" (Wasson & Kirschner, 2020. p. 824).

Studies focused on learning design highlight the growing interest in this area of research and practice. The ways in which teachers design courses have consequences for students' learning outcomes, yet teachers still struggle to make timely learning design decisions. Additionally, teachers rely primarily on personal experiences and summative assessments to make design decisions. This has prompted researchers to propose complementary approaches, such as class observations (Eradze et al., 2019), even though these approaches are equally hard to implement at scale. However, since teaching is dynamic, with its real-time character continuously influenced by the interactions between teachers and students (Ashwin, 2009), teachers need systems that can provide them with timely feedback regarding students' learning. Thus, alternative methods are needed to capture the ways in which students' learning behaviors do or do not align with the intended learning design. Persico and Pozzi (2015), who argue that technologies such as LA present an opportunity to

change learning design practices from being based on intuition and tacit knowledge to being a mature research and practice area supported by data, share this view.

2.2 Studies on LA in higher education

Although LA is still at a relatively early stage of development, researchers and practitioners have attempted to use it to support students' learning. Early LA studies focused on predictive analytics, with a significant number of researchers interested in identifying at-risk students in their academic programs. A frequently cited study is the Course Signals project at Purdue University, which was developed to support teachers in identifying at-risk students and providing real-time feedback to students (Arnold & Pistilli, 2012). The system used both LMS and demographic data, such as past academic history, focused on students at risk and led to a 145% reduction in the number of D and F grades, and increased retention in the university (Arnold & Pistilli, 2012).

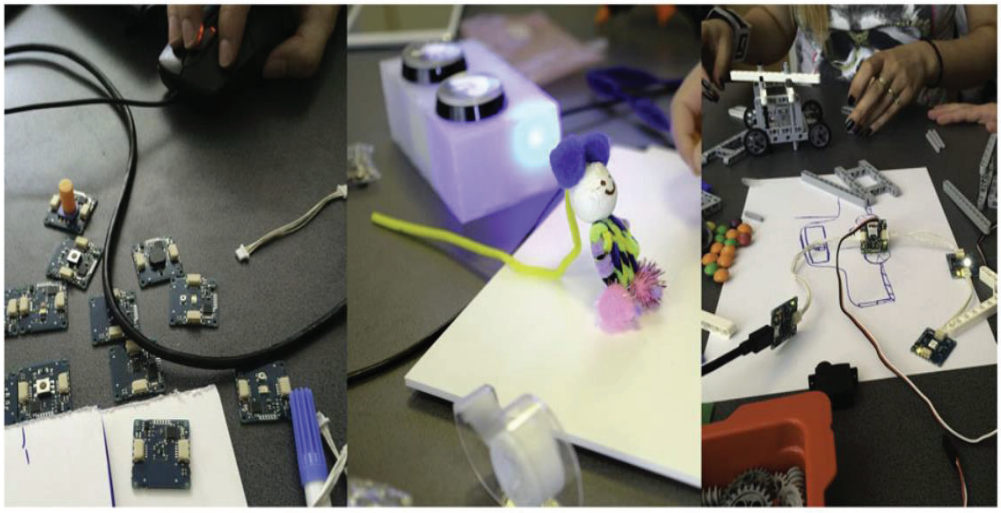
Another predictive study that sought to analyze students' data against their performance was conducted at the University of Maryland in the United States. This study used a tool called "Check My Activity," and correlations were made between students' virtual learning environment (VLE) data and final grades. The results indicated that students with C grades or higher used VLE more than their lower-scoring peers (Fritz, 2010). Predictive models have also been used by LA researchers to empower online teachers in making design decisions (Herodotou et al., 2019) and to model psychological constructs, such as anxiety, and discover how these affect student performance (Valle et al., 2021).

The field of LA is transitioning from focusing on generating predictive models to attaining a deeper understanding of students' social learning processes (Viberg et al., 2018). A distinctive subset of LA studies known as social LA (SLA), which highlights the social perspective of learning, has attracted increased attention (Buckingham Shum & Ferguson, 2012). As I highlight in the theory chapter, Social LA, particularly discourse-centric LA and social network LA, align with Vygotskian and other sociocultural theorists' views of discourse as important for understanding learning through analyzing subject knowledge, argumentation skills, and student–student interactions (Schunk, 2014; Knight & Littleton, 2015). Full details regarding studies conducted on social LA are provided in the systematic review of 26 studies, which comprise part of the exploratory phase of this thesis (Kaliisa et al., 2022a).

LA research has shifted from studies focused only on data from digital environments, which some researchers (e.g., Shaffer, 2017) refer to as low-hanging fruit, to collecting data from real-world teaching contexts by analyzing learning artifacts, traces, and natural human signals, such as the gestures, facial expressions and emotions captured in physical learning environments (Ochoa et al., 2017). This subfield of LA research is called multimodal LA. While the multimodal LA subfield is relatively young, initial studies have produced promising results. For example, Spikol et al. (2018) used diverse sensors, including computer vision, user-generated content, and data from learning objects, to study small groups of learners' interactions (see Figure 3). The purpose was to investigate the features of student group work that best predict team success in open-ended tasks. Their conclusion was that the distance between learners' hands and faces is a strong predictor of students' artifact quality, an attribute that underscores the value of student collaboration.

Figure 3

An Example of Multimodal Analytics



Note. This simulation was done with engineering students performing project work.

2.3 Studies on the challenges of LA adoption

LA faces a number of technical, ethical, and pedagogical challenges. Since the focus of this thesis was to explore the use of LA in supporting teachers' everyday practice, the first article reviewed studies that discuss the challenges facing teachers' adoption of LA. The full details of this review are reported in Article 1 (Kaliisa et al., 2021a). In brief, the key challenges identified were as follows: (i) teachers experiencing difficulties integrating technical and pedagogical expertise into LA use, (ii) a lack of connection between LA and educational theories or pedagogies, (iii) failure to align LA with teachers' practices, and (iv) ethical and privacy-related concerns.

I argue that some of these challenges could be addressed by integrating LA and learning design. The failure to align LA with teachers' practices could be addressed by opting for a participatory approach that involves working with teachers to identify problems and co-design LA solutions. To that end, the following sections present a detailed review of the literature on the following three strands of research that seek to address the challenges of LA: (1) the connection between LA and learning design, (2) studies on LA dashboards, and (3) studies on human-centered and participatory approaches in LA.

2.4 Studies on LA and learning design

Ten years ago, LA researchers pointed to the rich potential for connecting LA and learning design (Lockyer et al., 2013). They argued that the effective alignment of LA and learning design would benefit both fields and would offer teachers the evidence they need to improve their teaching practice (Macfadyen et al., 2020). The researchers further argued that information related to learning design provides a valuable context for advancing the interpretation of metrics from LA algorithms (Rienties et al., 2016; Mor et al., 2015), thus making learning design decisions more robust and informed by data (Persico & Pozzi, 2015).

Several researchers have explored the connection between LA and learning design. One of the earliest studies was conducted by Lockyer et al. (2013), who investigated how learning design could provide a framework from which to make sense of LA outputs. To achieve this, the authors used a theoretical example of design for case-based learning and two forms of analytics, which they called checklist analytics (student logins) and process analytics (student interactions and discussion posts). Using social network visualizations, the authors showed how the illustrated networks helped determine whether the intended pedagogical outcomes had been achieved.

In a UK-based study, Rienties et al. (2015) investigated how 87 modules were designed, and whether this affected students' LMS behaviors and final grades. Using clustering and correlation analysis, the authors found that the ways in which teachers design courses influence students' online behaviors and, consequently, their learning performance. In particular, the authors found that modules designed to focus on content and cognition activities resulted in lower completion and passing rates than other activities, such as assessments.
In New Zealand, several studies have been undertaken at different institutions under nationally funded research, including "Building an evidence base for teaching and learning design using LA data" (Gunn et al., 2017). These cases demonstrate how LA data, as a source of primary feedback, can be utilized by instructors to inform teaching and learning design and to provide personalized support to students. For example, a multi-disciplinary First-Year experience initiative at the University of Auckland combined student information from institutional and faculty databases with online activity logs and performance data to monitor learners' progress (Gunn et al., 2017). The findings showed that such data provide useful feedback to teachers on their learning design decisions, while timely support and mentoring contribute to students' performance. More recently, Lancaster et al. (2020) examined how learner interaction patterns associated with LMS use variables align with learning design decisions and course outcomes. The authors concluded that the teachers' design choices heavily influenced the students' use of the LMS, which later affected their final grades.

While most studies that examine LA and learning design have relied on data from online environments, Mangaroska et al. (2020) employed a multimodal LA approach to investigate learner cognitive processes and learner affective states in a selected set of programming activities in a co-located computer science class. Data from eye tracking, a wristband sensor, video-captured facial expressions, and log data from the online design environment revealed that learner behavior captured by multimodal data improves the understanding of performance, which teachers can leverage to make informed changes in their learning design. Using a similar approach, Martinez-Maldonado et al. (2021) studied teachers' spatial behaviors in the classroom using a multimodal LA tool called Moodoo. The findings revealed that insights from Moodoo could be used to generate a deeper understanding of how the pedagogical intentions embedded in learning design and personal teaching strategies are reflected in the ways in which teachers use the learning space.

Researchers have also conducted systematic reviews on the synergy between LA and learning design, demonstrating the growing interest and maturity of the two fields. For example, Mangaroska and Giannakos (2018) conducted a systematic review of 43 empirical studies that explored the connection between LA and learning design. The authors found that most LA and learning design studies are dominated by the use of data from a single system or platform, and that the implementation of multimodal LA is not widespread. They also found only three studies (e.g., Wise et al., 2014) in which LA was explicitly aligned with a theory-grounded learning design. More recently, Blumenstein (2020) conducted a systematic evaluation of effect sizes reported in 38 key studies in pursuit of effective LA approaches to measuring student learning gain for the enhancement

of higher education pedagogy and delivery. The author concluded that large positive effects on student outcomes were found in learning designs that fostered socio-collaborative and independent learning skills.

Work that is more recent has focused on the development of frameworks and tools that support the connection between LA and learning design. For example, as reported in Article 1 of this thesis (Kaliisa et al., 2021a), 18 LA frameworks that aim to support the connection between LA and learning design have been established. While few frameworks have been concretized into technological artifacts and concrete data streams, they provide guidelines for the support of teachers in the use of LA for learning design purposes.

Two main conclusions can be drawn from the literature addressing the connection between LA and learning design. First, LA can provide a basis on which to understand planned versus enacted learning design. Second, learning design provides a theoretical background from which to interpret analytics in a way that makes sense to teachers. While the literature indicates the potential of connecting these two fields of research, most studies in this area have relied on log data and taken a top-down approach (e.g., researcher-driven) to developing LA solutions (tools and frameworks) to support teachers' design practices.

2.5 Studies on LA dashboards

Higher education institutions are increasingly investing in building visual representations of LA dashboards (Jivet et al., 2017), which are defined as "single displays that aggregate different indicators about learner(s), learning process(es) and/or learning context(s) into one or multiple visualizations" (Schwendimann et al., 2016, p. 37). Dashboards are a key tool for representing LA; as such, researchers have concentrated on exploring their effectiveness in providing deep insights into student learning and using them to improve teaching and learning (Jivet et al., 2017; Verbert et al., 2013). Some comprehensive studies on LA dashboards have been presented in systematic reviews (e.g., Schwendimann et al., 2017; Jivet et al., 2017).

While I found many reviews on the theme of LA dashboards, none focused specifically on teacher-facing dashboards. Since the focus of this thesis was on designing and implementing an LA dashboard together with teachers, I decided to explore the existing literature focused on LA dashboards aimed at teachers. In this regard, I carried out a systematic review of studies reporting on teacher-facing dashboards to provide me with an understanding of the key issues in this sub-area of LA research and to inform the empirical work of the thesis.

2.6 A systematic review of teacher-facing dashboards

This review included 50 articles retrieved from ACM Digital Library, IEEE Xplore, SpringerLink, Science Direct, Wiley Online Library, and Google Scholar. In each study, I explored the purpose of the dashboard, the theoretical grounding, stakeholder involvement, and the design and implementation of the dashboard. Due to space limitations, I will provide only the findings from the review that are central to this thesis.

A relatively high number of teacher dashboards were designed to support teachers in optimizing or adapting their learning design and learning materials (n = 11) or planning upcoming lessons (n = 3). Several papers aimed to support teachers in providing feedback (n = 6) or offering personalized support to learners (n = 7), while others were vague regarding the type of intervention they were aiming to facilitate (n = 16). Martinez-

Maldonado et al. (2020) developed one example of a dashboard that was meant to support teachers' awareness; this dashboard unraveled the complexity of multimodal data by organizing it into meaningful layers that offered teachers and students critical insights.

In terms of theoretical frameworks, the review identified only five studies that mentioned the theoretical perspective informing the design of dashboards. Dourado et al. (2021) structured the information displayed on their dashboard in line with Rogoff's social participation theory, which proposes learning as participation in three interdependent planes of analysis: cultural/institutional, interpersonal, and personal (Rogoff, 1991). Singh et al. (2020) relied on engagement theory (Kearsley & Shneiderman, 1998) to select their data sources and analytics. Michos and Hernández-Leo (2018) used cultural-historical activity theory (Engeström, 2000) to develop a community awareness dashboard to support teachers who use social learning design platforms. Martinez-Maldonado et al. (2019) relied on spatial pedagogy to create a system that would provide feedback to teachers on their movement around the classroom. The limited number of studies relying on theory to build dashboards sparks questions regarding the perspectives behind dashboard indicators. This is especially important since dashboards are meant to provide insights into students' learning behaviors, which can only be defined and interpreted through learning theories.

Stakeholder involvement in the design process of teacher dashboards was reported by half of the analyzed papers (n = 25). Teachers were the most commonly involved stakeholders (n = 22), followed by system engineers or interface designers (n = 7), instructional designers (n = 6), and LA researchers (n = 4). Interestingly, for the studies that involved teachers, they were engaged mainly during the problem exploration phase, where researchers, through methods such as interviews, workshops, and surveys, requested input from teachers on the kinds of pedagogical needs the dashboards could address. Moreover, in many of the studies (n = 16), the teachers were only involved in providing feedback on the initial prototypes, before the researchers began developing the systems. For example, Chen et al. (2019) used four instructors to determine the suitability of their prototype, which helps teachers explore learning patterns and data stories; however, the teachers beyond this stage provided no extra input.

The analysis identified only two studies that went beyond exploring teachers' needs in the problem exploration phase. For example, during interactive sessions with school teachers, Van Leeuwen et al. (2019) first asked the teachers to describe what they actually did in the classroom; then, they presented them with specific possible sources of information that had already been logged by the system to understand which indicators would be most useful to the teachers. Yoo and Jin (2020) asked instructional designers, web designers, and engineers to provide multiple sketches and contribute to the design of their dashboard's interface. These sketches were then feedbacked together with the teachers. The review of teacher-facing LA dashboards generally showed that explicit stakeholder involvement—particularly teachers in the dashboard design process—remains limited. These findings echo the 2016 EU report titled "Research evidence on the use of LA," which states that even though many LA tools are developed and used across Europe, little research has focused on what the intended users (teachers) need for their everyday practice (Ferguson et al., 2016).

The review also highlighted that most teacher-facing dashboards are developed as part of exploratory work and thus stop at the prototype and piloting stages. Several exceptions to this are the SRES (Vigentini et al., 2020), OU Analyze (Herodotou et al., 2019), and OnTask (Pardo et al., 2018) dashboards currently in use by several institutions, teachers, and courses. This raises implications for realizing the actual impact of such

dashboards since they are implemented in controlled situations and small-scale studies that cannot be generalized.

To summarize, this short review of teacher-facing dashboards highlights the following three findings of relevance to this thesis: (1) interest in designing and developing dashboards to support teachers' awareness of students' learning activities is increasing, (2) stakeholder involvement during the design process is limited, and (3) dashboard developers rarely leverage learning theories to inform dashboard designs. This thesis will touch upon some of these shortcomings by taking a DBR approach to develop a teacher-facing dashboard grounded within the theory and based on teachers' pedagogical needs.

2.7 Human-centered and participatory LA design

Consensus within the LA community to increase stakeholder participation during the conception, design, and deployment of LA systems is growing (Buckinghum Shum et al., 2019). The desire to employ a human-centered approach in LA is based on the premise that the features and functions associated with LA systems should be conceived and defined by the intended end users rather than researchers and system developers (Buckinghum Shum et al., 2019). Mor and colleagues (2015) stated that "top-down pressures can have a heavy impact on the designs teachers produce…teachers need to be actively involved in their design and supported to do this" (Mor et al., 2015, p. 227).

The LA community has built on work from well-established human-centered and design communities, such as HCI (Grudin, 2017; Giacomin, 2014) and participatory design (Bratteteig & Wagner, 2014), and its identity has evolved. Buckingham Shum et al. (2019) took the first step toward participatory LA, proposing HCLA as a broad concept that reflects interests in the LA community to champion participatory approaches in LA research, with stakeholders' needs at the forefront (Chatti et al., 2020).

A strand of studies that have taken an HCLA approach was published in a special HCLA section (Buckinghum Shum et al., 2019) in the *Journal of LA* and more recent LAK conferences. Notable examples of such studies are Holstein et al. (2019), who presented a detailed case study on the iterative co-design of an LA tool, Lumilo. In this study, the authors illustrate an end-to-end process that indicates how non-technical stakeholders can participate in the design of LA systems. The authors concluded that LA designers should focus on stakeholder needs rather than analytics, and scaffold users on how analytics might inform their practice. Dollinger and colleagues (2019) discussed how LA researchers and designers can design and co-create tools with teachers. The authors illustrate their case using SRES, which was developed with teachers at several Australian universities and has been used at scale with over 30,000 students. Reflecting on the success of SRES, the authors emphasize what can be achieved when an LA platform is developed in full collaboration with the intended users.

Wise and Jung (2019) investigated five university teachers' use of LA to inform their teaching. Despite their relatively small sample, the authors concluded that involving teachers in the development of analytics tools and conducting early studies in situ can provide insights into tool design and use. Taking a slightly different approach, Ahn et al. (2019) presented a design narrative of developing dashboards to support teachers' pedagogical practices. The authors underscore the role of research–practice partnerships in helping LA designers balance the tensions that arise from making interfaces that are technically sound and fit for local needs. In another HCLA study, Rehrey and colleagues (2019) presented an action research study involving

teachers with no prior experience with LA across the university, building their capacity as agents of institutional change through a collegial LA Fellows program. The findings from the program's self-reports reveal that by engaging teachers in LA, new opportunities for understanding and improving student learning arise. More recently, Martinez-Maldonado et al. (2020) followed a co-design approach to design for the effective use of translucent LA systems in the context of teamwork in clinical simulations, while Chatti et al. (2020), through their indicator specification card (ISC), emphasized HCLA as a viable approach to designing useful LA indicators for and with users.

Studies that take a participatory approach toward LA remain limited. As noted by Buckingham Shum et al. (2019), "LA May Be 10 Years Old, but HCLA Is a Toddler" (p. 5). More specific work in this area is needed to develop theoretical knowledge and principles that will guide researchers and designers in engaging non-data experts in understanding basic analytics-related concepts and building a mutual understanding of educational constructs (Martinez-Maldonado et al., 2020).

2.8 Summary of the literature review

In this chapter, I synthesized the key research themes relevant to this thesis and highlighted several research gaps and issues in the fields of learning design and LA. These gaps strengthened the rationale for conducting this project and the theoretical and methodological choices made in the four articles. First, the shortage of empirical work that takes a bottom-up approach to understanding teachers' design practices before introducing LA systems justifies the DBR and the HCLA approach employed in this thesis. Second, the dominance of studies that use log data as evidence to explore the relationship between LA and learning design explains the use of multiple sources of data used in Article 3. The review also showed that few LA studies are grounded in LA theory. Thus, in Articles 3 and 4, a sociocultural perspective (Säljö, 2002) is employed as the lens through which the LA data, analytical techniques, and features used in the teacher dashboard were chosen. In sum, by addressing the above gaps highlighted in the literature, this thesis contributes to the theoretical, empirical, practical, and methodological developments in the literature on technology-enhanced learning, learning design, and LA.

Chapter 3: Theoretical Framework

The literature reviewed in the previous chapter highlighted the lack of theoretical grounding as one of the key limitations in existing LA research. The lack of theoretical grounding can be partially explained by the multidisciplinary nature of the LA field and the different and sometimes opposing epistemological and philosophical positions adopted by researchers. In this chapter, I highlight some of the epistemological and philosophical tensions surrounding LA research, and how these informed the theoretical position, I took in this thesis. Notably, I discuss some theoretical concepts here in a reconceptualization of what is discussed in the articles.

This chapter begins with a discussion of two contrasting philosophical perspectives (empiricism and rationalism), with particular attention being paid to their assumptions regarding big data/LA. Later, drawing from these perspectives, I articulate the position of theory in LA research from the sociocultural perspective that underpins this thesis. Here, the concept of "big data" is defined as the capture and analysis of large data sets about learners that can be analyzed computationally to reveal patterns about students' learning behaviors. Thus, "big data" and "LA" in this chapter are used interchangeably. (See Figure 4 for the illustration of the connection between the philosophical and theoretical elements in this thesis).

3.1 Empiricism: An inductive reasoning hypothesis

Empiricism is a philosophical view that claims that sensory experience is the ultimate source of knowledge (Leonelli, 2020). Thus, advocates of empiricism align with induction—an epistemological approach that underscores the objectivity of scientific knowledge in developing theory based on empirical data (Leonelli, 2020; Kitchin, 2014; Schunk, 2014)—with no need for prior theories (analogous to a pair of theory-tainted eyeglasses) (Ladyman, 2012).

One of the basic assumptions of radical empiricism about big data is that *data is fair and objective, and it can tell the story of human behavior without the need to involve humans* (Kitchin, 2014) or enter the sense-making process secondarily. This view is based on the contemporary notion by big data scientists that big data is exhaustive in scope, capable of capturing entire populations rather than small-scale samples based on case studies (Shaffer, 2017). Thus, according to this view, if we are interested in discovering the truth about a phenomenon such as students' learning behaviors, then using the traces available in digital learning environments and, more recently, physical environments (through, for example, multimodal LA), is enough to draw conclusions about students' learning without necessarily basing those conclusions on existing theories, viewpoints, or prior concepts (Ladyman, 2012; Tansley & Tolle, 2009). In this regard, as Siegel (2013) argues, the intention of predictive analytics is more to predict human behavior than to explain the reasons behind the observed behavior. Thus, following the empiricist data-driven approach, some LA researchers use data as the departure and endpoint to make conclusions (or use pretest and post-test techniques) without relying on theoretical preconceptions, a situation described by some radical empiricist advocates as "the end of theory" (Tansley & Tolle, 2009).

However, as I elaborate on later, the claims made by radical empiricists have been contested by big data skeptics, who argue that the techniques used by big data scientists are not value-free and offer less or even no structural explanations of the results gained from their analyses (Tansley & Tolle, 2009; Shaffer, 2017). For example, Wise and Shaffer (2015) drew a contrasting conclusion: "What counts as a meaningful finding when the number of data points is so large that something will always be significant?" (p. 6). Under this view, if

researchers collect oceans of data about learners and postulate variables bottom-up, intending to investigate every possible relationship among the variables, then it is probable that most variables will be somewhat correlated with each other (Frické, 2015). This, as Shaffer (2017) states, could present "mathematically rigorous but conceptually empty results."

Subject matter experts matter less: Another premise of big data among education proponents who employ the empiricist perspective is that the roles of subject matter experts and domain-specific knowledge matter less, with probability and correlations being the most important research measures for understanding learning behavior (Prensky, 2009). For example, LA researchers who subscribe to the empiricist view may not find it necessary to engage with practitioners, such as teachers, to help them make sense of the insights derived by algorithms. However, scholars such as Kvernbekk (2019) have warned against research that interferes with the space of practitioners by denying them their own judgment. Similarly, Porway (2013, cited in Kitchin, 2014, p. 5) notes that without subject matter experts being available to explain and interpret problems and provide context in advance, researchers are likely to get poor results, as they are usually equipped to explain the "what" but not the "why" of the insights generated from data.

In this sense, an epistemological position that disregards the role of experts in interpreting data from their own contexts could be harmful, as domain experts can easily dismiss the many supposed relationships within data sets as trivial (Miller, 2010). In other words, emphasizing practical and implicit knowledge is what allows practitioners to take center stage during the research process (Kvernbekk, 2019). In this regard, a human-centered approach to LA research (Buckingham Shum et al., 2019) that puts theory, experts, and practitioners at the forefront in the design and interpretation of LA is paramount. In what follows, I present some alternative perspectives (including the rationalist deductive thesis) that advocate for the use of theory while working with big data.

3.2 Rationalism: A deductive hypothesis

Rationalism is an epistemological view that considers reason to be the chief source of and test for knowledge (Ladyman, 2012). More formally, rationalists such as Plato view the criterion of truth as being not sensory, as argued by empiricists, but intellectual and deductive (Williamson, 2017). Rationalism believes that there are significant ways in which concepts and knowledge are gained independently of sense and experience (Leonelli, 2020) and that we gain knowledge a priori with logic; thus, knowledge is independent of sensory experience (Schunk, 2014).

As a reasoning approach, deductive reasoning works from the more general to the more specific case (Rips, 1994). Hence, from a research perspective, theory provides researchers with a basis from which to interpret and understand the patterns derived from data. As argued by Ladyman (2012), "We cannot just begin with the data, we need guidance as to what data are relevant and what to observe, as well as what known causal factors to take into account and what can safely be ignored" (p. 57).

This is an exemplary statement that underscores that theory cannot be read off while trying to make sense of students' learning based, for instance, on LA. For example, in this thesis, I used approaches such as SNA to analyze students' online discussions. While SNA can provide insight into students' interactions, researchers might find it difficult to make meaningful interpretations based on SNA metrics alone, such as betweenness centrality. In this regard, by taking a sociocultural approach, that defines learning as participation (Saljø, 2002),

conclusions about students' learning can be deduced based on observed social network interaction patterns (Saqr et al., 2018). This implies that a theory-informed inquiry is needed to reveal the connections between the large sums of data analyzed by LA systems and algorithms, since the data in themselves may not be meaningful (Gould, 1981).

Neither of the dominant philosophical approaches discussed above could independently offer the analytical lens through which to make sense of students' data. In this regard, I chose to take an abduction approach, which is open to a combination of inductive and deductive approaches in making sense of a phenomenon (Kitchin, 2014). In what follows, I provide a brief description of the abduction approach before introducing the sociocultural perspective that informed this thesis.

3.3 Abduction: A combination of the inductive and deductive approaches

Abduction is a flexible approach that is open to using a combination of inductive (empirically driven) and deductive (theoretically driven) approaches to reach a conclusion that explains a phenomenon (Kitchin, 2014; Hobbs et al., 1993; Shook & Paavola, 2021). While the abductive approach could be limited by the two approaches not informing each other, researchers taking this approach have an opportunity to move back and forth between data and theory to gain richer insights (Linneberg & Korsgaard, 2019). Here, the insights revealed within the data do not arise from a vacuum, do not speak for themselves, and are not the end-point for the research process (Kitchin, 2014). For example, in Article 2 of this thesis, I started with a deductive approach, the technology acceptance model (TAM) (Venkatesh & Davis, 2000), as the lens through which to interpret teachers' perceptions of LA and learning design experiences. However, during the data analysis, I realized that the constructs of TAM could not explain all the issues raised by the teachers (particularly those related to learning design practices). Thus, I employed an inductive approach and thematically analyzed the data that fell outside of the initial theoretical framework (Douven, 2011; Meyer & Lunnay, 2013); this allowed me to gain a comprehensive understanding of teachers' perspectives beyond the original research premise. This process led to the formulation of a new conceptual framework connecting LA and learning design (Article 2), justifying the potential of an abductive approach to developing theory. A similar approach was followed in Article 4, where Kirkpatrick's (2009) evaluation model was used as the point of departure for exploring teachers' use of CADA in authentic practice. This framework was later complemented by an inductive approach that captured additional insights beyond the framework. Further details about the abduction approach and how it was applied are provided in the methodology chapter.

In what follows, I discuss the sociocultural perspective (Säljö, 2009; Vygotsky, 1978), the overarching framework that inspired the selection of data sources, the analytical techniques, and the design of the teacher-facing dashboard in this thesis.

3.4 The sociocultural perspective

Research in teaching and learning has been influenced by the sociocultural—also called the socio-historical or cultural-historical—perspective (Engeström, 2000; Mercer, 2007; Säljö, 2009; Wertsch, 1991). The sociocultural perspective is grounded in the work of Russian psychologist Vygotsky (1978), who considered the interactions between social, cultural-historical, and individual factors the key to human development (Scrimsher & Tudge, 2003). Vygotsky noted that cognitive change and human development are intimately linked with cultural tools used in social interactions, through which learners acquire cultural values as they interact with more knowledgeable members, such as teachers, parents, and capable peers (Säljö, 2009). There are also several related theoretical positions, including the social constructivist perspective (Palincsar, 1995) and situated cognition (Greeno, 1997), as well as literature that deals with specific features of sociocultural theory (Lave & Wenger, 1991) and its relation to educational practices (Säljö, 2002). For instance, researchers from fields such as computer-supported collaborative learning (CSCL), which uses the sociocultural perspective (Ludvigsen et al., 2021; Lund & Hauge, 2011; Hontvedt & Arnseth, 2013; Ludvigsen & Mørch, 2010), focus on the sociocultural dimensions of learning activities and artifacts, and how these mediate and influence interactions between learners and technology (Matuk et al., 2021) in both formal (Ludvigsen et al., 2021) and informal learning settings (Oswald, 2020; Pierroux et al., 2020).

Although the sociocultural perspective is based on several theoretical concepts, four main concepts guided the analytical and design efforts used in this thesis: (i) the notion of language as an abstract tool to understand learning; (ii) learning as participation in social interactions and the mastery of new concepts; (iii) mediation; and (iv) artifacts (in the case of this thesis, language and digital tools). Notably, of the four articles included in this thesis, only Articles 3 and 4 explicitly draw on the sociocultural perspective. Largely, the sociocultural approach frames the entire thesis and justifies the methodological and design decisions made. In this thesis, I used the sociocultural perspective for the following two reasons: (i) empirical analysis: to provide a lens through which I, as a researcher, could analyze and make sense of students' online learning activities (Article 3), and (ii) technology design: to inform the design of an LA dashboard aimed at supporting teachers' sensemaking of students' online activities (Article 4). In the following section, I will explain how the sociocultural perspective was applied to these two levels.

3.4.1 Language as a tool for understanding learning

The Vygotskian conception of language as a cultural tool (Schunk, 2014; Lund & Hauge, 2011) highlights that language, which, in this thesis, is interpreted as "discourse" (consisting of both oral and written statements), is considered an important source for understanding students' learning. Thus, researchers who consider learning from a sociocultural perspective tend to focus on the analysis of classroom dialogue (both written and spoken) with the view that knowledge is not only possessed individually but is also created by and shared among learners in specific contexts (Mercer et al., 2017). This notion implies that, while analyzing students' discourse, the focus should be on the qualities of social and communicative learning processes (e.g., the gradual uptake of scientific vocabulary; productive conversations) rather than the intrinsic capability of individual students (e.g., based on exam scores) (Mercer et al., 2017). If relying on the sociocultural approach (Säljö, 2009), online discussions afford students additional opportunities to express their understanding of content and interact with their peers rather than relying solely on individual-centered modes of learning (Oshima et al., 2012). In this sense, as social and cognitive tools for communicating knowledge, an analysis of online discussion posts could present an opportunity to identify students' collaboration processes and knowledge construction. In this thesis, this notion provided a theoretical rationale for empirically focusing on written

language/discourse (as expressed in online discussions) as a key source of data for understanding students' learning processes (e.g., the use and mastery of key subject concepts). Hence, as I describe in Section 3.4.2 of this thesis, I used the sociocultural notion of language as a tool for understanding learning and analyzing online discussions as a means of identifying how students construct knowledge during collaborative online discussions.

3.4.2 Learning as participation in social interactions and mastery of key concepts

Learning as participation in practices and actions (Greeno, 1997), social interactions (Vygotsky, 1978), and legitimate peripheral participation (Lave & Wenger, 1991; Sfard, 1998) is another strand of the sociocultural perspective on which I am building. The notion of learning through social interaction proposes that individuals align their existing knowledge to create new meaning through actions and social interaction (Ludvigsen & Mørch, 2010). This aligns with Vygotsky's notion that "intermental" (social interactional) activity influences the "intramental" (individual cognitive thought) capabilities (Vygotsky, 1978), implying that knowledge is constructed through an interdependence of participants interacting with each other and with tools and objects in their environment (Säljö, 2010). From this perspective, researchers have concluded that peer discussions, active participation, and interaction with others are crucial to students' learning of conceptual knowledge (Børte et al., 2020; Damsa & Ludvigsen, 2016). Thus, in this thesis, specifically Article 3, I take a stance that depicts learning as involving *interaction* between participants by analyzing communicative actions, such as the social ties created when students interact during online discussions, to serve as a venue through which to assess students' learning and knowledge construction.

I also draw inspiration from Säljö (2002), who describes learning as the participation in, and mastery of, subject-specific discourses and practices mediated by artifacts. The notion of mastery of concepts seems to imply that the analysis of students' discourse could be a proxy for identifying students' mental functioning, with discourse exhibiting domain-related concepts considered to indicate a higher form of mental functioning (Wertsch, 1991). In this sense, learning is seen as the process of becoming a legitimate participant in a community, which implies mastering the practice and its norms, values, domain-specific language (Lave & Wenger, 1991), and the ability to use them in conversation with peers and more capable others (e.g., teachers). For example, when students discuss academic topics together and respond to each other's ideas using feedback from each other and their teachers, they have a higher chance of developing a deeper understanding than solitary thinking (Black & William, 2009; Linn & Eylon, 2011) because discussion may involve argumentation, negotiation, and persuasion, which support deepened understanding.

Influenced by the sociocultural notions of language as both a tool for understanding the learning process and participation in, and mastery of, subject-specific concepts, as a researcher, I chose two LA techniques to use to analyze students' interactions and the discourse they produced during the online discussions: social network analysis (SNA) and automated text network analysis (a computational, linguistic approach). These two approaches are considered suitable for identifying patterns of discursive activity that show students' use of subject-specific concepts and participation with one another (e.g., social ties), which are constructs congruent with the sociocultural perspective. SNA and automated text network analysis are part of a subset of an LA approach called social LA (Buckingham Shum & Ferguson, 2012), which is directed toward the study of group processes and the collaborative construction of knowledge from activities performed in social learning environments (e.g., online discussion forums) to identify knowledge construction and participation trajectories (Ferguson et al., 2013). The idea behind social LA is the recognition that social interactions are a major source of knowledge construction, and when properly analyzed (e.g., informed by a sociocultural learning

perspective), they can support the sense-making of complex educational data generated during social activities for teachers, students, and other educational stakeholders (Kaliisa et al., 2022a).

Since participation, mastery of concepts, and social interaction are judged as key proxies for understanding learning processes from a sociocultural perspective, I operationalized them as the lens for assessing students' learning in online discussions (Säljö, 2009). For instance, as highlighted in Article 3, the automated analysis of discussion posts was meant to identify how students used different concepts during the weekly online discussions. The analysis resulted in a network of topics based on the proximity of their representativeness, which was used as a mediating representation of student discourse within the online discussions (Wise et al., 2021). At the same time, the SNA of the students' interactions showed the students' participation dynamics in terms of social ties, which provided an avenue through which to identify the students' participation trajectories that, from a sociocultural perspective, serve as proxies for the students' learning processes.

Furthermore, to establish a context for the interpretation of the network and discourse analytics outputs, I followed Wise and Vytaseks' (2017) suggestion to conceptually and logistically coordinate LA solutions with respect to the overall learning design. The learning designs for the courses included in this thesis implicitly incorporated elements of the sociocultural perspective, characterized by instructional activities (e.g., online discussions) and an emphasis on learning outcomes, such as participation and engagement between learners. This explains why certain techniques and the LA dashboard (which are presented in the next section) were intentionally developed to analyze communicative interactions (e.g., interactions among students and the concepts they use) central to the learning design. For instance, in Article 3, I used the course objectives, discussion prompts, and task instructions outlined in the learning design as the basis for making sense of the patterns that emerged from the social network and discourse analysis approaches. For example, students who were not connected to any other peers in the sociogram did not represent elements of student–student collaboration as envisaged by the teachers, while discussion posts characterized by the use of external references and subject-specific concepts (e.g., constructivism; see Article 3)—detected using the text network algorithm—were considered to be contributions to the intended pedagogical objectives of the course or as representing higher levels of mental functioning (Wertsch, 1991). In this sense, learning designs provided a valuable context for me, as a researcher, to make sense of the LA output generated from the students' online interactions and contributions (Rienties et al., 2016) instead of relying on arbitrary correlations (Brooks, 2013), which might have led to false inferences about learning.

3.4.3 Mediation and artifacts

Mediation and artifacts are key concepts in the sociocultural perspective, going back to Vygotsky's (1978) original work and developed further in activity theory (Engeström, 2000; Conole, 2012). The idea of mediation claims that we do not act directly upon objects in the world; instead, there are cultural artifacts and tools (both conceptual and technological) that lie between us and the object of our activity (Atmanspacher, 1994). Wertsch (1991), a seminal researcher in the sociocultural tradition, considers mental functioning to be influenced and guided by the mediational means our minds employ to carry out tasks. For example, teachers and students can be supported through representational tools, such as language and visualizations, during the learning process. Such representations can scaffold (Wood et al., 1976) the design process and transform teaching and learning by externalizing human cognitive functions into objects we can see, share, and manipulate (Säljö, 2010)—and they are increasingly being supported by digital tools. For example, tools such as LA dashboards, which analyze and display students' learning activities in online and co-located settings, could be considered to support the

externalization of students' cognitive functions, and teachers can leverage this to support their teaching decisions (e.g., personalized feedback).

In this thesis, I use the concepts of mediation and artifacts in three ways: 1) to position learning design as a mediating intellectual artifact used by teachers to plan for students' learning, 2) to position Canvas as a mediating computational artifact used by teachers to implement learning design, and 3) to position LA (CADA, a teacher-facing dashboard) as a mediating computational artifact that enables teachers to make sense of students' online learning activities and scaffold their learning design decisions. The three positions are described below, and the connection between the concepts is illustrated in Figure 4.

3.4.3.1 Learning design as a mediating intellectual artifact

At the core of the sociocultural perspective is the notion that human activity is mediated by artifacts and tools (Atmanspacher, 1994). In a learning context such as a higher education institution, teachers plan for students' learning activities by preparing the order of the course activities and assignments, which, from a sociocultural perspective, are contextually bound and regarded as cultural tools that mediate how students learn and engage in course activities (Lund & Hauge, 2011; Rasmussen & Ludvigsen, 2010). Thus, learning design—, which, in this thesis, is conceptualized as the way in which teachers plan and order different course objectives, resources, and activities to support their students' learning—is considered an example of a mediating intellectual artifact. For instance, using the example of the pedagogy course reported in Article 3, the course teachers emphasized (1) supporting students to critically discuss the significance of digital technologies in organizations, schools, and cultural institutions (e.g., museums), and (2) enabling students to discuss academic texts in interdisciplinary teams and small groups in the classroom. The teachers planned to achieve this by setting up a weekly discussion forum in which students would be asked to make two contributions and respond to at least one other student. This implies that the students' actions, in the online discussions, were situated and in part determined by the learning design, and any attempt to make sense of their interactions may not easily be done without considering the aforementioned learning design that guided these social encounters. The teachers used Canvas as a computational artifact to support the design and implementation of the online discussion activities.

3.4.3.2 Canvas as a mediating and computational artifact

According to Goodyear and Retalis (2010), LMSs (e.g., Canvas, Blackboard, Moodle, and Itslearning) provide technological and pedagogical affordances to design, deliver learning content, and support student collaboration at many higher education institutions. Here, digital technologies such as Canvas, which has components such as a 'discussion forum', can support dialogic interactions beyond face-to-face interactions (Major & Warwick, 2019). In the courses studied in this thesis, the teachers used Canvas as a technological artifact through which to mediate and perform the teaching activities included in the learning design. Canvas provided a platform on which to facilitate students' online discussions by allowing joint knowledge construction, where students gained insights into and contributed to other students' contributions—which can be seen as a socioculturally inspired instructional approach (Säljö, 2009; Stahl, 2006). This notion aligns with activity theory (Engestrom, 2000), a socio-cultural framework that views a teacher as a subject who intends to create a learning activity or a learning design for a particular group of students (individual level). In pursuit of this instructional goal, the teacher, as the learning designer, employs a range of mediating artifacts (e.g., online discussions) and other tools contained in an LMS to design the activity (Engestrom, 2000; Lund & Hauge, 2011; Ludvigsen & Mørch, 2010). Although Canvas provides functionality for the overviews of different course activities (e.g., page views, participation rates, discussion contributions, and grades), the

information is unintuitive and not presented in ways that provide easy interpretation for teachers to support their learning design decisions (see Article 3 for details). This is where LA—in particular, the teacher-facing dashboard presented in Article 4—can be used as a mediating computational artifact that supports teachers in gaining awareness, interpreting, and making sense of students' online activities, as expressed in the Canvas online discussion platform.

3.4.3.3 A learning analytics dashboard as a mediating computational artifact

Analyzing large amounts of discourse is often time-consuming and impractical (Chen, 2019). In this thesis, a teacher-facing dashboard (CADA) was used as a formative assessment tool to mediate teachers' cognitive efforts by making students' learning processes visible through a range of descriptive visualizations indicating the students' participation and discourse. As I report in Articles 2 and 4, the teachers expressed interest in understanding students' participation and engagement in asynchronous online discussions. Thus, CADA was designed to automatically turn the Canvas LMS's low-level digital traces (online discussion posts and interactions/social ties) into learning constructs (participation and use of domain-specific concepts) or to use Knight et al.'s (2014) phrase "clicks to constructs," which are considered important by teachers and are also theoretically relevant levels of abstraction from a sociocultural perspective. Thus, to satisfy the requirement of developing a dashboard grounded in theory, CADA was designed based on the sociocultural learning constructs of learning as participation and language (discourse) as an intellectual tool in collaborative learning (see details in Article 4).

CADA provides an overview of both structural and content-level information that teachers can use to observe students' participation in online discussions briefly through visualizations such as sociograms, which illustrate students' social ties. The dashboard also provides a detailed analysis of discourse—summarized in terms of key concepts, individual posts, and sentiment—which are mediating artifacts representing students' online activity. While CADA does not currently provide intervention tips or hints for how to scaffold students' learning based on the visualized activity, it saves teachers from needing to collect and analyze data about students' learning and instead shifts the focus to sense-making and interpretation of the data to inform their teaching practice (Xu et al., 2021) and learning design. Within this context, CADA provides opportunities for students' online discourse to be visible to teachers—and thus be an artifact for reflection and sense-making of students' trajectories.

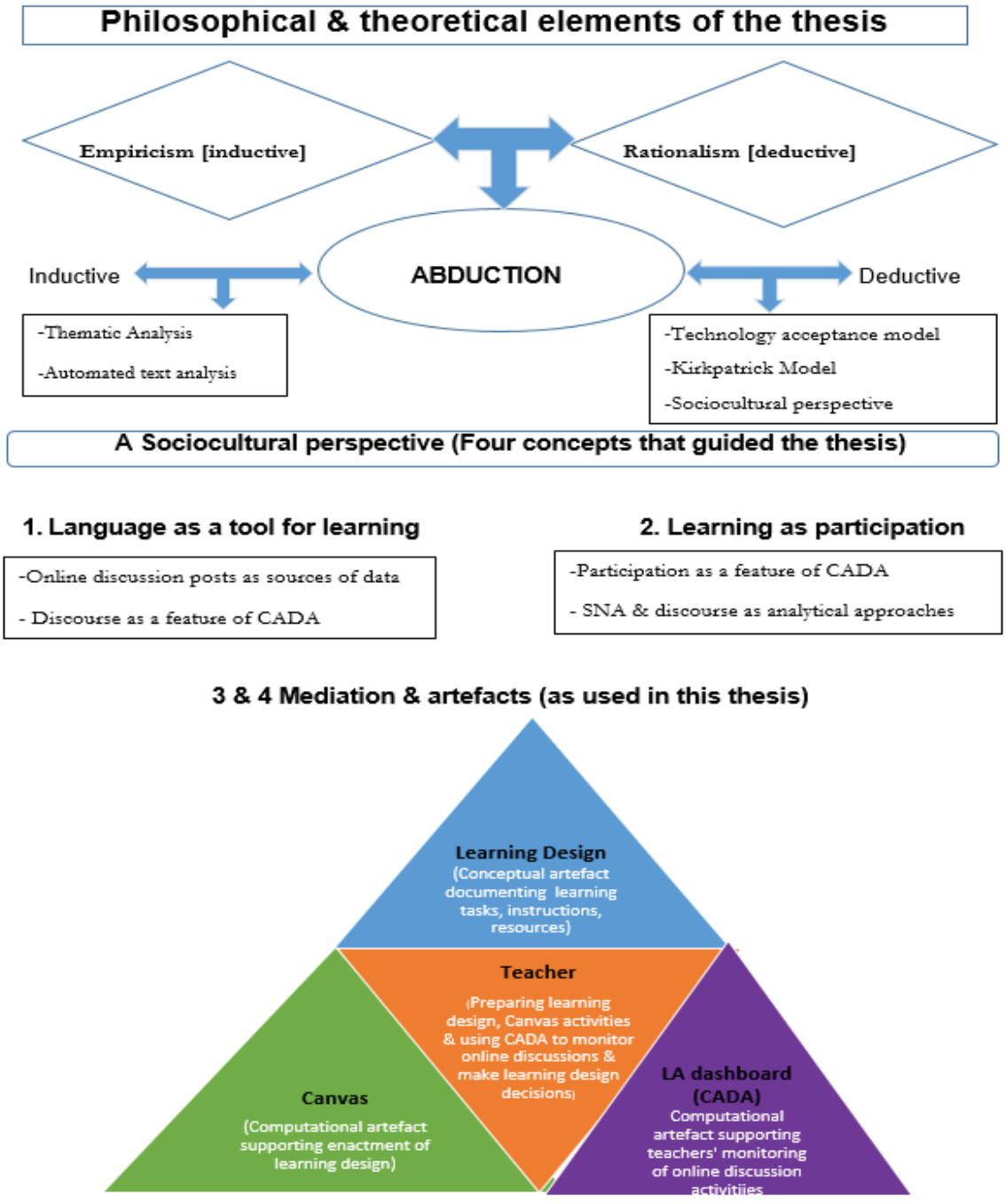
CADA has also been used as a diagnostic and instructional scaffold (Rummel, 2018). Since the sociocultural perspective encourages and presupposes teacher intervention and scaffolding (Daniels, 2002), teachers can act proactively by using the dashboard's diagnosis to scaffold the learning design process during or before the physical teaching sessions, with the goal of creating conditions that may lead to students reaching a specific competency level. For example, as seen in Article 4, teachers reported using information from CADA to assess the envisioned and enacted designs and, in some cases, using the analytics visualisations to restructure and customize face-to-face classroom activities during the run of the course. Moreover, as a scaffolding tool, the teachers used CADA's discourse feature to determine how the students were using subject-specific concepts and where the key concepts were not being addressed or properly interpreted. These issues were discussed during the class with the students—a form of whole-class scaffolding (Wise & Jung, 2019)—and all of them are informed by classical learning issues, such as scaffolding, which are grounded in the sociocultural approach.

Although analytics studies that use the sociocultural perspective might take it one step further and focus on encouraging students to reflect on their own activities and make sense of those activities to support self-

regulation (Knight et al., 2014), in this thesis, the focus was on presenting analytics to teachers to support the monitoring and awareness of students' online discussion activities. As reported in Article 4, some teachers presented the analytics from CADA to their students during face-to-face classes to engage them to reflect on their discourse patterns and raise awareness of their learning processes. Nonetheless, it is important to remember that primarily teachers used the analytics reported by CADA. Thus, the students' insights regarding the analytics were not analyzed, as this was beyond the scope of this thesis.

Figure 4

Concept Connections



Note. This figure illustrates the connections between the philosophical and theoretical concepts used and the analytical, methodological, and design choices made in this thesis.

Chapter 4: Methodology

This chapter presents this thesis's methodological approach, elaborating on the methodological choices made in the four articles and the rationale behind those decisions. It begins by outlining the overall research framework and design. It then describes the empirical cases and data collection and analysis procedures used. Finally, it reflects on the thesis's reliability, validity, and generalizability, as well as the ethical considerations involved.

4.1 The overarching framework: A DBR approach

The goal of this thesis was to study how LA's uptake by and relevance to teachers can be improved by engaging them in the planning, design, and implementation of theoretically grounded LA tools in authentic teaching practices. To achieve this, the conceptual and empirical work presented was inspired and guided by the DBR approach (Barab, 2006) as the overarching framework. DBR emerged as an approach to studying learning contexts through the systematic design and study of instructional strategies and tools (Barab, 2006; Van den Akker et al., 2006). Wang and Hannafin (2005) define DBR as follows:

> [A] systematic but flexible methodology aimed to improve educational practice through iterative analysis, design, development and implementation, based on collaboration between researchers and practitioners in real-world settings, and leading to contextually sensitive design principles and theories. (pp. 5–6)

The use of DBR in this thesis was motivated by the empirical setting at two institutions in the early stages of exploring LA. To understand the needs of the teachers and the context in which they operate, it was important to use an approach that allows different stakeholders to participate in defining and refining the nature of the LA systems they need. Moreover, this thesis used the DBR approach to attempt to overcome the atheoretical nature of existing (data-driven) LA studies, since DBR envisions a more rigorous connection with learning theory that results in theoretical and practical contributions (Walker, 2006). In this sense, DBR can be considered a good fit between the learning sciences and LA, both of which aim to provide solutions to practical educational problems (Reimann, 2016). Thus, a DBR-inspired approach was considered appropriate to (a) support the development of principles that will guide future processes of LA adoption and design through interactive and iterative design cycles with teachers, and (b) increase the understanding of how learning theories (e.g., the sociocultural perspective) can guide the development of LA tools and be improved upon based on the evidence generated during the design process.

The theories that can be generated through different DBR procedures (e.g., problem analysis and designing and implementing solutions) include domain theories (e.g., a theory about how students learn and teachers teach), design frameworks (e.g., the characteristics of an effective artifact), and design methodologies (e.g., guidelines for a process) (Edelson, 2002). In the case of this thesis, design frameworks and design methodologies characterized the theoretical contributions to which a DBR-inspired approach pertains. For example, as I reported in Article 4 and Chapter 6 of this thesis, the DBR process yielded different products. The first was a teacher-facing LA dashboard called CADA, which allows teachers to make sense of students' participation and discourse in online discussions at a glance. The second was a bi-directional LA course design framework that highlighted the key factors and conditions for supporting the connection between LA and learning design. The third design outcome was a set of guidelines and principles for designing and

implementing LA tools and reflections on how theory (e.g., the sociocultural approach) can support designs (both curriculum and software) with a direct impact on teaching practice. In this sense, the thesis contributes to future efforts to design and adopt LA among stakeholders (in the case of this thesis, teachers) in authentic practice.

The DBR approach is associated with challenges not often seen in traditional research approaches. For instance, DBR researchers often find tensions occurring between being researchers, implementers, and evaluators (McKenney et al., 2006). While these could offer the researchers an opportunity to gain deeper insights into the phenomenon under investigation, they might also result in an evaluator bias, with the participants reacting differently due to the researchers' presence (Patton, 2014). In the validity and reliability section of this thesis, I explain how I dealt with these limitations by following strategies suggested by McKenney et al. (2006), such as involving co-researchers in the analysis of findings, being reflexive about my own goals, and making the research setting as natural and genuine as possible. In what follows, I describe the following four sequential phases of DBR (see Figure 7) that inspired the conceptual and empirical studies included in this thesis: (1) problem analysis, (2) development of solutions, (3) intervention and evaluation of the solutions, and (4) reflection to produce design principles (Reeves, 2006). This discussion is not intended as a comprehensive description of the whole design process. The specific details are included in the four articles that form this thesis.

4.1.1 Phase 1: Problem analysis and requirement identification

One of the key features of DBR is the collaboration between researchers and practitioners to find solutions to pedagogically and practically significant problems (Reeves, 2006). To this end, the starting point for this thesis was to understand the current efforts being made to support teachers in adopting LA and the challenges involved. To achieve this, I conducted a systematic review targeting studies that reported on the challenges of LA adoption by teachers as well as strategies that have been adopted by LA researchers to overcome them. By doing so, I expected to improve my understanding of the current efforts in the field, the existing gaps, and how my thesis could contribute to bridging those gaps. The findings, which are reported in detail in Article 1, highlighted challenges such as the limited involvement of teachers and the limited alignment of LA with teachers' pedagogical needs. Moreover, the review identified some efforts being made by LA researchers to deal with existing challenges. For example, I identified frameworks aimed at supporting the adoption of LA by teachers, even though some were not empirically grounded in or aligned with technological artifacts to support their adoption. As discussed in the literature section, these gaps informed the empirical direction of this thesis.

To ensure that the LA solutions were informed by where the study was to be conducted, the results from article 1 were extended with an empirical study to understand teachers' learning design practices, pedagogical challenges, and perceptions of LA as a potential tool to support their practice. This exploratory study, which I report on in Article 2, generated insights that supplemented the findings of the review study. The key findings from this stage showed that teachers struggled to make timely learning design changes, since they rely mainly on summative assessments, which usually come at the end of the semester. At the same time, teachers reported difficulties monitoring students' learning behaviors online. Thus, the teachers expressed a need for LA that indicates students' participation and discourse patterns while they complete online activities, and in a timely manner to support timely learning design changes. One of the typical characteristics of DBR's problem analysis stage is the articulation of an initial framework to guide the next design stages (Reeves, 2006). Thus, the insights

gained from a systematic review and empirical study that involved teachers at two Norwegian universities were synthesized to develop the bi-directional LA-course design conceptual framework, which highlights guidelines and factors that support the design and adoption of LA to support learning design decisions. This framework was used to make methodological and theoretical decisions in the next DBR stage: the development of solutions.

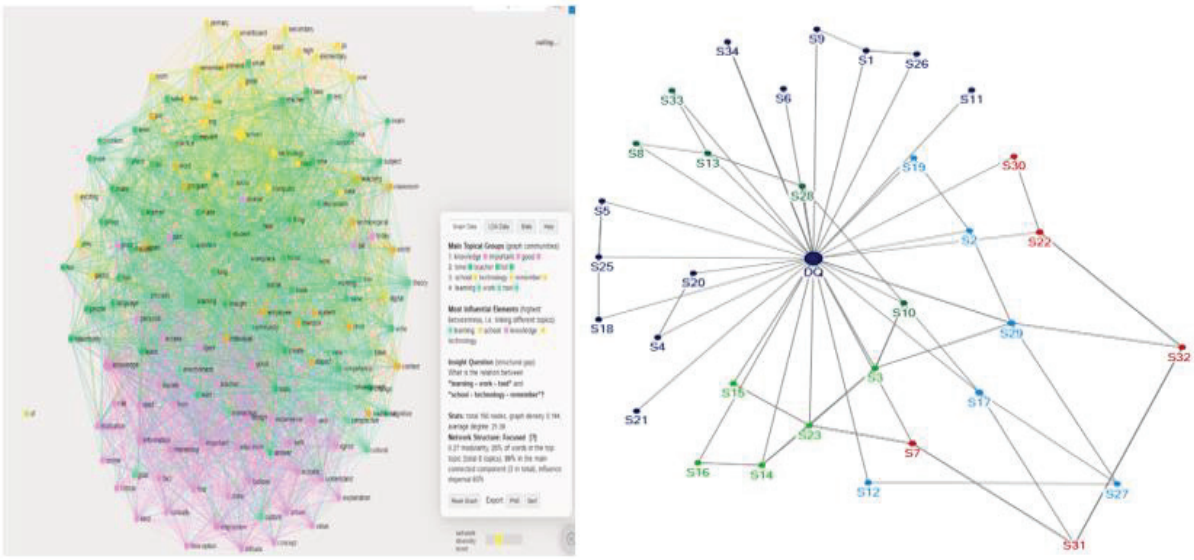
4.1.2 Phase 2: Development of solutions (paper prototypes and an automated dashboard)

Following the identification of a real educational problem, DBR researchers and practitioners work together to create prototypes based on existing design principles, which are later tested and refined until the desired outcomes are realized (Reeves, 2006). Thus, based on the results from the first phase, a range of solutions that could be used to support teachers' learning design practices were developed. Special focus was placed on developing analytics solutions that would make it easier for teachers to make timely learning design changes and capture students' participation in online-based environments, as these were critical to the teachers who participated in the interviews. For example, guided by teachers' responses in Study 2, in Article 3, I explored a range of data sources available within the Canvas LMS that I categorized as checkpoint (Canvas page views) and process analytics (online discussion posts and interactions).

These data forms were shared with teachers as paper prototypes to assess their potential in providing information about students' learning behaviors and whether teachers could use this as evidence to assess their enacted and intended learning designs. As reported in the theory chapter, the nature of the data sources and paper prototypes was informed by the teachers' pedagogical needs and sound theoretical concepts based on the socio-cultural perspective (Vygotsky, 1978). The visualizations, which were shared as paper prototypes, included social network visualizations, text networks, and graphs indicating students' page views in the Canvas LMS (see Figure 5). According to feedback from the teachers (article 3), the paper prototypes were found to be informative in terms of students' online behaviors and to provide insights to inform real-time course design changes. At the same time, the teachers found some of the visualizations, including the text networks, too complex, and demanded that they be presented in a simpler manner to support timely course adaptations. The teachers also found page views less intuitive, as shown by the correlation analysis results in Article 3, which showed no correlation between page views and students' participation in online discussions. Based on this information and feedback from the teachers, a high-fidelity prototype was created (see Figure 6) based on two main features: analyses of concepts and social interactions. Canvas page views were not included, as the teachers found them less informative. Moreover, simple text networks based on a word cloud were made in the initial digital prototype to address the teachers' concern for the complicated text networks presented during the paper-prototyping stage, which the teachers perceived as less informative in monitoring students' knowledge construction processes.

Figure 5

Paper Prototype Examples



Note. The above are examples of text (left) and social (right) network visualizations shared with teachers as paper prototypes.

After the findings from the teachers were published (Article 3), the hub for LA research (HulaR) at the University of Oslo indicated their interest in collaborating on developing an automated dashboard (CADA) (see Figure 6) that could be added as a plugin into the Canvas LMS for teachers to use in real-time. This shift was not initially planned, since, due to the limited funds available for my doctoral project, I was only able to conduct paper prototype interventions. However, with the HulaR network showing interest in the project, a plan to develop a digital prototype was introduced. From that point onward, the stakeholders in the DBR process expanded from only researchers and teachers to including a design team. A team of people with a range of skills and perspectives that included me as the researcher, designers, programmers, engineers, and teachers created the design process. The technical staff were all employed at the technology lab (Engage Lab) based in the Faculty of Educational Sciences, University of Oslo. Engaging many stakeholders enabled the development of a dashboard that aligns with teachers' needs while maintaining the necessary technical design requirements.

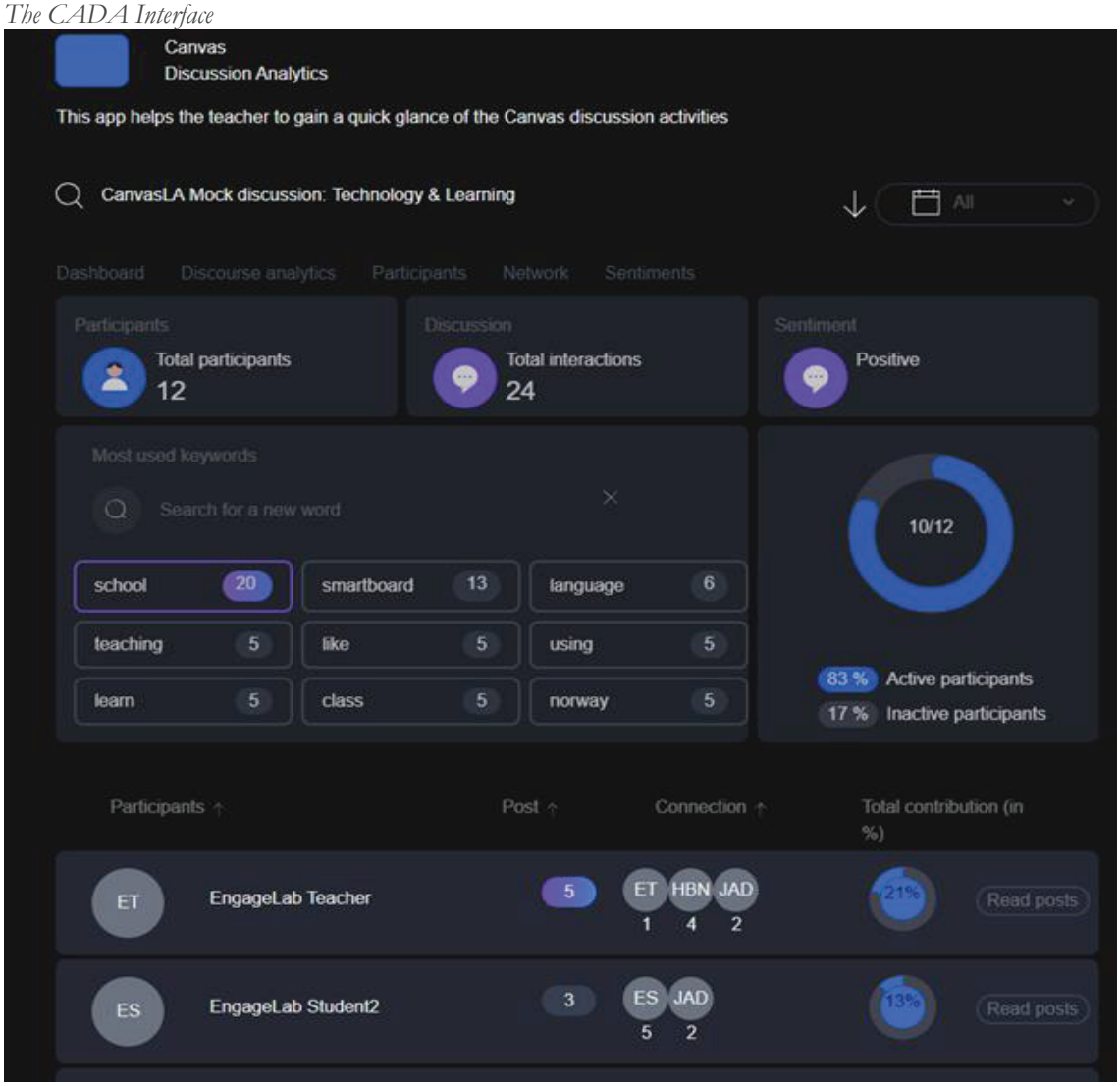
Based on the insights from the teachers and several discussions between the Engage Lab team, and me an automated, high-fidelity prototype called CADA (illustrated in Figure 6) was developed. CADA is an LA dashboard that visualizes participation, social networks, sentiments, and concepts used by students within the Canvas LMS discussion forum on a need-to-know basis. It provides an overview of both structural and content-level analytics that can help teachers gain a comprehensive understanding of students' learning processes during online discussions. A full description of CADA is provided in Article 4.

DBR involves a commitment to not only addressing local problems but also "engineering the contexts of study in ways that allow for the generation and advancement of new theory" (Barab, 2006, p. 153). This implies that what is revised between the DBR iterative cycles is not only the design itself, but also the theory that

underlies that design. Thus, the design of CADA lent itself to principles from the learning sciences to satisfy its theoretical foundation. As highlighted in the theory chapter, the design of CADA was informed by a sociocultural perspective, which is grounded in the work of Russian psychologist Vygotsky (1978). In particular, I drew inspiration from Säljö's (2002) concept of learning as the participation in, and mastery of, subject-specific discourses and practices mediated by artifacts (such as online discussions) (Säljö, 2002) and the sociocultural conception of language, which highlights that discourse, understood as both oral and written statements, is considered an important site for understanding individual students' learning (Knight & Littleton, 2015). Thus, the teacher-facing dashboard (CADA) was structured based on the concepts of participation and discourse. In this case, the iterative cycles not only were meant to improve the design features of the dashboard based on the teachers' feedback, but also acted as a way to evaluate the generative value of the sociocultural perspective in designing LA tools.

Figure 6

The CADA Interface



Note. This interface included general participation analytics (top), a summary of key concepts (middle), and connections between individual students (bottom).

4.1.3 Phase 3: Intervention, evaluation, and testing of solutions

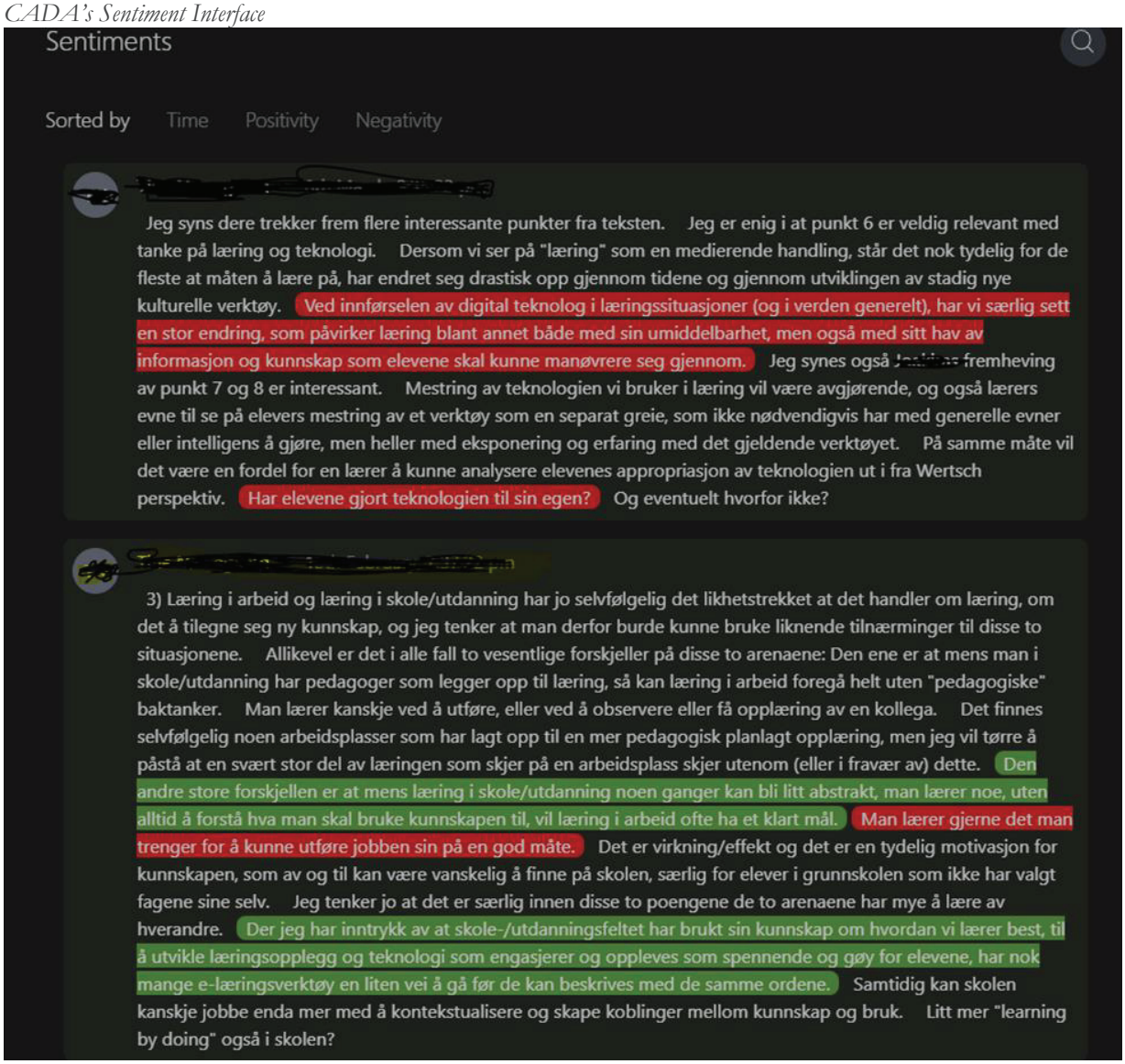
One of the key features of DBR is its refinement of solutions through iterative cycles of implementation and evaluation (Wang & Hannafin, 2005). In this thesis, the development of CADA went through several iterations and a series of pilot studies conducted in authentic university courses. These studies were based on different courses and teachers who were willing to make design changes to their courses to afford the rollout of the dashboard.

Iteration 1: The first iteration occurred in fall 2020, with four teachers and four courses. Initially, six teachers showed interest in trying out the prototype in their courses; however, due to delays in having the prototype ready by the start of the fall semester, I could only implement the dashboard in four courses. The first prototype was a simplified version, and during the intervention, the teachers provided suggestions for improving the initial digital prototype. For example, in our first prototype, we experimented with a variety of chart types (bar graphs, pie charts) and methods for displaying data to the teachers. Some teachers demanded an interface that was easier to navigate, with clear instructions for users while selecting discussion threads and interpreting social networks. Other teachers expressed the desire to display not only the key concepts used by students but also the context in which the words were used. In addition, though we initially listed the participating students in the form of a graph, the teachers found this overwhelming and insufficient, especially in discussions with a larger number of students (more than 50). Other teachers requested a feature to display the sentiment attached to the different discussion posts, with the expectation that such information would increase teachers' understanding of student engagement and learning during asynchronous online discussions. The new changes were then built into the revised prototype, which was used in the second iteration, an approach in line with DBR principles (Wang & Hannafin, 2005).

Iteration 2: The second iteration took place in the spring semester of 2021, with four teachers and four courses. In this stage, feedback from Iteration 1 was incorporated into the dashboard design. For example, the dashboard was given an improved interface, instructions for choosing the discussions and interpreting the social network graphs, a discourse analysis function highlighting the context in which concepts were used, a function to filter keywords, and a sentiment analysis feature to categorize the students' posts as negative, neutral, or positive (see Figure 7). To implement sentiment analysis in CADA, we used a standard sentiment analysis algorithm, VADER (Hutto & Gilbert, 2014), to detect sentiment within the discourse of the online discussion posts. The teachers assumed that such information could help monitor the affect of students on particular course topics, thus informing the more effective design of learning activities by, for example, elaborating on a topic that students reacted to in a certain way. However, the sentiment analysis feature was implemented toward the end of Iteration 2, which means that no empirical evidence for the potential of sentiment analysis for learning design was collected as part of this thesis. Details regarding the evaluation process of other features in CADA are provided in the data collection section (Section 4.4).

Figure 7

CADA's Sentiment Interface



Note: The above are discussion posts that are highlighted based on their sentiment polarity. Red represents negative, green positive and white neutral sentences

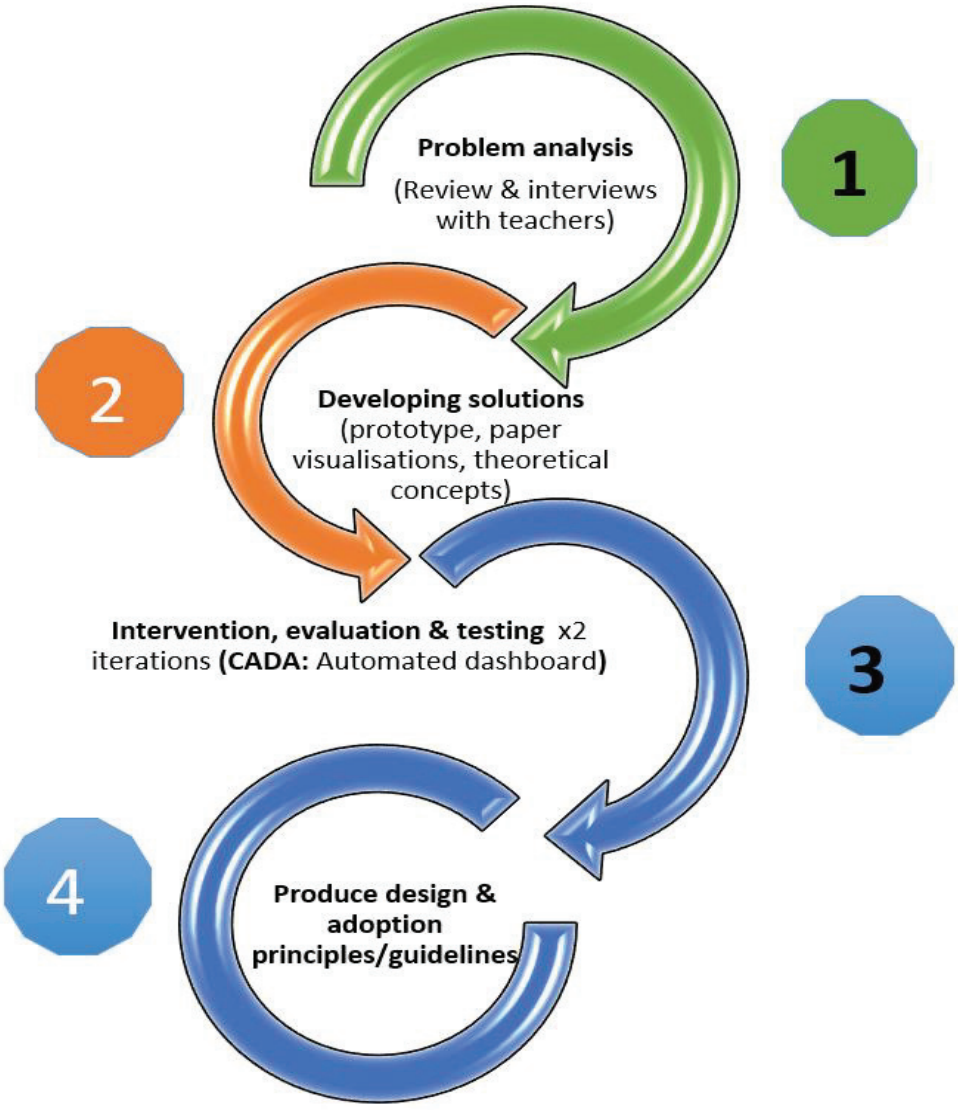
4.1.4 Phase 4: Reflection on producing design principles

The DBR process includes a reflection on the research procedure and all the findings, leading to both practical solutions and improved theoretical understanding (Reeves, 2006). In this thesis, after Stage 3, I reflected on the lessons learned to generate design and adoption principles of relevance to LA researchers and practitioners. In this sense, as I report in Article 4 and the contributions section, developing and applying CADA in authentic teaching environments was seen as a partial test of the generative value of the sociocultural perspective that informed its development, while the iterative and interactive cycles between the teachers, the designers, and the researcher over time contributed to the development of guidelines and design principles to support future LA design processes among teachers and the design of tools to support these processes' adoption (see a more

detailed discussion in Chapter 6). However, the design principles produced in this thesis should not be considered exhaustive given the time constraints that limited the number of iterations to only two.

Figure 8

The DBR Workflow



Note. These workflow phases were followed in this thesis.

4.2 Research design: A mixed-methods approach

I chose a mixed-methods design approach, which combines qualitative and quantitative research methods (Creswell et al., 2003), to achieve the thesis's aim and answer the research questions. Johnson et al. (2007) coined the following definition of mixed methods research based on a comprehensive analysis of interpretations by different mixed methods researchers:

> Mixed methods research is the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purposes of breadth and depth of understanding and corroboration. (p. 123).

Drawing on this broad definition, the justification for applying a mixed-methods approach was partially motivated by this thesis's exploratory nature, as well as the research questions, which required the use of different methods and analytical approaches. For example, RQ1 and RQ3 sought to explore teachers' experiences with LA and LA's use in authentic settings and were better answered using a qualitative approach. RQ2 sought to explore the potential of different LA data types and analytical approaches in providing insights into learning processes. This question was better answered using both qualitative and quantitative methods. In this case, the justification for employing a mixed-methods approach was because neither of the two approaches was sufficient to capture the details of the analysis (Ivankova et al., 2006).

Moreover, as I explained in the preceding chapter, I took an abductive approach to the thesis, combining both deductive (mostly top-down) and inductive (mostly bottom-up) analytical approaches (Shook & Paavola, 2021). A mixed-methods approach provides the best framework from which to allow combinations of different methods, worldviews, and alternative interpretations (Bryman, 2016). Using this approach also enhanced the study's methodological and theoretical triangulation (Johnson et al., 2007), which contributed to the trustworthiness of the findings by answering and interpreting questions from different points of view.

Johnson et al. (2007) identified the following three mixed-methods research design subtypes: (a) the "equal status" subtype, which is a purely mixed-methods approach that treats qualitative and quantitative methods as equally important; (b) the "qualitative dominant" subtype, which treats the qualitative approach as dominant and quantitative methods as complementary; and (c) the "quantitative dominant"' subtype, which treats the quantitative approach as most important and qualitative methods as complimentary. Here, I was guided by the qualitative dominant approach while also leveraging quantitative methods. For example, in Article 2, I started by interviewing teachers about their learning design and LA experiences. I followed up with a mini-survey to capture the teachers' perceptions of LA as a tool to support their learning design practices. In Article 3, I used both quantitative and qualitative analysis approaches to analyze students' discussion posts and interactions. For example, I performed a correlation analysis of the Canvas page views and students' participation in the online discussion forum, conducted an SNA of the students' interactions, thus providing an aggregated visual representation of undirected graphs and metrics such as degree centrality, and finally conducted an automated analysis of discussion posts that resulted in textual network graphs and metrics such as graph density. Following this analysis, the findings from the SNA and text network graphs were shared with the teachers to seek their opinions on the potential of such visualizations for informing their learning design decisions. However, the use of mixed methods comes with challenges. For example, I had to become familiar with new analysis methods (SNA and automated text network analysis) and understand the epistemological

and theoretical assumptions behind them. Moreover, since I used a sociocultural framework—, which is more aligned with, the qualitative approach—interpreting the insights from quantitative methods was not straightforward.

4.3 Empirical setting and cases

The empirical work of this thesis was conducted through three studies in the context of two Norwegian higher education institutions.

4.3.1 Study 1: Investigating teachers' design and LA experiences

The setting for the first empirical study was two Norwegian universities: the University of Oslo and Oslo Metropolitan University. A qualitative study involving 16 teachers comprised part of the exploratory phase, which aimed to establish the current state of LA awareness and how teachers perceive it as a potential tool to support their everyday teaching practices. The decision to include two universities was motivated by the need to examine any institutional differences that might enrich the proposed interventions and LA solutions. These universities were both in the preliminary stage of exploring the potential of LA. Thus, there were no concrete LA examples on which the teachers could draw. Thus, as I report in Article 2, I used vignettes during the interviews to help give the teachers an introduction to LA. The vignettes that were used included an illustration of an LA dashboard used at Open University (see Figure 1), showing data specific to the individual students and their online activity. Another visualization was an LA display showing the average time spent by students per week on the different modules (see Appendix 3) (Rienties & Toetenel, 2016). While these visualizations could have helped teachers gain a better understanding of what LA is about, it is possible that the complexity of the presented information could have affected their attitudes toward LA.

Teachers from the two institutions were recruited purposively using a snowball approach (Bryman, 2016). Recruitment was based on the teachers' (1) interest in using educational technology/LA as part of their teaching, (2) teaching experience, and (3) affiliation. The participants were recruited through close contacts who helped identify those who might be interested in LA and who fulfilled the profile of the sample population. Once the contacts were established, email invitations were sent explaining the rationale for the project and why they had been selected. As illustrated in Article 2 (Table 1), the largest number of participants came from education (9), followed by computer science (4), and one each from mathematics, technology, and business, respectively. The dominance of participants from education could be attributed to the fact that this was my primary faculty, which facilitated the easy recruitment of participants. The selection of participants from different disciplines and academic positions was motivated by the assumption that teachers' practices and needs can vary between disciplines and levels of experience. It was also assumed that generating insights from different groups could allow for the development of an LA tool that might be applicable to different disciplines. It is possible that the purposive and convenient sample that I used targeted teachers with an interest in using educational technologies or LA, which, in return, resulted in an overrepresentation of participants already interested in LA. Moreover, the differences in the disciplines could have influenced teachers' perceptions regarding LA, as was reported in Article 2, as teachers from the computer science and mathematics departments—with their more quantitative backgrounds—had more positive attitudes toward LA than their colleagues did in the humanities and arts disciplines. As highlighted by West et al. (2015), teachers' views on LA could be shaped by their disciplinary background and prior exposure to analytics. The data from this empirical case were used in Article 2.

4.3.2 Study 2: An undergraduate course on technology and pedagogy

The context for the second empirical study was a bachelor's-level course on technology and pedagogy at the University of Oslo. The course focused on technology-enhanced learning and was composed of 36 students and four teachers. It also included eight compulsory weekly online discussions and face-to-face lectures over eight weeks. Each week, the teachers initiated a new discussion thread based on the topic of the next lecture. This allowed the discussions to continue during the physical classes, where the teachers addressed any questions that had arisen from the discussion. One teacher coordinated the course, while the co-teachers were responsible for the specific modules. The course was blended, meaning that the students engaged in online activities but also participated in physical classes. The language of instruction was Norwegian; however, during the online discussions, the students contributed in both Norwegian and English. The selection of this course was motivated by the availability of compulsory activities conducted through the Canvas LMS, which provided an opportunity to collect a wide range of data related to students' online learning activities. Thus, the data for this study consist of online discussion posts, Canvas views, and participation rates, as calculated by the Canvas analytics system. Prior to the start of the course, I met with the four teachers responsible for it to ensure that the discussions would be organized in a manner that would allow them to assess the intended and enacted learning design. For example, the teachers provided clear instructions on what students would be expected to do during the online discussions so that when the analytics were generated, it would be possible to assess whether such objectives were achieved.

The data collection process in this course was done over three years with different cohorts (Spring 2019, 2020, and 2021). The decision to collect data for this amount of time was informed by the iterative nature of this thesis. For example, while the first iteration was aimed at exploring possible analytics to capture, the second and third iterations were aimed at testing the analytics solutions (paper prototypes and the fully automated dashboard). The data collected from this course formed the basis for Article 3.

4.3.3 Study 3: An intervention with CADA

The last phase of the empirical study involved seven courses (undergraduate and graduate) and seven teachers who used CADA in authentic practice. Unlike the first and second studies, Study 3 had an interventionist agenda. Thus, special attention was paid to planning the courses prior to the study. For example, prior to the intervention, a script with a systematic guide on how to navigate the dashboard was provided to all participating teachers. The intervention courses varied in terms of their size (number of students), level (undergraduate, graduate, or professional), and topics covered (research methods, technology, and pedagogy). The selection of courses in Study 3 was based on (1) the availability of a discussion forum as part of the course design, (2) the teachers' willingness to integrate the dashboard into their courses as a module and use it throughout the research period, (3) and the teachers' availability for interviews to evaluate the effectiveness of the dashboard. To identify potential intervention courses, I started with the teachers who had participated in the exploratory phases (Studies 1 and 2). Later, I contacted the university's IT department to provide me with details regarding courses that actively use online discussion forums. Using this information, I contacted the teachers in charge, asking them to be part of the intervention. Through this process, seven courses and seven teachers were recruited.

The intervention studies were conducted in two phases: a pilot stage in the fall of 2020, in which the initial prototype was implemented in authentic courses at the University of Oslo, and a second phase in the spring of 2021. During the second phase, the teachers worked with a fully developed dashboard throughout the semester. This study employed a qualitative approach since its aim was to gain insights into how teachers perceived the LA dashboard's potential in authentic practice. During the intervention process, I maintained constant contact with the teachers. The data collected during Study 3 formed the basis of Article 4.

4.4 Data collection

I used a number of methods to collect data regarding students' learning, teachers' experiences, and course designs. These methods were as follows:

(1) Interviews with teachers: The use of interviews allowed me to identify the participating teachers' feelings about and perceptions of LA (Article 2), validate and assess the usability of the visualized checkpoint and process analytics (Article 3), and gain in-depth experiences in teachers' use of dashboards in authentic teaching practices (Article 4) (see the interview guides in Appendix 2). All the interviews were conducted in English, audio-recorded, and transcribed verbatim.

(2) Discussion forum posts: The main source of data for the analysis of students' online activities was the discussion forum contributions posted on Canvas. Discussion forum posts represented the most meaningful source of data for evaluating how students reacted to their teachers' intended learning goals. This data also formed the basis for generating the LA prototypes that were shared with the teachers and later used to design the automated teacher dashboard. Given that Canvas does not have a plug-in to automatically extract discussion forum posts, the posts were manually collected from the LMS. The information collected included the student's name, the content of the discussion post/interaction, the source of the discussion post/interaction, and the target of the interaction. Student names were replaced with IDs immediately after the posts were extracted.

(3) Canvas log data: During the exploratory phase of the project, Canvas log data were used to assess whether they could contribute to the understanding of students' learning patterns. The information collected included students' weekly action logs (page views and participation entries). These data represented student visits to elements of a course and the nature of their participation in the online activities.

(4) Learning designs: These were used as a source of data that informed the interpretation of the insights gained from the students' online patterns. The learning designs were available on the respective course websites and included a description of the learning activities, course objectives, and resources.

(5) Mini-survey: This was used in Article 2 to explore teachers' beliefs regarding the ease of use and usefulness of LA tools on a five-point Likert scale. A mini-survey was administered shortly after each teacher interview, enabling me to capture the teachers' perceptions of LA.

4.5 Data analysis

4.5.1 Analysis of interviews and literature: An abductive approach

As mentioned in Chapter 3, the data analysis in this thesis was guided by an abductive approach, which combines the deductive and inductive approaches (Kennedy & Thornberg, 2018). The abduction approach has several strengths. For example, it allows the researcher to approach the coding and analysis process from two different orientations. On one hand, the deductive approach involves the researcher starting the coding using predefined codes based on existing literature or validated theoretical constructs, a process that can support the generalization of findings (Azungah, 2018). On the other hand, the inductive approach involves the researcher taking a bottom-up approach to analyze the data more thoroughly, generating codes and themes based on the participants' own words rather than predefined theoretical categories (Bryman, 2016).

In what follows, I provide a brief description of how the deductive and inductive approaches were applied in the qualitative analysis of the interview and literature review data in the four articles included in this thesis. In all the articles, I took primary responsibility for the data analysis, which involved assistance from the co-authors at different stages to discuss and further expand the coding. During the interview analysis, I chose one full response to an interview question as the unit of analysis since responses tended to represent one aspect of the conversation between the interviewers and interviewees.

4.5.1.1 Deductive analysis

Guided by a deductive-oriented coding process, in Article 1, the categorization of the LA frameworks was based on predefined codes derived from the orchestrating LA framework (OrLA) (Prieto et al., 2019). This framework identifies three roles to which LA tools should provide support (design and planning; awareness, adaptation, and intervention; and regulation and management). These three dimensions served to provide general guidance for analyzing the frameworks by coding for the presence or absence of each dimension (see Appendix 1, Table A1) and subsequently presenting and categorizing the findings for Research Question 2. In Article 2, the analysis began deductively by employing an existing scheme based on the widely accepted dimensions of TAM (perceived ease of use and perceived usefulness) (Venkatesh & Davis, 2000) (see Appendix 1, Table A2). Initially, TAM was used to conduct a mini-survey (see Table 2, Article 2) on teachers' LA perceptions and then a semi-structured follow-up interview that consisted of the same questions as the mini-survey—perceived ease of use of LA and perceived usefulness of LA. Thus, the analysis, coding, and reporting of the mini-survey and interview responses were based on the same TAM categories. This is demonstrated by themes in Article 2, such as teachers' awareness of LA and teachers' LA needs, which depict teachers' beliefs and intentions regarding LA—constructs derived from TAM.

In Article 4, the interview analysis was guided by Kirkpatrick's (2009) evaluation model using the following four dimensions: a) reaction, b) learning, c) behavior, and d) results. During the coding process, the "learning" and "results" categories did not generate enough instances of relevance to the research questions. Thus, they were removed and replaced with new codes that better represented the insights in the data. Additional categories, including "usability," "understanding," and "usefulness"—based on Few's (2009) design principles for dashboards—were added to the codebook (see Appendix 1, Table A4). The coding process involved reading the interview responses to establish whether they fit into the five predefined categories (reaction, usability, understanding, usefulness, and behavior). As displayed in Figure 9 (partial representation of the full dataset), to prepare the data for analysis, all the interview transcripts were translated into a qualitative table in a spreadsheet,

where each row consisted of one response to an interview question. Moreover, to provide a better context for each interview, I included metadata, such as the participant ID, the interview question number, and the iteration. The interview responses were segmented based on rows to facilitate the coding process. After segmenting the interview transcripts, I entered the five codes (based on Kirkpatrick and Few's dashboard design principles). Two researchers, including myself, manually coded directly in the spreadsheet using binary codes (e.g., 0 to represent absence and 1 to show the presence of a code). While the report did not involve a quantitative analysis of findings based on the binary codes, these were used to identify codes with the highest number of counts, which were then later used for qualitative reporting. Thus, based on Kirkpatrick and Few's design principles, themes such as "reaction to dashboard features" and "perceived usefulness" were generated and used to present narrative accounts in the findings section. To ensure consistency during the deductive-oriented coding process in Articles 1, 2, and 4, codebooks (with clear definitions, names, and sample data extracts) were created (see Appendix 1). This ensured that the co-researchers and I had a common understanding of what to look for in the interview and literature review data. All inconsistencies that arose during the coding process were settled through social moderation by discussing areas in which the ratings differed

Figure 9

A deductive coding example

Note: The above figure shows an example of the qualitative data table used in the coding of the interview data in Article 4.

4.5.1.2 Inductive analysis

During the interview and literature analysis in Articles 1–4, I found that a deductive orientation could not account for all the insights relevant to the study's research questions. Thus, I decided to apply an inductive approach based primarily on thematic analysis (Braun & Clarke, 2006) involving an iterative method of coding and finding patterns in the data (Kennedy & Thornberg, 2018). As I describe later, the inductive approach taken in this thesis did not follow a strict bottom-up analysis approach. Instead, I followed a more structured approach, with the coding and analysis guided by codebooks developed based on an initial bottom-up reading of the data regarding the study's research questions. Thus, guided by Braun and Clarke's (2006) stages for thematic analysis, the inductive analysis process followed a three-phase procedure, which is described below. The phases were not followed linearly but in an iterative manner that involved moving back and forth between the phases.

Phase 1: Familiarization. In all the articles, the first step involved reading the data scripts—commonly referred to as familiarization in thematic analysis (Braun & Clarke, 2006). For example, in Article 1, before coding and analyzing the screened articles, my co-researchers and I familiarized ourselves with the articles by reading titles and abstracts, noting possible ideas to code for in relation to the research questions. A similar approach was followed in Articles 2–4, where interview transcripts were reviewed several times in preparation for deeper-level analysis. In the case of these articles, the familiarization process started during the transcription of the interview transcripts.

Phase 2: Grouping initial insights into smaller codes and lower-level themes. Following a thorough and iterative reading of all the interview transcripts (Articles 2, 3, and 4) and screened articles (Article 1), my co-researchers and I inductively developed lower-level codes by highlighting key ideas, sentences, and phrases that seemed relevant to the research questions. These initial codes provided a context for the development of codebooks to guide the entire coding process. Drawing on the tripartite typology of thematic analysis by Braun et al. (2018), the coding process in Articles 1-4 followed a coding reliability thematic analysis approach. This approach can be described as a structured, inductive process in which the development of codes and themes is closely linked to research and data collection questions. Thus, for Articles 1-4, codebooks that contained a list of initial codes, their definitions, and examples of interview excerpts were developed and used as analytic inputs (see Appendix 1, Tables A1–A4).

The generation of lower-level codes followed different patterns in the different articles. For example, in Article 1, a co-researcher and I took a bottom-up approach and reviewed two studies for training purposes to become familiar with the literature. This process led to the development of initial codes based on the descriptions and contextual information provided in the papers. For example, the codes used in analyzing the first research question on technical, pedagogical, and institutional challenges facing teachers' adoption of LA were inductively developed based on common themes from the screened articles and prior literature. Moreover, additional categories, such as ethics and workload, emerged during the coding of the articles (see Appendix 1, Table A1). In Articles 2 and 4—in which many interviews were conducted—the initial categorization of codes (represented as nodes) was done using NVivo, a qualitative analysis software (Bryman, 2016). In Article 3, I had only four interviews; thus, I used the copy-and-paste function in Microsoft Word to select the relevant excerpts from the teacher interviews, guided by the research questions. This process generated categories for each code together with relevant interview excerpts. For example, Table 1 illustrates how the highlighted concepts were turned into codes and subsequently refined and translated into higher-level themes.

Phase 3: Developing, reviewing, and naming higher-level themes. Following the initial coding process described in Phase 2, the next step was to collate the lower-level codes into themes. Generating higher-level themes was not a one-off process; it involved iterative cycles of splitting, combining, and renaming themes through constant reflective discussions between co-researchers and colleagues outside the research team. To develop higher-level themes, I aggregated the codes developed in Phase 2 (see Table 1 for an example of this) into broader categories relevant to the research questions. In this sense, the lower-level codes were used as building blocks on which to develop higher-level themes (see examples below).

While generating the codes and themes, I focused on both the semantic (data-derived) and latent (researcher-derived) features of the data (Braun & Clarke, 2013). On the one hand, the themes at a semantic level were developed based on participants' words (as expressed in the interviews) and were closely related to the research questions—and sometimes even the interview questions. For example, the "start small" sub-theme in Article 4 is an example of a semantic-based theme, since it was derived from participants' statements while responding to the question on the necessary conditions to support teachers' use of dashboards (e.g., "it is very smart to start with a few teachers before scaling up…"). On the other hand, at a latent level, some themes were developed based on implicit or conceptual-level meaning involving deeper analytical work by the researchers beyond surface meanings and existing frameworks. For example, the sub-theme "agency" in Article 4 is a latent theme. The participants, as expressed in the interview excerpts, did not explicitly talk about agency; however, they used terms such as "flexible" and "customizable" while referring to the nature of the LA tools they prefer. In this case, based on the researchers' interpretation of the statements and relevant literature on human-centered LA, the term "agency" was found to be appropriate for describing teachers' thoughts on LA dashboards.

In hindsight, the categorization of themes in Articles 1–4 could have been improved upon with a focus on latent-oriented themes other than semantic ones, which could limit the depth of engagement with data, yet critical to qualitative research practice. Moreover, in Articles 2 and 4, some of the sub-themes could have stood as independent themes instead of being grouped under the general concepts derived from the research questions. This could have generated richer insights beyond themes that aligned closely with the research questions and pre-existing frameworks (i.e., insights derived using the deductive approach described above).

Table 1

Inductive coding example

Interview excerpt	Codes/low-level themes	Themes
"I think using strict guidelines does not work because teachers, including myself, all have different ways of and plans for teaching" (T2IT1). "I think it is important that, as a researcher, you do not state what should be done with the tool but instead offer options from which teachers can choose; if there is a way to allow a teacher to edit the ideal state where they would like their students to be at the end of the course, and the tool helps to illustrate this process, that could be very important." (*Excerpts from Article 4 interviews*)	-Flexibility -Freedom to choose -Customization	Agency
Online courses take more time to design than face-to-face courses. "What I always start with is considering the target group and what we want to achieve. When interacting with the students, you get a feeling if they are interested or bored and use it to improve on the courses. When I teach a course for more than three years, I have a good sense of what works and what does not. One part of it is evaluation and feedback from students, and sometimes that happens in a very formal way. Other times, it happens informally. The quality of the essay at the end of the course will usually tell me what topics have been processed and understood and what ones have not been, and that helps to see where I need improvement. I am co-teaching now with a colleague, so when one is teaching, the other one takes notes. Was it problematic? And then we discuss how we can improve it." (*Excerpt from Article 2 interviews*)	-Situational factors -Teaching mode -Student characteristics -Course objectives -Course structure -Beliefs/intuition -Experience -Feedback -Summative assessments	Course design influences

4.5.2 Social network analysis of discussion forum posts

SNA is concerned with the mapping of social structures in terms of the relationships and interactions among the actors that comprise them (Borgatti et al., 2009; Mørch et al., 2020). As I highlighted in the theory chapter of this thesis, my interpretation of learning was guided by a sociocultural perspective, particularly the notion of learning as participating and engaging in social interactions between two or more people (Säljö, 2002). Vygotsky argues that all cognitive functions originate from social interactions, and learning is the process by which learners are encultured into a knowledge community (Vygotsky, 1986). As such, the structures and patterns of interactions deserve consideration when analyzing educational data generated from social activity processes, and SNA is one method of addressing them. Thus, an analysis of the students' interactions in the online discussions was one of the main approaches used in Article 3. Preparation of the discussion posts for the SNA required several steps. First, I received anonymized data files in Microsoft Word from the teacher in charge of the course. Second, I reformatted the data using Microsoft Excel based on the flow of the discussion

threads. The new format included social network relationships based on student–student, student–teacher, and teacher–student interactions. Since the discussions ran for seven weeks, I prepared a similar file for each discussion thread. One challenge with discussions in the Canvas LMS is that Canvas has a flat structure (participants cannot directly respond to others until after at least two other responses have been made), which makes it difficult to accurately associate certain responses. Thus, Canvas's "Reply/Go to Theme" function was used to establish the direction of the post. In some cases, I manually read the content of the discussion to establish the direction/target of the contribution.

The completed file included two main columns: a vertex and an edge. A vertex is defined as an engaged user, and an edge is defined as a connection between two users (Borgatti et al., 2009). If Student 1 (S1), for example, contributed to answering the main discussion question (DQ), this was coded as S1-DQ. Once the data were formatted into an Excel file, they were exported to a third-party SNA tool called NodeXL (Smith et al., 2009). Different network modes can be constructed while conducting SNA. For example, single-mode networks create networks based on one dataset or participant, and two-mode networks include two datasets, one with participants and the other with their affiliations (Borgatti et al., 2009). Asynchronous online discussions are often represented as two-mode networks, involving two networks of participants and discussion topics, where the latter mediate the relationships of the former (Mørch et al., 2020). Thus, in Article 3, I employed a two-mode network approach to represent how the students (Actor 1) responded directly to the discussion topic (the posted question) and indirectly to the person who posted the question (Actor 2). In this case, connections were defined as existing between students responding to either each other's posts or the original discussion question, even indirectly. Meanwhile, as I already noted about the challenges of the Canvas discussion format, the affiliation network could provide false connections and misguided interpretations in which students might respond to others unintentionally due to Canvas's flat structure. While I controlled for this challenge by manually reading the posts to determine their direction, this solution is not feasible with commonly used approaches (e.g., web scraping) for the automated analysis of such interactions. This necessitates researchers to be vigorous while choosing and interpreting data to ensure that the visualized networks correspond to the input data, or what quantitative ethnographers refer to as "closing the interpretive loop" (Shaffer, 2017).

While SNA has different metrics, in Article 3, I used degree centrality (measures to determine the number of ties an individual student actor had with the other student actors) and betweenness centrality (which represented students who facilitated the spread or control of information within the network) (Borgatti et al., 2009). The metrics used in the articles depended on the nature of the research question. For example, in Article 3, I primarily used degree centrality because I was interested in discovering the number of times the students posted and interacted with others—a factor connected to the instructions provided by the teachers (e.g., making two posts and responding to at least one other). However, the degree of centrality also depends on the reachability of a person within a network. As noted by Freeman (1978) in one of his early works on SNA, an important actor in a network has multiple connections (i.e., high degree centrality) and can easily connect with others (closeness centrality) and act as a link between others (betweenness centrality). Thus, I chose betweenness centrality to identify the students' engagement in the discourse based on high betweenness scores, which reflected their ability to control and transmit information within the network (Saqr et al., 2020). Accurately identifying such information (for students involved in a discussion forum) could be valuable to teachers in preparing subsequent instructional activities (e.g., distributing students based on their centrality), identifying potential leaders for small-group interactions in the classroom, or providing personalized support to students in the periphery.

While SNA provides insights into students' online interactions in terms of social structures and dominance, in my experience, for this approach to be informative for teachers, it requires well-organized discussion forums with the technical ability to record students' posts and responses with greater accuracy (e.g., clearly showing where responses are directed) and automation than what platforms such as Canvas provide. Moreover, SNA does not provide a topical context for what students are discussing during their interactions. Thus, it is difficult for researchers and teachers to gain a more nuanced description of student engagement and learning in terms of subject-specific metrics, or an interpretation of the complex dynamics generated during online learning activities. Thus, I chose to analyze the content of the discussions for a nuanced understanding of the students' discourse.

4.5.3 Discourse analysis: A text network analysis of online discussions

As discussed in the theory chapter, from a sociocultural perspective, analyzing language can inform us about learning processes. This notion invited the analytical focus on the content of the students' discourse to unveil and categorize the key concepts and topics that emerged from the students' weekly discussion posts. As reported in Article 3, I performed a text network analysis of discussion forum posts using a computational linguistic tool called Infranodus (Paranyushkin, 2019). This web-based tool converts textual artifacts into a network of topics based on the most influential words and topical clusters (Paranyushkin, 2019).

As detailed in Article 3, before analyzing the discussion forum posts, a number of steps were taken. First, all the discussion contributions in each of the seven weeks were compiled into one file. The reason for this was to enable the analysis of each discussion thread in light of the weekly task assigned by the teacher and the intended learning objective for that particular week. This meant that the unit of analysis was the weekly discussion topic. Second, text normalization was conducted. This involved turning the different variations of the same word or concept into a similar format. For example, the words "encourage," "encouraged," and "encouragement" were grouped into "encourage" to reduce redundancies in the text network models. Third, syntax information and stop words, such as "of," "in," and "is," were removed. The reason for this was to ensure that the models would only generate concepts considered meaningful to the teachers in light of the course topics and objectives. After these procedures were completed, an automated analysis of the discussion contributions was conducted. This resulted in text network graphs (see examples in Figure 5) highlighting the main topical groups, the most influential elements (concepts with the highest betweenness centrality), an insightful question that helped the researchers see the structural gaps as depicted by the text network models, and, lastly, statistics on the total number of nodes, the graph density, and the network structure (Paranyushkin, 2019).

The automated analysis of discussion posts generates insights into students' textual discourse and network structure that provide teachers with an early signal by quickly identifying the text's main agenda, especially in connection to the intended pedagogical intent. The drawback, however, is that such an analysis may not be easy for teachers to interpret, as reported in Article 3. For example, the text network algorithm (Infranodus) discussed in Article 3, which used a data-driven approach to quantify the discussion posts, has the potential to produce semantic networks using arbitrary node positions (Shaffer, 2017). In hindsight, an alternative discourse analysis approach, such as ENA, which aggregates and models topics as dynamic, weighted node-link networks within a relevant unit of analysis (e.g., individual messages aggregated by a week), could have allowed a richer description of student discourse. Again, complexity might have emerged. Moreover, the aggregation of discussion forum contributions at the student level and thereafter aggregated by week could

have provided a better interpretation of individual students' concept use and how they relate to the learning design, other than combining them at the group and weekly levels.

4.5.4. Correlation Analysis of LMS page views and online discussion posts

In Article 3, I performed a Pearson correlation analysis (Benesty et al., 2009) using SPSS version 6.0 to determine whether a correlation existed between the Canvas page views and student participation, as measured by their entries in the discussion forum. The reason for analyzing page views (categorized as checkpoint analytics) and participation (categorized as process analytics) in the online discussions was influenced by the study's exploratory aim of finding data sources that could be used in designing LA solutions to support teachers' learning design decisions.

Table 2

Overview of the methodological elements of this thesis

Element	Article 1: Study 1a	Article 2: Study 1b	Article 3: Study 2	Article 4: Study 3
Type	Systematic Review	Empirical	Empirical	Empirical
Data	Empirical articles	Interviews Mini-survey	Log data (page views, online discussion posts, and interviews.	Interviews, researcher experiences
Sample	33 empirical articles	16 teachers	36 students and four teachers	360 students, seven teachers, and seven courses
Analysis	Thematic analysis, narrative	Thematic analysis, descriptive statistics	SNA, text network analysis, correlation analysis, thematic analysis	Thematic analysis)

4.6 Reflections on methodological quality

In this section, the credibility of the methodological decisions made in this thesis is discussed. In particular, I articulate how the thesis addressed the issues of reliability, validity, generalization, and research ethics.

4.6.1 Reliability

Reliability is defined as consistency within an employed analytical procedure such that other researchers can employ the same procedure and come to similar conclusions (Bryman, 2016). When presenting the qualitative findings from all three empirical articles, I used detailed extracts from the participants' responses to ensure that the context would not be lost. Additionally, throughout the data collection and analysis process, I consistently shared my preliminary findings with my supervisors and fellow students, as well as at research meetings in which some of the themes and interpretations were discussed and alternative interpretations explored. Moreover, I maintained a detailed record of all the steps and methodological and theoretical decisions taken to make it easy for readers and future researchers to perform an audit of all the decisions made.

Lastly, to ensure consistency and reliability of our codes, in Articles 2–4 I developed a codebook based on relevant theoretical perspectives (such as TAM) to guide the analysis of the interview transcripts, making it easy for the two coders to maintain consistency. Although social moderation was used to discuss the differences in our coding, the absence of statistical instruments to determine the consistency and validity of our codes could have compromised the codes' reliability.

4.6.2 Validity

In qualitative research, validity is operationalized through terms such as credibility, which refers to the trustworthiness and dependability of the research findings (Bryman, 2016). In qualitative research, validity is achieved through practices such as triangulation, which involves gathering and analyzing multiple perspectives, using diverse sources of data, and using alternative frameworks during analysis (Patton, 2014) for credible conclusions (Creswell & Miller, 2000). To avoid making conclusions based on just one source of data, in Article 3, I combined page views, online discussion posts, and interviews to provide a better understanding of students' online learning patterns. In addition, I employed analytical triangulation by using different analytical approaches. For example, in Article 3, I used SNA, text network analysis, inferential statistics, and thematic analysis. By combining multiple observers, methods, and data sources, I was able to overcome the intrinsic bias that comes from single-method and single-researcher studies (Creswell & Miller, 2000).

To ensure that my interpretation of the data was valid and in line with what the participants thought, I conducted member checks—or what some scholars call respondent validation (Bryman, 2016). Through this approach, I sent the transcripts back to the respondents to seek additional input and ensure that my interpretation of the data was similar to that of the respondents. This process allowed me to dialogue with participants beyond the data collection process and receive feedback in the form of additional input and corrections. For example, in Article 2, I provided space for respondent validation. In doing so, some participants provided new input, enhancing the credibility of the analysis (Bryman, 2016). Moreover, in Article 3, to assess whether the visualizations generated made sense to the teachers, the teachers were interviewed to assess the relevance of the suggested visualizations.

The construct and ecological validity of this thesis were improved with a DBR approach—an approach that is theory-driven, characterized by the iterative stages of identifying an educational problem and working closely with teachers in an authentic teaching environment (Wang & Hannafin, 2005). Moreover, by including teachers as active participants in the planning, design, and implementation of an LA solution, this thesis aligns with the qualitative principle of multivocality, which emphasizes close collaboration with participants to ensure a valid and nuanced understanding of the problem at hand (Tracy, 2010).

4.6.3 Generalizability

The generalizability of the findings in this thesis was examined through the concept of naturalistic generalization. According to Stake and Trumbull (1982), naturalistic generalization is characterized by readers gaining insights into aspects of research that they find applicable to their own context. It emphasizes the practical and functional application of research findings based on readers' tacit knowledge (Lincoln & Guba, 1985). The development of CADA is one way in which the findings from this thesis achieved transferability. For example, when I presented CADA at conferences, some researchers recognized its potential in their own contexts. This means that the dashboard resonated with their own personal contexts, thus achieving

naturalistic generalization. Moreover, in Articles 1–4, I provide the detailed and systematic processes behind the conceptual and empirical work that led to the development of the dashboard, including the theoretical background, the analytical techniques used, the pedagogical problems encountered, the teachers' interests, the actors involved, and the challenges faced. Even if other researchers do not use CADA, they will be able to draw from it to determine how they can use it in their own contexts.

The design and implementation guidelines discussed in Article 4 are also relevant beyond the immediate confines of the research context, both theoretically and practically (Charmaz, 2005). This implies that this thesis achieved resonance with its findings, having the potential to be valuable and transferable across a variety of contexts and situations. Lastly, to achieve analytical generalization (Maxwell, 2004), I used a sociocultural perspective as the lens through which to interpret my findings and design CADA. Thus, the analysis and findings reported from the specific cases discussed in this thesis might offer insights to other researchers on how these mechanisms could be applied to other contexts. For example, as I argue in Article 4, the theoretical constructs that informed the design of CADA could be used by other researchers and designers in any context guided by a sociocultural perspective.

4.6.4 Ethical considerations

The empirical work on which this thesis was based involved the collection of data regarding students' online behavior through the Canvas LMS. Therefore, the surveillance nature of this data could raise ethical issues, particularly related to privacy. In what follows, I provide details on how the empirical studies adhered to ethical regulations, and I offer reflections on the challenges faced and how they were addressed. I refer to two ethical principles identified by Bryman (2016) that should be considered in social research: seeking informed consent and ensuring confidentiality/privacy.

Seeking informed consent: Informed consent involves any freely given, specific, informed, and unambiguous indication from a person who affirms that his/her personal data may be processed (Brevik, 2013). This principle emphasizes that participation in a research project should be voluntary and based on the participant being given sufficient information about the research and the implications of participating. Informed consent means that the researcher must disclose all relevant information and any possible risks of participation, especially any issues regarding what will happen to the data obtained. In this thesis, five ethics protocols (application IDs 685178, 587741, 556047, 901414, and 798531) were approved by the Norwegian Center for Research Data (NSD).

In all three empirical studies, I applied for ethical clearance from NSD and later sought consent from the participants before their data were collected and analyzed (see Appendix 4 and 5). For example, before interviewing the respondents in the first study, I informed them about their ethical and privacy rights, including their right to withdraw at any time. I also asked for permission to record the interviews. I assured all the participants that their data would remain anonymous. Once the analysis was complete, the data were anonymized. While reporting the findings (see Article 2), none of the respondents were identified by name.

In the second empirical study, the analyzed data included Canvas page views, participation rates, and discussion posts within the Canvas LMS. Notably, the collection of this data required no effort from the students, as it was automatically collected as they navigated the Canvas LMS or contributed to the discussion forum. However, I still required the students' consent before I used their data. Following the same procedure as in

Study 1, I submitted an application to NSD, which allowed me to proceed with analyzing the data based on obtaining informed consent from each student. To seek consent, I physically went to classes to explain to the students the rationale of the study, why I was requesting their data, and how that data was to be protected. I also reminded them of their right to withdraw without any consequences. In the end, I managed to obtain consent from 30 students out of the 36 in the class. However, missing the consent of six students had some methodological implications. For example, since I used SNA as an analysis method, I needed all the students who were part of the discussions to be involved, as including all the participants would provide sufficient power to network statistics. This is especially true since networks can rely on a small group of centralized actors that influence connections with others, as I report in Article 3. This dilemma indicates how the two goals of subject protection and dataset completion for robust findings end up competing (Grunspan et al., 2014).

The last empirical studies were two pilot studies that involved teachers who had implemented CADA in their university courses. All participating teachers gave their informed consent, and their data were kept anonymous. However, there were some additional ethical issues that I had to consider. First, before integrating CADA into the Canvas LMS, the university IT services team requested that all ethical and privacy regulations be adhered to. For example, the dashboard was required to keep students' data within the same LMS environment and ensure that the analyzed information was only accessible by the teachers in charge of the course. Since, as a researcher, I required access to some of the data produced by the dashboard, I had to seek consent from the students. Because the tool was implemented in seven different courses, seeking consent from all students was going to be very difficult. Therefore, I decided to seek consent from one of the intervention courses to allow me to observe how the dashboard was being used in a real-life context. All students in this course gave their informed consent.

Ensuring confidentiality/privacy: This principle emphasizes keeping participants' personal data secure and protecting them from unauthorized access by outside parties (Bryman, 2016). The GDPR defines personal data as any information that can be used to identify a person directly or indirectly. This can include the person's name, physical identity, cultural identity, online identifiers, or identification number (Voigt & Von dem Bussche, 2017). In this thesis, I ensured that all student and teacher data were kept in an unidentifiable form for no longer than required.

Chapter 5: Summary of Articles

In this chapter, I summarize the four articles that constitute the thesis, and how they contributed to the goal of this thesis. All four articles have already been published. The articles are presented chronologically in the same order they were written and in line with the DBR process that inspired and guided this thesis.

5.1 Article 1

Kaliisa, R., Kluge, A., & Mørch, A. I. (2021a). Overcoming challenges to the adoption of learning analytics at the practitioner level: A critical analysis of 18 learning analytics frameworks. *Scandinavian Journal of Educational Research*, 1–15. https://doi.org/10.1080/00313831.2020.1869082

This paper presents the challenges facing LA adoption at the practitioner level and the efforts that have been made to overcome them. Since the current thesis was guided by a DBR approach, this paper aimed at defining the problem to provide a strong conceptual and theoretical background for the subsequent studies. The background that informed this paper was the limited number of best practice examples of LA use by teachers at the classroom level. Since my interest was in exploring how LA can support teachers' practice, I decided to explore what the literature has said about the challenges associated with teachers' use of LA, and the existing efforts to overcome them. With this background, a descriptive, systematic review of 18 LA frameworks and 15 LA studies that report on the challenges facing teachers' adoption of LA was conducted. The review had two aims: to critically analyze the challenges teachers face when adopting LA in everyday practice, and to analyze existing LA frameworks and their relevance to helping teachers overcome existing LA adoption challenges. The study sought to answer the following research questions:

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

In examining RQ1, the following five challenges affecting LA adoption by teachers were identified: (i) difficulty integrating technical and pedagogical expertise in LA use, (ii) a limited connection between LA and educational theories, (iii) a lack of alignment between LA systems and teachers' practice, (iv) ethical and privacy concerns, and (v) extra workload. While Challenges 1-3 are about pedagogy, the findings showed that the focus of existing LA studies is to address the technical challenges (e.g., designing dashboards to facilitate data access), in addition to working with teachers to design and implement LA tools in their pedagogical practice (i.e., to clarify what the displayed data mean for teaching and learning).

In response to RQ2, the study revealed a large body of research that has attempted to develop relevant frameworks and tools to support teachers in collecting, representing, analyzing, interpreting, and acting upon LA outputs. The findings also revealed efforts being made by LA researchers to bridge the gap between LA and theory by suggesting frameworks grounded in learning theories. The study revealed that a number of LA frameworks suggested by researchers have not been empirically tested against actual LA adoption in teachers' everyday practices. Moreover, most frameworks have not been concretized into technological artifacts and concrete data streams, implying that teachers might struggle to translate the guidelines into actual use.

Article 1 contributes to this thesis's overall goal by offering insights into the challenges teachers face in adopting LA, the existing solutions (LA frameworks and tools), and these solutions' weaknesses. A key takeaway from this study is the need to take a bottom-up approach to LA interventions, with teachers taking a central role in critical conversations about the planning, design, and evaluation of LA tools. While this article took a theoretical approach to exploring challenges facing LA adoption, the findings were later used during the planning of the empirical studies that investigated teachers' actual experiences that informed the rest of the thesis. For example, this paper presented evidence on existing challenges, such as the limited connection between LA and teachers' practice, which motivated the decision to use a DBR approach. Moreover, by analyzing the current LA frameworks and highlighting their limitations, this study provided context for the development of a new LA and learning design conceptual framework based on an empirical study that investigated teachers' LA needs and learning design practices (article 2). In hindsight, article 1 could have benefited from a critical analysis of actual LA tools (e.g., dashboards) used by the teachers, since this could have generated more nuanced insights into design and adoption challenges ahead of the empirical studies.

5.2 Article 2

Kaliisa, R., Mørch, A. I., & Kluge, A. (2021b). 'My point of departure for analytics is extreme skepticism': Implications derived from an investigation of university teachers' learning analytics perspectives and design practices. *Technology, Knowledge and Learning*, 1–22. https://doi.org/10.1007/s10758-020-09488-w

Article 2 focuses on examining teachers' learning design practices, challenges, and perceptions of LA as a potential tool to support their teaching and learning design practices. The findings from Article 1 reveal that there is a misconnection between existing LA tools and teachers' everyday practices. This challenge was partially explained by the limited involvement of teachers in conversations about their pedagogical challenges. Since the evidence from article 1 was based on a theoretical study that reported researcher-discussed adoption challenges and theoretical frameworks, an empirical study with teachers was conducted to complement the findings in article 1.

Considering the identified gap (e.g., misconnection between existing LA tools and teachers' everyday practices) and the overall aim of the thesis, a bottom-up approach was taken to conduct a qualitative study with 16 teachers at two Norwegian universities (the University of Oslo and Oslo Metropolitan University) using semi-structured interviews and a mini-survey. The aim was to empirically explore how teachers design courses, the challenges they face, their perceptions about LA, and their needs and contextual pre-conditions for using LA in their everyday practices. The following research questions guided this study:

> RQ1: What are the driving factors behind university teachers' course design practices?
> RQ2: What is the current state of university teachers' awareness, acceptance, needs, and perspectives regarding LA?
> RQ3: What are teachers' expectations regarding their use of LA to support course design?

In response to RQ1, the findings identified that teachers' course design practices are underpinned by situational factors (the nature of the course and the size of the class), feedback sources (course evaluations, summative assessments, informal reflections, and discussions with students and fellow teachers), and teachers' intuition and experience (based on in-classroom assessments and personal beliefs about the learning process). However, as previously noted by Bakharia et al. (2016) and emphasized by teachers during the interviews, such

approaches are prone to personal bias and fail to trace students' learning behavior in online learning environments, and they also make it difficult to provide timely feedback to teachers. These findings provide a theoretical context that suggests the use of alternative approaches (in this case, LA) to support timely learning design adaptations.

In response to RQ2 and RQ3 and guided by the principles of TAM, this study identified mixed reactions among teachers regarding their awareness, understanding, and potential use of LA to support their course design practices. Most teachers appreciated the formative and normative value of LA in providing more objective evidence about students' learning patterns and shaping learning processes. For example, some teachers requested analytics related to students' participation and discourse patterns during online discussions as a way of supporting their learning design practices. However, other teachers were skeptical of LA's role in evaluating teachers' and students' performance based on unnuanced data with limited depth of observation. This information underscored the importance of choosing appropriate LA data and metrics to ensure that they represent actual learning processes.

This article contributes to answering RQ1 of this thesis in several ways. First, it illustrates teachers' learning design practices and the challenges they face. It also highlights teachers' perceptions of LA as a potential tool for supporting their everyday teaching practice. This implies that all the decisions regarding the nature of data analytics and data analytics techniques were developed from the bottom up, based on teachers' own pedagogical needs. For example, the teachers highlighted the type of LA they wished to get from the digital systems, thus providing a strong theoretical foundation for the data and techniques used in the next stages of this project. The findings in this article were synthesized to propose a "bi-directional LA course design" conceptual framework (see Figure 11) that clarifies key elements (context, digital representations, technical requirements, and stakeholders) that influence teachers' design practices and highlight their implications for LA integration. For example, the *context element* was informed by the course design practices that the teachers reported as context-dependent and requiring attention before designing and making sense of LA. *Digital tools* are another element derived from the teachers' need for platforms (e.g., LMSs) to support the enactment of the learning designs. *Technical and functional requirements are a dimension* based on the teachers' desire for tools (e.g., dashboards) through which to analyze LA data and support their teaching, as well as the need for incentives and training to support the use of LA in practice. *Stakeholders:* The teachers expressed a need for the consideration of different actors (e.g., students, higher education leaders, and technical people) to support the adoption of LA. This explains why students and teachers were placed at the center of the bi-directional LA course design framework. This framework was a point of reference for the other studies.

5.3 Article 3

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*, *7*(3), 33–47. https://dx.doi.org/10.18608/jla.2020.73.4

This article explores the potential of different forms of LA data and how they could provide insights to support teachers in making learning design decisions. Building on the findings from Article 2, several data sources that teachers suggested as useful in understanding students' learning processes were explored. Moreover, the literature revealed that most existing studies that explore the connection between LA and learning design are based on system log data, with limited attention given to the analysis of content data (i.e., teaching and learning concepts). In addition, a review of LA dashboard research revealed that few studies seek teachers' input prior to developing automated tools. Against this background, this study developed a number of visualizations (paper prototypes) using multiple analytical approaches, including SNA, text network analysis, and inferential statistics. The prototypes were based on data from a one-semester undergraduate blended learning course at the University of Oslo. The following two research questions guided this study:

> RQ1: Do LA visualizations generated from different sets of process and checkpoint analytics provide informative insights to support learning design decisions?
> RQ2: What is the perceived value among teachers in using LA visualizations as tools to evaluate and make timely and informed learning design decisions?

In response to RQ1, the SNA and text network analysis of discussion forum posts revealed that gaining a clear understanding of the enacted and intended learning design requires a detailed analysis of different forms of data. For example, from a sociocultural perspective, the SNA of students' interaction patterns revealed how students interacted with each other, an important proxy for students' learning. However, capturing interactions without knowing what the students are talking about provides little information to the teacher. To address this, text network analysis was employed to analyze the content of the discussions. This analysis revealed the different concepts that students used during the different discussions. Moreover, a close analysis showed that the patterns revealed by the text networks were related to the tasks provided by the teachers on a weekly basis. The analysis of page views did not reveal any correlations with student participation. This information played a major role in determining the types of data to include in an automated dashboard.

In response to RQ2, teachers were invited to respond to the different visualizations and whether they found them to be potential proxy indicators of students' learning and could therefore later be used to inform their learning design decisions. The thematic analysis of the teachers' interviews showed that the teachers found the visualizations to increase their awareness of the quality of the students' online discourse by identifying the main themes and their magnitude in online discussions. The teachers also saw the potential of the LA visualizations to help facilitate discussions between teachers and students. However, the teachers emphasized that for the LA visualizations to impact their everyday practice, they need to be shared in real-time and be kept simple, but with enough detail to gain a rich understanding of students' learning processes over time. The teachers also asked that the analytics be embedded within the same online teaching environment (Canvas) for easy access. Some teachers even asked for analytics showing students' epistemic connections based on the discussion posts.

By using the course objectives as the basis on which to interpret the patterns that emerged from the online discussions, we demonstrated how to increase the relevance of LA metrics by connecting them to the pedagogical intentions embedded within learning design. This article contributes to the thesis's overall goal and research questions by offering empirical insights into the constructs and metrics to use while developing a dashboard to support teachers' everyday practice. For example, to respond to teachers' need for timely and simple visualizations, an LA dashboard that can be plugged into Canvas was developed (this is detailed in Article 4). This paper also demonstrates the need to consider learning design while attempting to make sense of students' course analytics. Furthermore, the results provided context for how SNA and discourse analysis could be implemented in a teacher dashboard, which is also presented in Article 4.

5.4 Article 4

Kaliisa, R., & Dolonen, J. A. (2022b). CADA: a teacher-facing learning analytics dashboard to foster teachers' awareness of students' participation and discourse patterns in online discussions. *Technology, Knowledge and Learning*, 1-22. https://doi.org/10.1007/s10758-022-09598-7

The focus of Article 4 is to present the full design process involved in establishing CADA. The literature review showed that the active involvement of stakeholders, particularly teachers, in the planning and designing of LA dashboards remains limited, and theories and concepts from the learning sciences are rarely used to inform dashboard design decisions. The literature also revealed that most dashboard developers only involve teachers in the initial stage of seeking feedback on prototypes. Moreover, studies report a lack of theoretical grounding for studies connecting LA and learning, which could lead to a selection of LA indicators that are only proximal and not consequential. The research carried out in this study had two main objectives. First, to design a teacher-facing LA dashboard to analyze students' asynchronous online discussions. The second was to have the teachers implement the dashboard in actual practice to monitor and assess students' behavior in online discussions during the run of the course.

Following a DBR approach and guided by concepts from the sociocultural perspective (participation and discourse) and HCI, this article discusses the process of designing, testing, and evaluating a teacher dashboard in an authentic university course. We evaluated the dashboard through ten in-depth interviews with seven university teachers who used CADA in seven blended undergraduate and graduate courses over a one-year period. This paper answers the following research questions:

> RQ1. What are teachers' experiences with using CADA?
> RQ2. How can we design and implement LA dashboards that meet teachers' pedagogical needs and expectations?

Regarding RQ1, the results showed that the teachers who participated throughout the design process were positive about the dashboard features, and, when asked about using the dashboard in the future, they showed interest. The teachers stressed the importance of CADA in providing information about students' learning processes through simple visualizations, which they leveraged to gain a more nuanced understanding of how particular terms were used by the students. Additionally, where necessary, the identified misconceptions were used as a basis on which to structure and customize the face-to-face classroom activities. Moreover, the alignment of the dashboard metrics with relevant theoretical constructs (participation, and discourse) allowed the teachers to review the envisioned and enacted learning designs and make slight course design changes on

the fly. Meanwhile, the teachers emphasized the need for LA dashboards to provide actionable insights by moving beyond *what things are* toward *how things should b*e.

Regarding RQ2, the findings highlighted a number of design and implementation considerations for LA researchers and technology developers. These include giving teachers agency and control over what LA systems provide, offering them appropriate training and exemplars, communicating to them the value of LA systems explicitly, and considering ethics as a design requirement.

This article highlights the contributions made by this thesis. In particular, it summarizes all the phases described in Articles 1–4 as an artifact in the form of a teacher dashboard, which has value within the immediate context of the study, since teachers have already started using it in their everyday teaching practice. Moreover, the article presents teachers' experiences with using the dashboard in authentic practice, thus validating CADA's applicability and contributing to the development of guidelines and design principles to support future processes of LA design with teachers and the design of tools to support adoption. In summary, this article addresses the overall goal of the study and RQ3, which sought to determine how to design LA systems together with teachers.

Chapter 6: Thesis Contributions and Conclusions

In this concluding chapter, I synthesize the findings in the four articles discussed in terms of their theoretical, empirical, practical, and methodological, contributions to the fields of LA and technology-enhanced learning. This section begins with a brief summary of the key findings as they relate to the three overarching research questions and is followed by a presentation of the thesis's contributions, as well as limitations and implications for future research.

6.1 Summary of findings

The aim of this thesis was to study how LA's uptake by and relevance to teachers can be improved by engaging them in the planning, design, and implementation of theoretically grounded LA tools in authentic teaching practices. To achieve this goal, three research questions were addressed through the lens of the four DBR stages described in Chapter 4. In what follows, I provide a brief summary of the key findings for each of the research questions.

6.1.1 Main findings regarding RQ1

RQ1 sought to gain insights into teachers' learning design practices, as well as their experiences with, challenges in using, and need for LA. This question was motivated by the necessity to develop LA systems based on teachers' needs, and to involve teachers in the design process to increase the relevance and uptake of the systems developed (Buckinghum Shum et al., 2019). First, the findings showed that most teachers' design practices are influenced by factors such as the nature of the courses taught, the size of the class, and feedback from summative assessments and course evaluations. The findings also showed that some teachers rely on their own experiences and intuition to make design changes. However, these methods are prone to bias and are usually presented at the end of a course, which implies that teachers are unable to make timely learning design decisions. Based on this finding, the teachers were asked whether they perceived LA as a viable option for improving their learning design practices. As reported in Article 2, the teachers were divided about this. Some were skeptical of LA being used as an evaluation tool to assess teachers' performance based on data they perceived as unnuanced. Others, however, perceived LA as a potential tool to support their learning design practices, if provided promptly. When asked about the nature of LA they needed, the teachers showed interest in using LA to monitor students' participation and discourse patterns in online discussions, which they reported as difficult to capture through the summative assessments that are commonly used.

Regarding the challenges teachers face in LA adoption, the systematic review of the literature in article 1 pointed to challenges such as the limited alignment of LA with teachers' practice, difficulties integrating technical and pedagogical expertise in LA use, the limited use of theory when developing LA systems, and ethical and privacy issues that affect the use of certain LA systems. These findings, which are discussed in more detail in the contribution section, lay a strong conceptual and empirical foundation for exploring LA solutions that address such challenges.

6.1.2 Main findings regarding RQ2

RQ2 sought to examine the potential of different LA data sources and techniques and how they might offer insights into students' learning to support teachers' learning design decisions. This question was informed by the gaps in the literature on LA and learning design, which is dominated by the use of log data as evidence to explore the relationship between LA and learning design (Mangaroska & Giannakos, 2018). In addition, since this thesis was aimed at developing LA solutions for and with teachers, it was important to explore the different data sources and techniques to decide, together with the teachers, which ones provided information that could support their pedagogical decisions. Thus, to answer RQ2, multiple data sources from an undergraduate course (see Article 3), which were labeled checklist analytics (page views) and process analytics (social interactions and discussion posts), were collected and analyzed. The findings showed that checklist analytics, such as page views, do not significantly relate to students' learning processes, meaning that they are not a reliable source for informing learning design decisions. The process analytics, which were analyzed through text network analysis and SNA, provided teachers with a baseline understanding of students' learning processes as they relate to the course objectives, thus providing data-informed evidence for the impact of different pedagogical activities. However, the teachers emphasized the need for the analytics visualizations to be simple to understand and embedded within the same environment used by teachers and students (LMS). In summary, through its exploration of the different LA data types and techniques, sharing of the LA outputs as paper prototypes with teachers, and the collection of the teachers' views regarding the potential of the visualizations in their teaching practice, RQ2 laid the foundation for the design of CADA reported in Article 3.

6.1.3 Main findings regarding RQ3

RQ3 sought to generate lessons and recommendations for the design and implementation of empirically and theoretically informed LA tools. It was informed by the increasing need for LA studies to follow a participatory approach and to leverage theory to inform the design of LA systems together with teachers (Buckinghum Shum et al., 2019). To answer this question, inspired by a DBR approach, the thesis built on findings from RQ1 and RQ2 to design an LA dashboard for and with teachers. To fulfill the theoretical requirement, a sociocultural approach was used as the lens through which to guide the selection of the indicators for the dashboard. As detailed in Article 4, this study generated a number of LA design and adoption guidelines for researchers, teachers, technology developers, and academic institutions. For example, the findings showed that teachers should be placed at the forefront of the design of teacher-oriented LA systems to ensure agency and control. The findings also highlight the need to start small and to consider ethics and privacy as design requirements. Furthermore, the alignment of dashboard metrics with relevant theoretical constructs (participation and discourse) allowed the teachers to review the envisioned and enacted learning designs and to make smaller course design changes as the course continued. The results highlighted here are discussed in further detail in the next section.

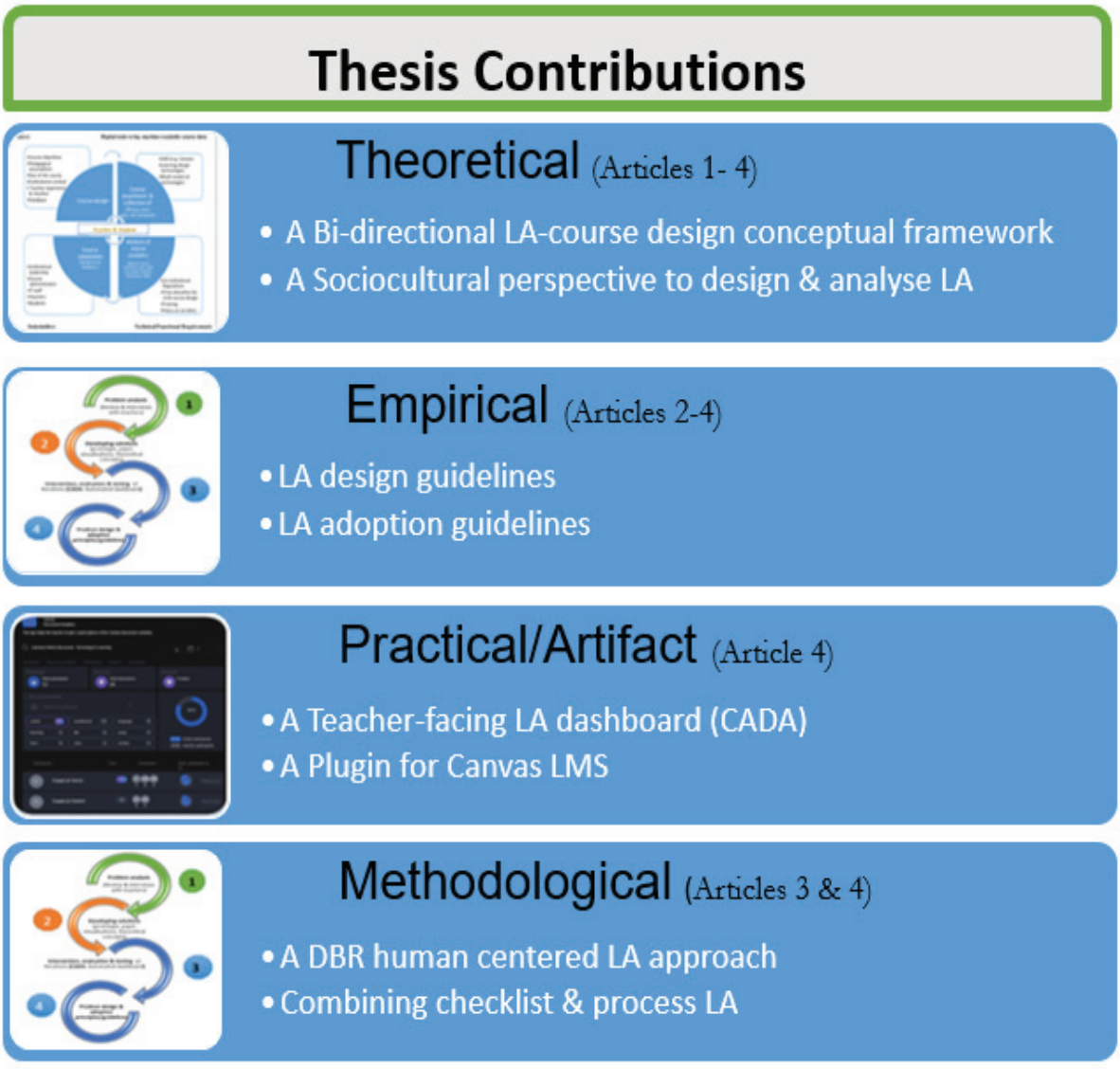
6.2 Thesis contributions

This section highlights the contributions this thesis makes (see Figure 10) to the fields of LA, learning design, and technology-enhanced learning. In particular, the discussion centers around the following key contributions: (1) *theoretical contributions*, such as the bi-directional LA course design conceptual framework, as well as theoretical explanations on how the sociocultural perspective guided the analysis and design of LA systems; (2) *empirical insights* in the form of guidelines for researchers, practitioners, and education institutional

leaders to guide future processes of LA design and adoption, (3) *a practical contribution* in the form of a teacher-facing LA dashboard; and lastly, (4) *methodological reflections* on the use of DBR from an HCLA perspective and combining multiple data and LA analytics approaches.

Figure 10

Summary of Key Contributions



Note: This figure illustrates the theoretical, empirical, practical and methodological contributions of the thesis.

6.2.1 Theoretical contributions

The bi-directional LA and course design conceptual framework (Figure 11) is one of the theoretical contributions this thesis makes to the fields of LA and learning design. DBR is characterized by an articulation of an initial framework to guide the next design stages (Reeves, 2006). Thus, the bi-directional LA course design conceptual framework was developed based on the findings from the problem analysis stage of the DBR-inspired process followed in this thesis. For example, the findings from Article 1 showed that despite the existence of LA frameworks to support teachers' adoption of LA, the majority of them are conceptually developed but not tested empirically. In addition, an empirical study with higher education teachers (Article 2) showed a number of circumstantial or serendipitous factors that influence teachers' learning design decisions (e.g., context), the nature of teachers' LA needs (e.g., digital tools and technical support), and the conditions for their adoption (e.g., the active involvement of stakeholders). In consideration of these factors and the literature review, the findings were synthesized to create a bi-directional LA course design conceptual framework that clarified the key factors, actors, and conditions needed to connect LA and learning design in practice. The adjective "bi-directional" was chosen to emphasize the relational and complementary nature of LA and learning design practices, with each element affecting the other. The framework consists of four dimensions: *context*, *digital representations*, *technical support*, *and stakeholders*. To illustrate the relevance and applicability of the LA course design conceptual framework in authentic practice, I briefly describe how each of the dimensions guided the empirical studies and the design work reported in Articles 3 and 4.

Context: The framework underscores the need to consider context (including learning design) to establish the conditions under which teachers work, and to use this as the basis on which to determine the nature of applicable LA interventions. This is important since, in light of findings from a recent study that explored teachers' use of LA dashboards at a fully online university (OU, UK) compared to a more blended university (the University of Oslo), the LA systems used at the two institutions varied due to contextual differences (Kaliisa et al., 2021c). In Article 3, I worked with four teachers to explore the potential of different forms of LA in supporting learning design decisions. To achieve this goal, the teachers, guided by factors within their context, designed relevant activities informed by the course objectives, class size, and their own pedagogical assumptions. Thus, asynchronous online discussions were chosen as one of the course activities.

Digital representations: The main function of LA is to capture, analyze, and visualize students' learning processes. Thus, this dimension emphasizes the need for a digital environment to assist teachers with implementing the designed activity and be able to gather relevant analytics. Although progress has been made within the LA community to gather students' behavioral traces (e.g., gestures, gaze, and emotions) in co-located settings using multimodal LA techniques (Ochoa et al., 2017; Spikol et al., 2018), the majority of LA data is gathered from digital learning environments. For example, in this thesis, to enact online discussions, Canvas, a platform that can support multiple digital tools, and with functionality for online discussions, was chosen as a tool to facilitate them.

Technical and functional requirements: This dimension highlights the necessary resources and support mechanisms (e.g. LA tools, LA institutional regulations, training, policy on LA ethics) to support the integration of LA and course design practices. After setting up the learning activity on the Canvas LMS, the teachers needed information about the students' discussion activities. However, generating timely and relevant analytics from the Canvas LMS was difficult for them, as the system only provides general statistics on students' learning actions. Thus, a technical tool that could provide analytics beyond page views was needed. This is where

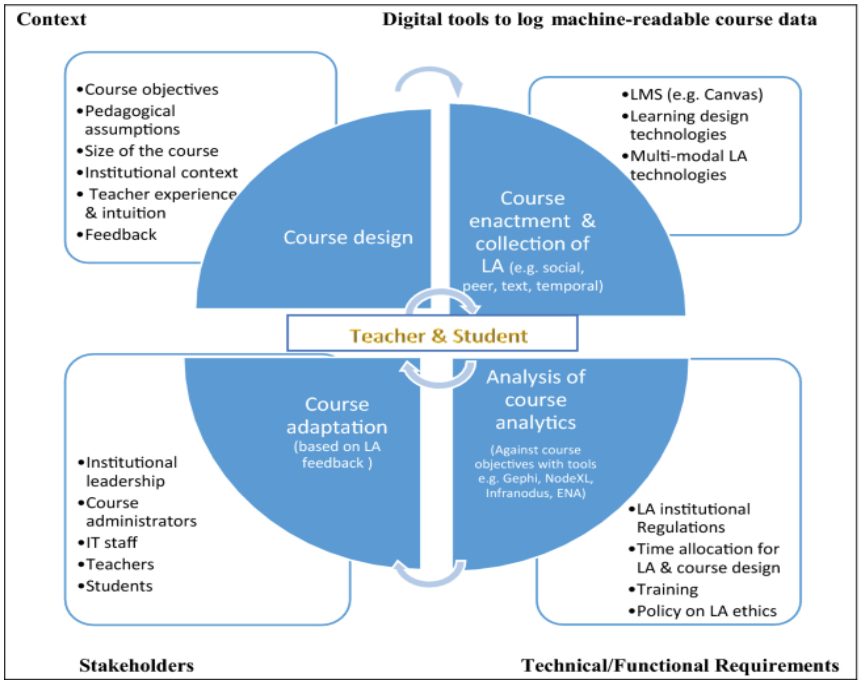
CADA (see Section 6.2.3) was developed and used to analyze students' online discussions by providing information about participation and discourse patterns and feeding the information back to the teacher for action. In this way, as reported in Article 4, CADA acted as an instructional scaffold to support the timely adaptation of the learning design.

Stakeholders: The framework underlines the role of stakeholders while planning to develop and integrate LA systems into teachers' everyday practices. In particular, as illustrated in the framework model (Figure 11), teachers (designers of learning activities that produce analytics) and students (the data providers) are put in the center to signify their role in the LA design and implementation process. Moreover, the framework recognizes the need for additional stakeholders. For instance, the process of designing courses, designing an analytics tool (CADA), and adding this as a plugin into the main university LMS (Canvas) was a multi-stakeholder endeavor. As described in Article 4, teachers were involved in designing the courses and suggesting relevant analytics indicators, students played a role as the data providers, institutional leaders provided guidelines and approvals for developing the dashboard, ethical committees ensured compliance with ethical and privacy matters, and technology designers provided the technical support to develop CADA. This process foregrounds the value of having different stakeholders on board to support LA interventions.

In summary, while the bi-directional LA course design conceptual framework needs to be considered within the context in which it was developed, it illustrates the key factors and actors involved in the process of adopting LA in authentic contexts. Hence, contributing to future efforts to support LA adoption. One key takeaway is the need to consider all dimensions during the LA adoption and design process since changes in or the absence of one dimension affect the LA course design's bi-directional cycle. Theoretically, the different elements of the conceptual framework, as illustrated above, offer researchers, technology designers, institutions, and teachers a guide that clarifies the necessary conditions for adopting LA and learning design in practice. This framework can be generalized to different contexts, and theoretical perspectives that inform teachers' learning designs.

Figure 11

The Bi-directional LA Course Design Conceptual Framework



Note: The above model illustrates the framework developed from the synthesis of literature and teachers' experiences with LA and learning design.

Using a sociocultural perspective to design and interpret LA: Another theoretical contribution made by this thesis is its illustration and discussion of how theory and for this thesis, a sociocultural perspective can be adapted to design LA tools, interpret analytics results, and identify pedagogically meaningful insights. A common criticism of LA is its lack of alignment with theory, particularly in designing LA interfaces (Wise & Shaffer, 2015). In this thesis, drawing from a sociocultural perspective (Säljö, 2002), two constructs of participation and discourse were selected as the central features of CADA. These constructs were chosen based on the sociocultural conception of learning as a process of participation in shared learning activities (Lave & Wenger, 1991; Sfard, 1998) and discourse as an important tool for understanding learning (Knight & Littleton, 2015). Thus, in Article 3, I focused on students' discourse—in this case, the conversations generated from asynchronous online discussions (*the focal context*)—as a site from which to identify patterns of activity that represent knowledge acquisition (Kollar et al., 2018) using discourse analysis. In addition, in Article 3, I used SNA to analyze student–student interactions on the online discussion forum. Using SNA metrics such as betweenness centrality and degree centrality, the analysis identified different sub-groups of students (e.g., most active vs. least active, or central vs. peripheral participants). However, making sense of the findings and the sub-groups was made possible with explanations deriving from the sociocultural perspective, including the role of peripheral and active participation in the learning process (Säljö, 2009). Unlike predictive LA models, which aim for empirical precision at the expense of theoretical relevance (Bergner, 2017), the sociocultural approach taken in this thesis improved the explanatory power of the LA metrics by providing me, as the researcher, with a coherent framework from which to choose data and indicators, as well as to make appropriate conclusions grounded in theoretical evidence.

To improve the accuracy of assessing students' interactions and discourse from the online discussions, I considered the intended learning design, which, from a sociocultural perspective, is considered a conceptual and intellectual artifact (Lund & Hauge, 2011). For example, in Article 3, one of the task instructions provided by the course instructor was for each student to make two discussion posts and respond to one other student. From a teaching perspective, by looking at the degree centrality metrics for each student, teachers could make actionable interpretations at a glance to determine whether a student had fulfilled the required task (for instance, whether they had written at least three posts). Thus, unlike a data-driven researcher who would have concentrated on SNA metrics to generate models and make inferences about students' learning, I took a sociocultural perspective, considering the peripheral context to be essential to understanding how students interact in the online discussion and how their behaviors are connected more to the learning design than the arbitrary correlations provided by the algorithms (Brooks & Thompson, 2017).

I would like to emphasize that LA researchers may not necessarily start with an explicit theory as their point of departure. For example, I took a bottom-up (data-driven) approach in this thesis, starting from a more exploratory perspective without necessarily aligning to a specific theoretical framework. For instance, in Article 3, I used a computational linguistic tool (Paranyushkin, 2019) to identify discourse patterns within students' online discussion posts that could respond to teachers' needs. After identifying the patterns, I shared them with the teachers to make sense of them as they pertained to the anticipated learning outcomes. Through this process, the teachers chose patterns that were pedagogically relevant. For example, the text networks had nodes highlighting the key authors that the students were asked to use during the discussion. According to one of the teachers, this indicated that students were using the recommended course resources. I used this knowledge to draw inspiration from the sociocultural notion of discourse and the mastery of key concepts (Säljö, 2002) to make appropriate and theoretically grounded conclusions. This helped me, as a researcher, to move past simple metrics, such as the total number of topical groups and graph density, to interpret more nuanced metrics of learning constructs (Wise & Shaffer, 2015).

This thesis demonstrates that it is possible and important to connect LA with learning theory to achieve pedagogically and theoretically sound conclusions. This is accomplished by illustrating how the sociocultural perspective and learning design provided a context from which to choose relevant indicators for the teacher-facing dashboard and to interpret the patterns identified from the exploratory SNA and discourse analytics outputs. Without a theoretical framework, it can be difficult to decide what indicators to use in a dashboard and, during the analysis of the students' data, which findings require special attention. Thus, I argue that research connecting LA and theory is timely, particularly for an emergent field of LA that is still struggling to close the gap between research and practice. While I do not claim that this thesis contributed to the advancement of the sociocultural approach, choosing analytical methods and theoretical constructs that informed the design of an LA dashboard (CADA) could be seen as a partial test of the generative value of the sociocultural perspective that informed CADA's development (Reimann, 2016). Thus, this work can serve as a framework for other researchers and LA industry professionals, and it can stimulate conversations around the need to develop tools that are motivated by theory and produce pedagogically meaningful outputs.

6.2.2 Empirical contributions: Design and adoption guidelines

Among the key empirical contributions of this thesis are the detailed, evidence-based insights and guidelines gained from the three empirical studies and the DBR process as a whole. Throughout this thesis, different theoretical frameworks, including TAM (Venkatesh & Davis, 2000), the bi-directional LA course design conceptual framework, and specific notions about learning from the sociocultural perspective (Säljö, 2002), were put forth. Since DBR results in not only practical solutions (CADA in the case of this thesis) but also theoretical contributions, in this section, I reflect on the overall DBR process to highlight the guidelines produced to improve the theoretical understanding and future processes of designing and adopting LA tools with teachers in authentic settings.

Guideline 1: The adoption of LA tools into practice takes time—less is more. While LA tools such as CADA could generate insights to inform teaching decisions, the process of making them an everyday practice among teachers takes time. As reported in Article 2, some teachers were skeptical of the LA outputs, considering them to be intrusive and to interfere with their space—yet based on data they call unnuanced. In this case, changing teachers' attitudes and building trust took time. At the same time, some teachers were constrained by institutional factors, such as some of the courses' limited flexibility for making design changes. Thus, some teacher participants required up to two iterations to begin using analytics in their everyday practice. An important implication for LA researchers is to be aware that small interventions that are carefully designed and involve a small group of users might provide better outcomes in terms of encouraging adoption at the practitioner level. For example, the work described in this thesis began with a small group of teachers who taught an undergraduate course. It was these four teachers who later acted as ambassadors and spread the word to other teachers regarding CADA's potential to support their practice. As an additional point to encourage adoption and reduce skepticism, teachers and other stakeholders could be assured that, the tools being developed are not meant to judge their performance or make them lose control, but to be support mechanisms. In practice, this might require researchers to communicate the value of LA systems explicitly, so that teachers do not see LA as a burden—an additional task to compete with their already limited resources.

Guideline 2: LA and learning design should be treated as bi-directional and complementary: This thesis offers empirical evidence for the potential of LA as a tool to support teachers' everyday teaching and learning design practices, particularly in blended higher education settings. Articles 3 and 4 strengthen the idea that when LA outputs are provided to teachers promptly, those teachers can gain a more nuanced understanding of their students' learning processes. The teachers can then use this understanding to assess envisioned and enacted learning designs. In Article 3, the analysis of students' discussion forum posts through social networks and discourse analysis revealed that in Week 1, there was limited interaction among the students—a pattern that did not align with the intended pedagogical intent (students responding to each other's comments). In addition, in Article 3, the findings showed no correlation between page views and student participation in the discussion forum. Had there been an overall correlation between the Canvas page views and students' participation in the discussion forum, the teachers could have used this as a proxy through which to identify the likelihood of certain resources being viewed by students, as well as when students log in. Such information could be used by teachers to determine the resources to be revised (based on views) as well as to remind students to log into the Canvas LMS during a time that will likely trigger participation. Moreover, using text network analysis to explore students' discourse features on a week-by-week basis allowed us to gain a nuanced view of the main concepts used by the students and how those concepts were related to the task assigned by the teacher for that week. The fact that we were able to model student progress through the lens of the weekly assessment task suggests that the course design—particularly the tasks set by the respective teachers—could have

influenced those patterns, as noted by Rienties et al. (2017).

As an implication, I argue that, in practice, the identification of such patterns through LA approaches and tools could afford teachers to self-monitoring their own learning designs and interventions to determine how effectively students will utilize the intended designs and whether revision of the course may be beneficial during the course's run or in future iterations. From the perspective of a just-in-time intervention, the insights in terms of text network models presented in Article 3 could provide teachers with context on the nature of the discourse used by students. This could allow the teacher to have a "bird's eye view" of how the students are moving within the course infrastructure. In particular, teachers can use these insights to promote active student learning by redesigning tasks or providing instructions that facilitate stronger networks.

While many studies have used social LA approaches to analyze students' learning during collaborative activities (e.g., Kaliisa et al., 2019), a recent review of social LA revealed that few of these studies have shared their insights with teachers to inform their learning design decisions (Kaliisa et al., 2022). A possible explanation for this could be the limitations associated with traditional, human-driven approaches to the analysis of students' learning artifacts—i.e., the laborious efforts required (Lewis et al., 2013)—that are far from feasible to use in real-time. Article 4 demonstrated that teachers were able to gain insights into their students' learning through the CADA tool, which they used to make design changes during the course. This was arguably one of the few efforts made to share social LA visualizations with teachers in real-time to inform their physical/synchronous teaching sessions. This proof-of-concept expedition of social LA moves toward addressing the concerns voiced by teachers in Article 2 regarding the problem of untimely feedback for students regarding their summative assessments.

Guideline 3: LA tools should be simple to use but should include the necessary details to address pedagogical needs. One of the key guidelines of relevance to LA tool designers and researchers is the need to keep LA tools simple, but with enough detail to facilitate pedagogical decisions. The teacher participants from Article 3 were invited to respond to the different LA visualizations and offer their opinions on their potential to provide insights into their students' learning—insights that could later be used to inform their learning design decisions. These teachers found the analytics visualizations to be informative to help facilitate discussions between the teachers and students. A key point emphasized by the teachers in this study was the need for the analytics to be presented in a simple and timely manner, while at the same time providing the necessary details to support the teachers in understanding their students' learning processes. This finding stresses that teachers would typically have minimal time to study and interpret data from LA systems, justifying the need to keep them simple. In practice, this finding points toward possible tension among LA researchers and designers, who might be required to find a balance between technically sound LA systems, but with limited complexity to address teachers' pedagogical needs. It is therefore imperative for researchers and LA system designers to work closely with teachers to ensure that systems and the outputs they present are usable and meaningful for the teachers. As argued throughout this thesis, this might require a methodological shift from researchers and technology developers establishing tools without input from the intended users to embracing participatory approaches that recognize the importance of having users as active agents in the design process.

Guideline 4: *Give agency to teachers; involve them throughout the design process*: While this might sound like a straightforward and obvious guideline, LA adoption by teachers is still affected by their limited involvement in the design process, which hinders trust in the developed system. Throughout the work conducted as part of this thesis, I worked closely with teachers to identify their needs, suggest solutions, co-design an LA

dashboard, and implement the dashboard in real educational contexts. For example, as reported in Article 2, the use of interviews at the beginning of the thesis acted as a gateway through which the teachers could contribute to the nature of the LA tool and the metrics they wanted. The teachers used the same avenue to discuss their concerns about LA. As I highlight in Articles 3 and 4, the analysis of teachers' experiences and needs uncovered practical considerations that guided the design of CADA. Thus, unlike radical empiricists, who believe that practitioners are not needed and that data scientists or engineers can design and interpret data from LA systems (Kitchin, 2014), I took a practitioner-oriented approach, with the assumption that teachers possess practical and implicit knowledge (Kvernbekk, 2019) that can shape the design of a dashboard and how it will be taken up in practice. Thus, the methodological approach taken in this thesis presents a viable solution for bridging the gap between theory and practice in LA research in the form of recognizing teachers' LA needs and considering them during the design of CADA. This could provide agency to teachers and contribute to their wider adoption, acceptance, and sustainability, a general concern in the LA field (Viberg et al., 2018).

Guideline 5: *Consider ethics and privacy as LA design and adoption requirements*: Several ethical and privacy-based issues arose during the design and implementation of CADA that required special consideration. For example, the following questions, among others, were asked: How will students' data be visualized? Who has access to these visualizations? Do teachers need consent to access students' data through the dashboard? Do teachers have an ethical obligation to act once they receive information about their students? How should data regarding the teachers be visualized? At the same time, some teachers wanted control over how the data about themselves would be visualized on the LA dashboard. As an implication, to support the sustainable design of ethically responsible LA systems, higher educational institutions should design local ethics and privacy policies to guide researchers, teachers, and technology developers on how to handle students' data. Existing LA frameworks, such as those presented by Greller and Drachsler (2012) and Sclater et al. (2016) that offer guidelines for the ethical adoption of LA, could provide a good starting point from which institutions can design local LA policies. In particular, institutional policies should be explicit on the kind of data researchers and teachers are able to use without consent from students, whether students have access to recourse if they feel that they have been negatively impacted by LA interventions, and when teachers should intervene. In addition, the teachers included in this study were sometimes hesitant to take action based on analytics due to the additional workload involved (for instance, redesigning courses), a challenge that was also discussed in Article 1. If a teacher has an ethical obligation to act based on analytics, higher educational managers should be made aware of the impact of LA interventions on teachers' roles and should provide the necessary resources to support them.

6.2.3 Practical/artifact contribution

CADA: An LA teacher dashboard

A main contribution of this thesis is the planning, designing, implementation, and evaluation of a teacher-oriented LA dashboard. CADA, the product of a three-year co-design process, was designed to help teachers gain insights into their students' participation and discourse patterns during asynchronous online discussions. As discussed in Chapters 1 and 2, teachers working in technology-enhanced learning environments often find it difficult to monitor students in online learning activities (Lillejord et al., 2018). As a result, they need support in the form of tools that can provide automated and timely feedback about students' learning. In our recent work, which reviewed studies employing social LA approaches in CSCL environments (Kaliisa et al., 2022a), we found a few social LA tools that teachers can use to simultaneously analyze students' online interactions and discourse. The results showed that the majority of the existing tools are used outside of actual learning environments and demand extra effort from researchers and teachers to perform the analysis. Additionally, as noted by other researchers (Van Leeuwen et al., 2015) and in my own studies as part of this thesis (Article 3), for teachers to use LA in their everyday practice, the LA tools need to be automated, timely, and embedded within the same teaching environment. Based on these gaps, this thesis followed a DBR-inspired process to develop a practice-oriented, teacher-facing dashboard that would support teachers with information about students' online learning processes at a glance and help them make informed teaching and learning design decisions. CADA is a teacher-facing dashboard that visualizes participation, social networks, sentiment, and the key concepts used by students within the Canvas LMS discussion forum on a need-to-know basis. It provides an overview of both structural and content-level analytics, which could help teachers gain insights into students' learning processes during asynchronous online discussions.

From a practical perspective, CADA shows how LA systems can be leveraged to inform teaching practice. For instance, as reported in Article 4, seven teachers used CADA in authentic teaching contexts over two iterations. The teachers reported using the insights gained from CADA to assess their envisioned and enacted learning designs, while others used the insights to make small course design changes on the fly. While some LA studies use approaches such as predictive analytics and experimental studies to generate insights into students' learning (Brooks & Thompson, 2017; Herodotou et al., 2019), such approaches might take a long time to affect actual practice since teachers may lack the time, methodological and statistical skills to interpret models and translate them to practice (Wasson & Kirschner, 2020). Echoing Reeves (2006), "Reading research papers and translating the findings into practical solutions is a formidable task for educational practitioners" (pp. 58–59). This implies that LA researchers cannot simply rely on generating models, advancing technical methods, and working with technology developers to develop LA solutions with the expectation that teachers will use them in practice. The process of developing CADA shows that the design and implementation of educational technologies need to be tailored to the immediate context of use and the intended users. In this way, this thesis contributes to reducing the gap between LA research and practice by providing lessons to guide future processes of LA design with teachers as well as for the design of tools themselves to support adoption (e.g., CADA).

In the Norwegian context, this thesis—CADA in particular—contributes to the ongoing effort at the national level to develop human and infrastructural capacities for LA. Interest in LA is growing throughout Norway; it has manifested in efforts such as the establishment of the Center for Science of Learning and Technology (SLATE) at the University of Bergen—which is partially funded by the Norwegian Ministry of Education—

and advancements in Norway's technological infrastructure (e.g., the ICT infrastructure company for Norwegian research and education [UNINETT] and dataporten (University of Bergen, n.d.). Recently, a group of experts was established by the Norwegian Ministry of Education to assess the potential of LA use in primary, secondary, vocational, and higher education. One of the key issues highlighted by this group was the need to address the gap between teachers' LA needs and skills to interpret LA outputs (Norwegian Government, June 10, 2022). In this regard, LA dashboards, such as CADA, could be one way to support teachers with limited LA skills by providing informative visualizations that require minimum analytical competence.

Empirical studies within the Norwegian context are needed to provide evidence for the application of LA on a small scale before making significant investments in macro-level implementation. This is necessary since the implementation of LA typically does not occur spontaneously, but instead starts small, like the research described in this thesis. The CADA tool could serve as an example for national stakeholders and individual educational institutions seeking to develop LA competencies among teachers, researchers, and technical personnel, since this is a key prerequisite for developing LA projects at the micro (course), meso (institutional), and macro (national) levels. Moreover, since CADA is a plugin for Canvas, the main LMS for higher education in Norway (Damşa & Fremstad, 2018), it could become a nationwide resource for higher education institutions in Norway. The focus at the time of writing this thesis is to fully integrate CADA as a plugin into the Canvas LMS to enable access by all the teachers across the University of Oslo and other Norwegian institutions. Moreover, since CADA is one of the few plug-in tools that has been produced at the University of Oslo, the lessons learned from this thesis can be transferred to other projects for the development of similar tools or to expand CADA's functionality. We also plan to share the developer source codes and open-access resources with descriptions of the CADA development process. For example, at the University of Oslo, the technical solutions implemented in CADA are being reused to implement a plugin for the microblogging tool Talkwall (Smørdal et al., 2021), which focuses on dialogic pedagogy to support participation and discourse in co-located classrooms. As highlighted in Article 2, teachers prefer systems that are integrated within the same learning management system. This means that, although Talkwall is an important pedagogical tool, its implementation by teachers could require extra effort if it is not integrated within the same institutional LMS used by teachers. Thus, the development of CADA as a plugin in Canvas is a breakthrough in terms of the possibility of creating other plugins to stimulate student-centered learning and informed learning design decisions within the Canvas LMS. Moreover, as of February 2022, researchers from some Nordic universities are exploring the potential of using CADA within their own contexts, demonstrating its potential to expand. It is clear that CADA has value both within the immediate context of this study and beyond due to its ability to be transferred to other institutions using Canvas and related LMSs.

6.2.4 Methodological contributions

The first methodological contribution this thesis makes is related to the use of DBR and the HCLA approach in a blended-learning higher education context. While the use of DBR in this thesis might not be considered novel, I argue that its application to the field of LA is important given the recent attention given to opting for more participatory approaches and HCLA, where the stakeholders are kept "in the loop" and considered central actors (Buckingham Shum et al., 2019; Wise et al., 2021). According to the review of studies on existing teacher-facing dashboards presented in Chapter 2, the active involvement of stakeholders, particularly teachers, in the planning and designing of LA dashboards remains limited. The review showed that the few studies that have tried to involve stakeholders usually stopped at the exploratory stage of the design process.

This means that teachers, who are the intended users of the LA tools and the subject matter experts, are denied the opportunity to contribute practical and domain-specific knowledge during the LA system development process. Kvernbekk (2019) refers to this as invading the space of the practitioners. Many experimental studies on LA have been conducted with the purpose of predicting how teachers or students will use LA other than testing this tool in authentic teaching environments (Rienties et al., 2015).

Another methodological contribution made by this thesis is its use of different data sources and LA approaches. A review of studies that address the connection between LA and learning design (Mangaroska & Giannakos, 2018) reported that the majority of studies are dominated by the use of log data—considered "a low hanging fruit" (Wise & Shaffer, 2015)—with limited use of metadata (data regarding the course structure and objectives) or the actual artifacts produced by students. Viberg et al. (2018), in their systematic review of 252 LA studies between 2012 and 2018, made the same observation, reporting that 72% of the studies they reviewed used a single method of data collection to make sense of students' complex learning processes. To address this gap, Article 3 built on teachers' LA needs uncovered in Article 2 to leverage different forms of data and analytical approaches to gain a better understanding of the complex nature of students' learning on online platforms. The inclusion of metadata also allowed for inferences regarding how demonstrated learning aligns with the intended learning designs. For example, the SNA of students' interaction patterns revealed how students interacted with each other, while the automated text networks showed the nature of the discourse in which students were engaged and how it related to the course objectives. Furthermore, the analysis of students' Canvas page view data allowed for a more authentic assessment of the students' behaviors in the Canvas LMS, even though these behaviors never correlated with students' actual performance measured by their participation in the online discussion forum (Article 3).

A key implication for researchers is to be aware of the limitations of trace-based LA data as a proxy for making inferences about students' learning. This is particularly critical since researchers typically have minimal control over the learning environments from which such data is collected. In this thesis, I use the example of Canvas page view data produced by the Canvas LMS. There is no explanation of how the views are calculated or what this could imply for students' learning. In these cases, as noted by Hewitt (2015), researchers end up working with post hoc data (e.g., page views) produced by systems and data structures that the researchers or teachers did not create, thus only providing rough estimates of the learning phenomena the researchers intend to explore. For instance, in Article 3, it is possible that students who had higher Canvas page views had logged into the LMS several times, searching for course materials without opening or contributing to the discussion forum. Relying only on trace data to make conclusions about students' learning behaviors and using these data to make teaching decisions could be misleading. Thus, by combining different sources of data and analytical approaches (both qualitative and quantitative) at different levels of granularity, this thesis foregrounds how LA researchers can move from low levels of abstraction toward higher-level constructs that present meaningful learning constructs (Wise et al., 2021).

6.3 Limitations and implications for future research

In this section, I address the limitations of this thesis and discuss how they point to issues that should be raised in future research.

Time pressure while working with an imperfect interface: While the DBR approach taken in this thesis contributed to practical solutions within the immediate context, this process required more time than I had available as a doctoral student. For instance, some of the features of CADA (such as sentiment analysis) were not implemented during the time of the intervention since the developers required more time. Moreover, while the first version of CADA was set to be used in classrooms early in the fall semester of 2020, this ended up not being possible due to the developers' other responsibilities (for example, their responsibilities as Engage Lab staff) and the disruptions brought about by the COVID-19 pandemic. As a result, the number of intervention courses was limited to four instead of the planned eight. The same challenge was met during the second iteration. After the first pilot, the lab had to make changes to the dashboard before it could be deployed in the spring semester of 2021. As such, potential intervention courses that were run early in the spring semester could not be included. These challenges could have affected the nature of the design and adoption guidelines developed in this thesis, with the possibility that more guidelines could have been developed with more or longer iterations. For future studies that use a DBR approach, adequate time and planning are needed to get stakeholders on board and to ensure that all technical requirements are in place prior to the intervention.

In addition, finding teachers who were interested in and committed to trying out a new tool in authentic practice was not straightforward. The teachers were not aware of the potential benefits of using LA tools, and convincing them to make some course design changes to accommodate the requirements of such tools took time. In Article 2, as also expressed by the title of the article, "My point of departure for analytics is extreme skepticism," some teachers were skeptical about the potential of LA to provide insights into students' learning. However, after some teachers experimented with LA tools in authentic practice, their initial perceptions of LA usefulness became more positive. This implies that teachers need time to experiment with LA tools before they can positively engage with them. In this sense, future research could examine teachers' engagement with LA over time and explore how initial perceptions (for example, the initial skepticism found in Article 2) of LA could change to be more positive after exposure to and use of LA tools in practice.

Furthermore, the potential of CADA's sentiment analysis functionality was not tested empirically with the teachers and is thus not described within the scope of this thesis. Researchers have recognized that learning is deeply tied to and inseparable from emotion and that emotions are ever-present in education and can dictate many elements of classroom interactions (D'Mello, 2017). For example, epistemic emotions depict how a learner responds to content, and they can have implications for future success in course materials (Chevrier et al., 2019). Increased attention to uncovering the many facets of sentiment and emotion from online discourse is justified and implies the need for future studies to examine this phenomenon (Han et al., 2021). In particular, future research should look into the impact of providing teachers with information about students' sentiments within online discussion forum posts to gain a more nuanced description of student engagement and learning. Possible questions to explore include: How does negative sentiment manifest in online discussion posts? What kinds of sentiments are associated with different kinds of posts? How can teachers use insights from sentiment analysis to inform their designs? Is there a relationship between learning design or specific learning activities and the nature of the sentiment revealed? Future research could also explore the potential of combining sentiment analysis with other approaches, such as ENA and SNA since previous studies that have taken this approach have shown potential (Misiejuk et al., 2021) in providing a comprehensive interpretation of human

behavior. Meanwhile, my initial experience with analyzing sentiment in educational discourse shows that the approach is not straightforward and requires significant effort to ensure valid interpretations and findings. This is particularly true because most sentiment algorithms are designed for non-educational text analysis purposes, which could render them less accurate for analyzing academic content and discussions. Educational researchers may need to review these algorithms to find better ways to capture sentiments in academic discussions.

Sampling and analysis limitations: The intervention cases reported in Articles 3 and 4 were all conducted within courses from the educational sciences and at a single Norwegian University, which limits the generalizability of these findings to other disciplines, institutions, and countries. However, it is important to note that the studies in this thesis were selected to serve as illustrative cases that could generate important lessons for the adoption of LA, specifically at institutions in the early stages of exploring the potential of LA. Notably, the main purpose of the thesis was not to achieve the statistical generalization characterized by large samples (Bryman, 2016), but to achieve a naturalistic generalization from which researchers and practitioners could gain insights and later apply them in their own contexts. Moreover, since the evidence presented in this thesis was derived from teachers working in a higher education setting, it is possible that the experiences and challenges reported here are similar to those in other higher education institutions in Norway and abroad. Future studies might consider applying the approach followed in this thesis to more institutions, teachers, and disciplines to improve the generalizability of the findings.

Furthermore, while I strove to conduct a discourse analysis of students' online discussions, the techniques used were limited to the identification of the key topics in the discussion contributions and the analysis of students' social ties to understand how they were engaged. While this form of analysis is congruent with the sociocultural approach, higher-level discourse analysis intended to identify key discourse features, such as exploratory talk (Mercer et al., 2019) and epistemic connections (Shaffer, 2017), was not done. The decision to focus on general discourse features, such as key concepts and social interactions, was based on the needs of teachers (as reported in Article 2), who demanded analytics that showed the key concepts and students' participation/engagement during online discussions. In hindsight, Article 3 could have benefited from a deeper analysis of student discourse to capture the students' trajectories and meaningfully quantify the quality of discourse for learning (e.g., argumentation and epistemic connections). During the early stages of my Ph.D. research, I explored several computational linguistic tools, including Coh-Metrix, which analyzes higher-level language and discourse features (Kaliisa et al., 2019); however, the results were specific to the general language features (e.g., deep cohesion and narrativity) identified in discussion posts other than domain-specific discourse features.

If I were to repeat this study, I would build on previous work that operationalized student discourse in online discussions at the message level (e.g., Ferguson et al., 2013) and extend the analysis of student discourse and capabilities of CADA by training a classifier to capture different elements of discourse within online discussions (e.g., exploratory, epistemic, and disputational) presented for individual students on a two-dimensional space defined by the number of contributions/interactions per student. This kind of information could provide teachers with a better awareness of students' learning. Moreover, I could leverage more advanced computational approaches, such as ENA, to provide both quantitative and qualitative insights into learning processes (Shaffer, 2017; Kaliisa et al., 2021d). For example, in our recent work (Kaliisa et al., 2022c; not part of this thesis), we used the same online discussion data presented in Article 3 to analyze students' epistemic connections using ENA and binary classifications, where student discourse was coded based on the course objectives and modeled as epistemic networks. The findings revealed that students' epistemic and social

connections were related to the design of each week's tasks, with implications for teachers in monitoring their own learning designs. By taking this approach, researchers could gain a nuanced view of students' epistemic and social connections over time, which could support the design of activities that promote student engagement and productive, knowledge-building discourse.

Relying on online discussion data. This thesis's focus on data from online discussions implies that a number of aspects about students' learning were not captured. While the decision to use online discussions was influenced by teachers' interests from Article 2 (e.g. interest in monitoring students' participation and engagement in online discussions), this decision could be seen as problematic since no other relevant indicators of learning were captured. In particular, since the thesis was conducted within a blended learning institution, the data available were limited to elements of the course offered through online platforms. Future researchers, particularly those working with blended learning institutions and professional higher education programs, might consider employing alternative approaches, such as multimodal LA, to capture students' learning processes within the same environment where the learning occurs to correlate the evidence accumulated in the digital and in-person environments (Ochoa et al., 2017). Doing this may reduce the "streetlight effect" (focusing on readily accessible sources of data) and move toward gathering fine-grained learning traces (such as emotions and movements) within the same educational environment, where digital tools (Ochoa et al., 2017) do not necessarily mediate learning. Furthermore, since the data displayed on teacher-facing dashboards are based on students' learning activities, developing a dashboard with a double interface for both students and teachers could offer better value for learning and teaching. In particular, it would be interesting to investigate the impact of sharing LA with students while engaging in online activities and how this might impact students' self-regulation behaviors.

The tension between theory and stakeholder needs: While the sociocultural learning perspective was used as a guiding framework in this thesis, its application was not explicit throughout the thesis. In particular, since the initial studies were exploratory in nature (e.g., Articles 1 and 2) and due to the teachers' needs, this meant that the theoretical perspectives were not at the forefront until the design of the prototypes and the CADA dashboard stage. This challenge denotes the tension between developing LA tools that are centered on stakeholder needs and the aspiration to develop tools that are grounded in theory. A suggestion for future research is for researchers to start with an explicit theoretical perspective while ensuring that the designed solutions attend to the stakeholders' needs.

Evaluation limitations: In Article 4, the evaluation of the dashboard would have benefited more from the use of multiple evaluation approaches (log analysis) than from interviews alone. While interviews provide insights into users' perceptions, they are often affected by participant bias (Bryman, 2016). This makes it difficult to evaluate the actual use and impact of the system, as evidence is based on what the teachers say. Moreover, even though CADA was designed to support teachers' awareness of students' learning processes, the interview approach used in Article 4 could not capture evidence of how the teachers made sense of and reacted to the visualized information. In this regard, future studies that evaluate the use of LA systems and how teachers make sense of them could benefit from a methodological approach that employs several methods (interviews, log analysis, or video) to capture evidence for the use and effectiveness of different LA systems. Moreover, to capture the actual impact of LA systems, future studies should follow a longitudinal approach that allows change processes to be captured over time.

Ethical limitations: The progress of this thesis was hampered by the challenge of seeking consent from the students. In particular, during one of the data collection exercises during the pandemic (Spring 2020), I was unable to follow the same protocol that I used before the pandemic (going to classes physically to seek students' consent). At the University of Oslo (my empirical context), all teaching had been moved online. This meant that I was unable to meet students face to face, as I had planned. While it was possible to contact students via email, this process was not successful, with only 2 out of the 45 responding to my request. Moreover, after classes moved online, there were many absences and disruptions in the online classes, as students and teachers were all getting used to the "new normal" way of learning and teaching. In the end, I was unable to gain consent from the students and instead planned for a new data collection phase (spring of 2021), in which I managed to meet the students physically to ask for their consent. As an implication and lesson for researchers designing LA systems and using data from institutional LMSs such as Canvas, conducting ethical research using LA tools in blended learning contexts is undoubtedly very challenging. In particular, it is difficult to work with data from systems such as Canvas, which are closed and require student consent before the data (including non-personal data) can be used. Part of the challenge is that GDPR regulations refer to students' data in a general sense, which makes it difficult for institutions, ethical committees, and individual researchers to make the right data use decisions. Moreover, while students occasionally indirectly provide consent to the university when they register (in alignment with the institution's fiduciary duty) (Prinsloo & Slade, 2017), the conditions and situations in which researchers can use such data are not explicit and can require clarification (Greller & Drachsler, 2012).

6.4 Concluding remarks

As higher education continues to embrace digitalization, institutions gain increased access to a higher volume of student (learning) data, creating opportunities for timely and data-informed teaching decisions and customized student support. This thesis has illustrated that offering teachers appropriate and timely information regarding students' learning behavior through tools such as CADA helps teachers make timely and informed learning design decisions. However, for analytics to be relevant to teachers and lead to sustainable changes in their teaching practices, it is critical to engage teachers and other relevant stakeholders in the identification of teaching and LA needs before the solutions are designed and implemented, and to treat LA solutions as tentative with potential to improve over time as part of an iterative process. Moreover, the design of LA systems should be informed by relevant theoretical perspectives to ensure that LA outputs align with teachers' pedagogical practice. Thus, higher education institutions have a duty to build teachers' capacity through training as well as providing the necessary resources to develop and implement LA systems. Moreover, researchers who intend to develop LA systems should aim for small initiatives—like the one described in this thesis—to build trust and capacity before scaling up. The theoretical, methodological, design and adoption insights illustrated in this thesis aim to generate conversation and provide a sound basis for researchers, practitioners, technology developers, and higher educational institutions to develop and implement pedagogically relevant and theoretically motivated LA and education technology systems in authentic practice.

References

Agostinho, S. (2011). The use of a visual learning design representation to support the design process of teaching in higher education. *Australasian Journal of Educational Technology*, *27*(6), 961-978.

Ahn, J., Campos, F., Hays, M., & DiGiacomo, D. (2019). Designing in context: Reaching beyond usability in learning analytics dashboard design. *Journal of Learning Analytics*, *6*(2), 70–85.

Arnold, K. E., & Pistilli, M. D. (2012). Course signals at Purdue: Using learning analytics to increase student success. In *Proceedings of the 2nd international conference on learning analytics and knowledge* (pp. 267–270).

Arnseth, H. C., & Ludvigsen, S. (2006). Approaching institutional contexts: Systemic versus dialogic research in CSCL. *International Journal of Computer-Supported Collaborative Learning*, *1*(2), 167–185.

Ashwin, P. (2009). Conceptualising teaching and learning interactions in researching higher education. In Tight, M., Mok, K. H., Huisman, J., & Morphew, C. (Eds.), *The Routledge international handbook of higher education* (pp. 37–46). Routledge.

Atmanspacher, H. (1994). Complexity, meaning and the cartesian cut. *Journal of Consciousness Studies*, *1*(2), 168–181.

Azungah, T. (2018). Qualitative research: Deductive and inductive approaches to data analysis. *Qualitative Research Journal (18),* 383–400.

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. In *Proceedings of the sixth international conference on learning analytics & knowledge* (pp. 329–338).

Barab, S. (2006). Design-based research: A methodological toolkit for the learning scientist. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 153–169). Cambridge University Press.

Beer, D. (2018). *The data imaginary: six reasons why data analytics have become so powerful*. British Politics and Policy at LSE. https://blogs.lse.ac.uk/politicsandpolicy/data-imaginary/

Bennett, S., Agostinho, S., & Lockyer, L. (2015). Technology tools to support learning design: Implications derived from an investigation of university teachers' design practices. *Computers & Education*, *81*, 211–220.

Bennett, S., Agostinho, S., & Lockyer, L. (2017). The process of designing for learning: Understanding university teachers' design work. *Educational Technology Research and Development*, *65*(1), 125–145.

Bergner, Y. (2017). Measurement and its uses in learning analytics. In Lang, C., Siemens, G., Wise, A., & Gasevic, D. (Eds.), *Handbook of Learning Analytics*, *35*(2), 34-47.

Benesty, J., Chen, J., Huang, Y., & Cohen, I. (2009). Pearson correlation coefficient. In I. Cohen, Y. Huang, J. Chen, & J. Benesty (Eds.), Noise reduction in speech processing (pp. 1–4). Berlin, Germany: Springer. https://dx.doi.org/10.1007/978-3-642-00296-0_5

Black, P., & William, D. (2009). Developing the theory of formative assessment. *Educational Assessment, Evaluation and Accountability*, *21*(1), 5–31. https://doi.org/10.1007/s11092-008-9068-5

Blumenstein, M. (2020). Synergies of learning analytics and learning design: A systematic review of student outcomes. *Journal of Learning Analytics*, *7*(3), 13–32.

Borgatti, S. P., Mehra, A., Brass, D. J., & Labianca, G. (2009). Network analysis in the social sciences. *Science*, *323*(5916), 892–895.

Børte, K., Nesje, K., & Lillejord, S. (2020). Barriers to student active learning in higher education. *Teaching in Higher Education*, 1–19. https://doi.org/10.1080/13562517.2020.1839746

Bratteteig, T., & Wagner, I. (2014). *Disentangling participation: Power and decision-making in participatory design*. Springer.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101.

Brevik, L. M. (2013). Research ethics: An investigation into why school leaders agree or refuse to participate in educational research. *Problems of Education in the 21st Century*, *52*, 7–20.

Brooks, C., & Thompson, C. (2017). Predictive modelling in teaching and learning. In Lang, C., Siemens, G., Wise, A., & Gasevic, D. (Eds.), *Handbook of Learning Analytics*, 61–68.

Brown, M., McCormack, M., Reeves, J., Brook, D. C., Grajek, S., Alexander, B., & Weber, N. (2020). *2020 Educause Horizon Report Teaching and Learning Edition*. EDUCAUSE.

Bryman, A. (2016). *Social research methods*. Oxford University Press.

Buckingham Shum, S., Ferguson, R., & Martinez-Maldonado, R. (2019). Human-centred learning analytics. *Journal of Learning Analytics*, *6*(2), 1–9.

Buckingham Shum, S. B., & Ferguson, R. (2012). Social learning analytics. *Journal of Educational Technology & Society*, *15*(3), 3–26.

Charmaz, K. (2005). Grounded theory in the 21st century: A qualitative method for advancing social justice research. *Handbook of Qualitative Research*, *3*(7), 507–535.

Chatti, M. A., Muslim, A., Guesmi, M., Richtscheid, F., Nasimi, D., Shahin, A., & Damera, R. (2020). How to design

effective learning analytics indicators? A human-centered design approach. In *European conference on technology enhanced learning* (pp. 303-317). Springer, Cham.
Chen, Q., Li, Z., Pong, T. C., & Qu, H. (2019, April). Designing narrative slideshows for learning analytics. In *2019 IEEE Pacific Visualization Symposium (PacificVis)* (pp. 237–246). IEEE.
Chen, G. (2019). Visual learning analytics to support classroom discourse analysis for teacher professional learning and development. The Routledge international handbook of research on dialogic education, 167-181.
Chevrier, M., Muis, K. R., Trevors, G. J., Pekrun, R., & Sinatra, G. M. (2019). Exploring the antecedents and consequences of epistemic emotions. *Learning and Instruction*, *63*, 101209.
Clow, D. (2013). An overview of learning analytics. *Teaching in Higher Education*, *18*(6), 683–695.
Coates, H., James, R., & Baldwin, G. (2005). A critical examination of the effects of learning management systems on university teaching and learning. *Tertiary Education and Management*, *11*, 19–36.
Conole, G. (2012). *Designing for learning in an open world* (Vol. 4). Springer Science & Business Media.
Creswell, J. W., & Miller, D. L. (2000). Determining validity in qualitative inquiry. *Theory Into Practice*, *39*(3), 124–130.
Creswell, J. W., Plano Clark, V. L., Gutmann, M. L., & Hanson, W. E. (2003). An expanded typology for classifying mixed methods research into designs. In A. Tashakkori and C. Teddlie (Eds.), *Handbook of mixed methods in social and behavioral research,* Thousand Oaks, CA: SAGE. 209–240.
Damşa, C., de Lange, T., Elken, M., Esterhazy, R., Fossland, T., Frølich, N., & Aamodt, P. O. (2015). *Quality in Norwegian higher education: A review of research on aspects affecting student learning*. NIFU Report.
Damşa, C. I., & Ludvigsen, S. (2016). Learning through interaction and co-construction of knowledge objects in teacher education. Learning, culture and social interaction, 11, 1-18.
Damşa, C., & Fremstad, E. (2018). Pedagogical Use of Canvas: Report on the use of Canvas in pilot courses at the Faculty of Educational Sciences. https://www.readkong.com/page/pedagogical-use-of-canvas-report-on-the-use-of-canvas-6240088
Daniels, H. (2002). *Vygotsky and pedagogy*. Routledge.
De Liddo, A., Shum, S. B., Quinto, I., Bachler, M., & Cannavacciuolo, L. (2011, February). Discourse-centric learning analytics. In *Proceedings of the 1st international conference on learning analytics and knowledge* (pp. 23–33).
D'Mello, S. (2017). Emotional learning analytics. In Lang, C., Siemens, G., Wise, A., & Gasevic, D. (Eds.). *Handbook of learning analytics* (p. 115).
Dollinger, M., Liu, D., Arthars, N., & Lodge, J. (2019). Working together in learning analytics towards the co-creation of value. *Journal of Learning Analytics*, *6*(2), 10–26.
Dourado, R. A., Rodrigues, R. L., Ferreira, N., Mello, R. F., Gomes, A. S., & Verbert, K. (2021, April). A teacher-facing learning analytics dashboard for process-oriented feedback in online learning. In *LAK21: 11th International Learning Analytics and Knowledge Conference* (pp. 482–489).
Douven, I. (2011). *Abduction*. Stanford Encyclopedia of Philosophy https://plato.stanford.edu/entries/abduction/?utm_campaign=%F0%9F%A6%89%2010x%20curiosity&utm_medium=email&utm_source=Revue%20newsletter
Engeström, Y. (2000). Activity theory as a framework for analyzing and redesigning work. *Ergonomics*, *43*(7), 960–974.
Eradze, M., Rodríguez-Triana, M. J., & Laanpere, M. (2019). A conversation between learning design and classroom observations: A systematic literature review. *Education Sciences*, *9*(2), 91.
Edelson, D. C. (2002). Design research: What we learn when we engage in design. The Journal of the Learning sciences, 11(1), 105-121.
Freeman, L. C. (1978). Centrality in social networks conceptual clarification. Social networks, 1(3), 215-239.
Ferguson, R. (2012). Learning analytics: Drivers, developments and challenges. *International Journal of Technology Enhanced Learning*, *4*(5–6), 304–317.
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, 1-153. https://doi.org/10.2791/955210
Ferguson, R., Wei, Z., He, Y., & Buckingham Shum, S. (2013, April). An evaluation of learning analytics to identify exploratory dialogue in online discussions. In Proceedings of the Third International Conference on Learning Analytics and Knowledge (pp. 85-93)
Frické, M. (2015). Big data and its epistemology. *Journal of the Association for Information Science and Technology*, *66*(4), 651–661.
Fritz, J. (2010). Video demo of UMBC's "Check My Activity" tool for students. *Educause Quarterly*, *33*(4).
Gašević, D., Dawson, S., Rogers, T., & Gasevic, D. (2016). Learning analytics should not promote one size fits all: The effects of instructional conditions in predicting academic success. *The Internet and Higher Education*, *28*, 68–84.
Giacomin, J. (2014). What is human centered design? *The Design Journal*, *17*(4), 606–623.
Gould, P. (1981). Letting the data speak for themselves. *Annals of the Association of American Geographers*, *71*(2), 166–176.

Greeno, J. G. (1997). On claims that answer the wrong questions. *Educational Researcher*, *26*(1), 5–17.
Greller, W., & Drachsler, H. (2012). Translating learning into numbers: A generic framework for learning analytics. *Journal of Educational Technology & Society*, *15*(3), 42–57.
Grudin, J. (2017). From tool to partner: The evolution of human-computer interaction. *SynThesis Lectures on Human-Centered Interaction*, *10*(1), 1–183.
Grunspan, D. Z., Wiggins, B. L., & Goodreau, S. M. (2014). Understanding classrooms through social network analysis: A primer for social network analysis in education research. *CBE—Life Sciences Education*, *13*(2), 167–178.
Goodyear, P., & Retalis, S. (2010). Technology-enhanced learning: Design patterns and pattern languages. BRILL.
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*. Project Report. https://bit. ly/39lzBHO.
Han, Z. M., Huang, C. Q., Yu, J. H., & Tsai, C. C. (2021). Identifying patterns of epistemic emotions with respect to interactions in massive online open courses using deep learning and social network analysis. *Computers in Human Behavior*, *122*, 106843.
Hutto, C., & Gilbert, E. (2014). Vader: A parsimonious rule-based model for sentiment analysis of social media text. Proceedings of the International AAAI Conference on Web and Social Media, 8(1).
Hernández-Leo, D., Villasclaras-Fernández, E. D., Asensio-Pérez, J. I., Dimitriadis, Y., Jorrín-Abellán, I. M., Ruiz-Requies, I., & Rubia-Avi, B. (2006). COLLAGE: A collaborative learning design editor based on patterns. *Journal of Educational Technology & Society*, *9*(1), 58–71.
Herodotou, C., Hlosta, M., Boroowa, A., Rienties, B., Zdrahal, Z., & Mangafa, C. (2019). Empowering online teachers through predictive learning analytics. *British Journal of Educational Technology*, *50*(6), 3064–3079.
Hewitt, J. (2015). Commentary on "distributed revisiting: An analytic for retention of coherent science learning." *Journal of Learning Analytics*, *2*(2), 102–106.
Hobbs, J. R., Stickel, M. E., Appelt, D. E., & Martin, P. (1993). Interpretation as abduction. *Artificial Intelligence*, *63*(1–2), 69–142.
Holstein, K., McLaren, B. M., & Aleven, V. (2019). Co-designing a real-time classroom orchestration tool to support teacher–AI complementarity. *Journal of Learning Analytics*, *6*(2), 27–52.
Hontvedt, M., & Arnseth, H. C. (2013). On the bridge to learn: Analysing the social organization of nautical instruction in a ship simulator. *International Journal of Computer-Supported Collaborative Learning*, *8*(1), 89–112.
Hutchings, P., Huber, M. T., & Ciccone, A. (2011). *The scholarship of teaching and learning reconsidered: Institutional integration and impact* (Vol. 21). John Wiley & Sons.
Ivankova, N. V., Creswell, J. W., & Stick, S. L. (2006). Using mixed-methods sequential explanatory design: From theory to practice. *Field Methods*, *18*(1), 3–20.
Jivet, I., Scheffel, M., Drachsler, H., & Specht, M. (2017). Awareness is not enough: Pitfalls of learning analytics dashboards in the educational practice. In *European conference on technology enhanced learning* (pp. 82–96). Springer, Cham.
Johnson, R. B., Onwuegbuzie, A. J., & Turner, L. A. (2007). Toward a definition of mixed methods research. *Journal of Mixed Methods Research*, *1*(2), 112–133.
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*, *7*(3), 33–47. https://dx.doi.org/10.18608/jla.2020.73.4
Kaliisa, R., Kluge, A., & Mørch, A. I. (2021a). Overcoming challenges to the adoption of learning analytics at the practitioner Level: A Critical Analysis of 18 Learning Analytics Frameworks. *Scandinavian Journal of Educational Research*, 1–15. https://doi.org/10.1080/00313831.2020.1869082
Kaliisa, R., Mørch, A. I., & Kluge, A. (2021b). 'My point of departure for analytics is extreme skepticism': Implications derived from an investigation of university teachers' learning analytics perspectives and design practices. *Technology, Knowledge and Learning*, 1–22. https://doi.org/10.1007/s10758-020-09488-w
Kaliisa, R., Mørch, A. I., & Kluge, A. (2019, September). Exploring social learning analytics to support teaching and learning decisions in online learning environments. In the European *conference on technology enhanced learning* (pp. 187–198). Springer, Cham.
Kaliisa, R., Rienties, B., Mørch, A. I., & Kluge, A. (2022a). Social learning analytics in computer-supported collaborative learning environments: A systematic review of empirical studies. *Computers and Education Open*, (3) 100073. https://doi.org/10.1016/j.caeo.2022.100073
Kaliisa, R., & Dolonen, J. A. (2022b). CADA: a teacher-facing learning analytics dashboard to foster teachers' awareness of students' participation and discourse patterns in online discussions. *Technology, Knowledge and Learning*, 1-22. https://doi.org/10.1007/s10758-022-09598-7
Kaliisa, R., Scianna, J., Mørch, A. I., & Kluge, A. (2022c). Using Learning Analytics to assess the intended and enacted learning design: An Epistemic Network Analysis Approach. ISLS 2022 Annual Meeting.

https://www.dropbox.com/s/9mwx6t8mi75op15/CSCL2022%20Proceedings.pdf?dl=0
Kearsley, G., & Shneiderman, B. (1998). Engagement theory: A framework for technology-based teaching and learning. *Educational technology*, *38*(5), 20–23.
Kennedy, B. L., & Thornberg, R. (2018). Deduction, induction, and abduction. In Schreier, M., & Flick, U (Eds.), *The SAGE handbook of qualitative data collection*, (pp. 49–64). SAGE.
Kirkpatrick, D. L. (2009). *Implementing the four levels: A practical guide for effective evaluation of training programs: Easyread super large 24pt edition*. Read How You Want. readhowyouwant.com
Kitchin, R. (2014). Big data, new epistemologies and paradigm shifts. *Big Data & Society*, *1*(1), 2053951714528481.
Knight, S., & Littleton, K. (2015). Discourse-centric learning analytics: Mapping the terrain. *Journal of Learning Analytics*, *2*(1), 185–209.
Kollar, I., Wecker, C., & Fischer, F. (2018). Scaffolding and scripting (computer-supported) collaborative learning. In Fischer, F., Hmelo-Silver, C. E., Goldman, S. R., & Reimann, P. (Eds.), *International handbook of the learning sciences* (pp. 340–350). Routledge.
Koper, R. (2005). An introduction to learning design. In *Learning design* (pp. 3–20). Springer, Berlin, Heidelberg.
Kvernbekk, T. (2019). Practitioner tales: Possible roles for research evidence in practice. *Educational Research and Evaluation*, *25*(1–2), 25–42.
Ladyman, J. (2012). *Understanding philosophy of science*. Routledge.
Lancaster, A., Moses, S., Clark, M., & Masters, M. C. (2020). The positive impact of deliberate writing course design on student learning experience and performance. *Journal of Learning Analytics*, *7*(3), 48–63.
Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge University Press.
Leonelli, S. (2020). *Scientific research and big data*. Standford Encyclopedia of Philosophy. https://plato.stanford.edu/entries/science-big-data/?ref=hackernoon.com
Lewis, S. C., Zamith, R., & Hermida, A. (2013). Content analysis in an era of big data: A hybrid approach to computational and manual methods. *Journal of Broadcasting & Electronic Media*, *57*(1), 34–52.
Lillejord, S., Børte, K., Nesje, K., & Ruud, E. (2018). *Learning and teaching with technology in higher education–a systematic review*. Oslo: Knowledge Centre for Education. http://www.kunnskapssenter.no
Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Sage.
Linn, M. C., & Eylon, B. S. (2011). *Science learning and instruction: Taking advantage of technology to promote knowledge integration*. Routledge.
Linneberg, M. S., & Korsgaard, S. (2019). Coding qualitative data: A synthesis guiding the novice. *Qualitative Research Journal, 19 (3),* 259–270.
Lockyer, L., Heathcote, E., & Dawson, S. (2013). Informing pedagogical action: Aligning learning analytics with learning design. *American Behavioral Scientist*, *57*(10), 1439–1459.
Ludvigsen, S., Lund, K., & Oshima, J. (2021). A conceptual stance on CSCL history. In U. Cress, C. Rosé, A. F. Wise, & J. Oshima, (Eds.), *International handbook of computer-supported collaborative learning* (Vol. 19). Springer, Cham. https://doi.org/10.1007/978-3-030-65291-3_3
Ludvigsen, S., & Mørch, A. (2010). Computer-supported collaborative learning: Basic concepts, multiple perspectives, and emerging trends. *The International Encyclopedia of Education*, *5*, 290–296.
Lund, A., & Hauge, T. E. (2011). Designs for teaching and learning in technology-rich learning environments. *Nordic Journal of Digital Literacy*, *6*(4), 258–272.
Maassen, P., & Stensaker, B. (2011). The knowledge triangle, European higher education policy logics and policy implications. *Higher Education*, *61*(6), 757–769.
Macfadyen, L. P., Lockyer, L., & Rienties, B. (2020). Learning design and learning analytics: Snapshot 2020. *Journal of Learning Analytics*, *7*(3), 6–12.
Mangaroska, K., & Giannakos, M. (2018). Learning analytics for learning design: A systematic literature review of analytics-driven design to enhance learning. *IEEE Transactions on Learning Technologies*, *12*(4), 516–534.
Mangaroska, K., Sharma, K., Gaševic, D., & Giannakos, M. (2020). Multimodal learning analytics to inform learning design: Lessons learned from computing education. *Journal of Learning Analytics*, *7*(3), 79–97.
Martinez-Maldonado, R. (2019, March). "I spent more time with that team": Making spatial pedagogy visible using positioning sensors. In *Proceedings of the 9th international conference on learning analytics & knowledge* (pp. 21–25).
Martinez-Maldonado, R., Echeverria, V., Mangaroska, K., Shibani, A., Fernandez-Nieto, G., Schulte, J., & Buckingham Shum, S. (2021). Moodoo the tracker: Spatial classroom analytics for characterising teachers' pedagogical approaches. *International Journal of Artificial Intelligence in Education*, 1–27.
Martinez-Maldonado, R., Elliott, D., Axisa, C., Power, T., Echeverria, V., & Buckingham Shum, S. (2020). Designing translucent learning analytics with teachers: An elicitation process. *Interactive Learning Environments*, 1–15.
Matuk, C., DesPortes, K., & Hoadley, C. (2021). Conceptualizing context in CSCL: Cognitive and sociocultural perspectives. In Cress, U., Rosé, C., Wise, A. F., & Oshima, J. (Eds.), *International handbook of computer-supported*

collaborative learning (pp. 85–101). Springer, Cham.
Maxwell, J. A. (2004). Using qualitative methods for causal explanation. *Field Methods*, *16*(3), 243–264.
McKenney, S., Nieveen, N., & van den Akker, J. (2006). Design research from a curriculum perspective. In J. Van den Akker, K. Gravemeijer, & S. McKenney (Eds.), *Educational Design Research*, 67–90. Routledge.
Mercer, N. (2007). Sociocultural discourse analysis: Analyzing classroom talk as a social mode of thinking. *Journal of Applied Linguistics and Professional Practice*, *1*(2), 137–168.
Mercer, N., & Littleton, K. (2007). Dialogue and the development of children's thinking: A sociocultural approach. Routledge.
Mercer, N., Hennessy, S., & Warwick, P. (2019). Dialogue, thinking together and digital technology in the classroom: Some educational implications of a continuing line of inquiry. International Journal of Educational Research, 97, 187-199.
Meyer, S. B., & Lunnay, B. (2013). The application of abductive and retroductive inference for the design and analysis of theory-driven sociological research. *Sociological Research Online*, *18*(1), 86–96.
Michos, K., & Hernández-Leo, D. (2018). Supporting awareness in communities of learning design practice. *Computers in Human Behaviour*, *85*, 255–270.
Miller, H. J. (2010). The data avalanche is here. Shouldn't we be digging? *Journal of Regional Science, 50*(1), 181–201.
Misiejuk, K., Scianna, J., Kaliisa, R., Vachuska, K., & Shaffer, D. W. (2021, February). Incorporating sentiment analysis with epistemic network analysis to enhance discourse analysis of Twitter data. In *International conference on quantitative ethnography* (pp. 375–389). Springer, Cham.
Mor, Y., Ferguson, R., & Wasson, B. (2015). Learning design, teacher inquiry into student learning and learning analytics: A call for action. *British Journal of Educational Technology*, *46*(2), 221–229.
Mørch, A. I., Andersen, R., Kaliisa, R., & Litherland, K. (2020). Mixed methods with social network analysis for networked learning: Lessons learned from three case studies. In *Proceedings of the 2020 12th international conference on networked learning*, 1-10.
Major, L., & Warwick, P. (2019). Affordances for dialogue: The role of digital technology in supporting productive classroom talk. In The Routledge international handbook of research on dialogic education (pp. 394-410). Routledge.
Nguyen, Q., Rienties, B., & Whitelock, D. (2020). A mixed-method study of how instructors design for learning in online and distance education. *Journal of Learning Analytics*, *7*(3), 64–78.
Ochoa, X., Lang, A. C., & Siemens, G. (2017). Multimodal learning analytics. In Lang, C., Siemens, G., Wise, A., & Gasevic, D. (Eds.), *The Handbook of Learning Analytics*, *1*, 129–141.
Oswald, E. (2020). Remembering in public: A case study of museum-user communication on Facebook. In Hetland, P., Pierroux, P., & Esborg, L. (Eds.), *A History of Participation in Museums and Archives* (pp. 147–167). Routledge.
Oshima, J., Oshima, R., & Matsuzawa, Y. (2012). Knowledge Building Discourse Explorer: a social network analysis application for knowledge building discourse. *Educational technology research and development*, *60*(5), 903-921.
Öztok, M. (2016). Cultural ways of constructing knowledge: The role of identities in online group discussions. International Journal of Computer-Supported Collaborative Learning, 11(2), 157-186.
Paranyushkin, D. (2019). InfraNodus: Generating insight using text network analysis. In *Proceedings of the 28th international conference on the world wide web (WWW '19)* (pp. 3584–3589). ACM. https://dx.doi.org/10.1145/3308558.3314123
Pardo, A., Bartimote, K., Shum, S. B., Dawson, S., Gao, J., Gašević, D., & Vigentini, L. (2018). OnTask: Delivering data-informed, personalized learning support actions. *Journal of Learning Analytics*, *5*(3), 235–249.
Pardo, A., Poquet, O., Martínez-Maldonado, R., & Dawson, S. (2017). Provision of data-driven student feedback in LA & EDM. In Lang, C., Siemens, G., Wise, A., & Gasevic, D. (Eds.), *Handbook of Learning Analytics*, 163–174.
Patton, M. Q. (2014). *Qualitative research & evaluation methods: Integrating theory and practice*. Sage Publications.
Persico, D., & Pozzi, F. (2015). Informing learning design with learning analytics to improve teacher inquiry. *British Journal of Educational Technology*, *46*(2), 230–248.
Pierroux, P., Hetland, P., & Esborg, L. (2020). Traversing citizen science and citizen humanities: Tacking stitches. In Hetland, P., Pierroux, P., & Esborg, L. (Eds.), *A History of Participation in Museums and Archives* (pp. 3–24). Routledge.
Piety, P. J., & Pea, R. D. (2018). Understanding learning analytics across practices. *Learning Analytics in Education*, *215*, 232.
Prensky, M. (2009). H. sapiens digital: From digital immigrants and digital natives to digital wisdom. *Innovate: Journal of Online Education*, *5*(3), 1–9.
Prinsloo, P., & Slade, S. (2017). Big data, higher education and learning analytics: Beyond justice, towards an ethics of care. In Daniel, B. K. (Ed.), *Big data and learning analytics in higher education* (pp. 109–124). Springer, Cham.
Prieto, L. P., Rodríguez-Triana, M. J., Martínez-Maldonado, R., Dimitriadis, Y., & Gašević, D. (2019). Orchestrating learning analytics (OrLA): Supporting inter-stakeholder communication about adoption of learning analytics at

the classroom level. Australasian Journal of Educational Technology, 35(4).
Palincsar, A. S. (2005). 12 Social constructivist perspectives on teaching and learning. An introduction to Vygotsky, 285.
Rasmussen, I., & Ludvigsen, S. (2010). Learning with computer tools and environments: A sociocultural perspective. In Littleton, K., Wood, C., & Staarman, J. K. (Eds.), *International Handbook of Psychology in Education,* (pp. 399–433). Emerald Group Publishing.
Reeves, T. (2006). Design research from a technology perspective. In J. Van den Akker, K. Gravemeijer, & S. McKenney (Eds.), *Educational design research* (pp. 64–78). Routledge.
Rehrey, G., Shepard, L., Hostetter, C., Reynolds, A., & Groth, D. (2019). Engaging faculty in learning analytics: Agents of institutional culture change. *Journal of Learning Analytics*, *6*(2), 86–94.
Reimann, P. (2016). Connecting learning analytics with learning research: The role of design-based research. *Learning: Research and Practice*, *2*(2), 130–142.
Rienties, B., Giesbers, B., Lygo-Baker, S., Ma, H. W. S., & Rees, R. (2016). Why some teachers easily learn to use a new virtual learning environment: A technology acceptance perspective. *Interactive Learning Environments*, *24*(3), 539–552.
Rienties, B., Herodotou, C., Olney, T., Schencks, M., & Boroowa, A. (2018). Making sense of learning analytics dashboards: A technology acceptance perspective of 95 teachers. *International Review of Research in Open and Distributed Learning*, *19*(5). 187–202.
Rienties, B., Nguyen, Q., Holmes, W., & Reedy, K. (2017). A review of ten years of implementation and research in aligning learning design with learning analytics at the Open University UK. *Interaction Design and Architecture (s)*, *33*, 134–154.
Rienties, B., Toetenel, L., & Bryan, A. (2015, March). "Scaling up" learning design: Impact of learning design activities on LMS behavior and performance. In *Proceedings of the fifth international conference on learning analytics and knowledge* (pp. 315–319).
Rips, L. J. (1994). *The psychology of proof: Deductive reasoning in human thinking*. MIT Press.
Robson, S., & Wihlborg, M. (2019). Internationalization of higher education: Impacts, challenges and future possibilities. *European Educational Research Journal*, *18*(2), 127–134.
Rogoff, B. (1991). Social interaction as apprenticeship in thinking: Guided participation in spatial planning. In L. B. Resnick, J. M. Levine, & S. D. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 349–364). Oxford University Press.
Rummel, N. (2018). One framework to rule them all? Carrying forward the conversation started by Wise and Schwarz. *International Journal of Computer-Supported Collaborative Learning*, *13*(1), 123–129.
Ragan, T. J., & Smith, P. L. (1999). Instructional design. *New York: Macmillan Publishing Company*.
Säljö, R. (2002). Learning as the use of tools: A sociocultural perspective on the human–technology link. In Light, P., & Littleton, K. (Eds.), L*earning with computers* (pp. 158–175). Routledge.
Säljö, R. (2009). Learning, theories of learning, and units of analysis in research. *Educational Psychologist*, *44*(3), 202–208. https://doi.org/10.1080/00461520903029030
Säljö, R. (2010). Digital tools and challenges to institutional traditions of learning: Technologies, social memory and the performative nature of learning. *Journal of Computer Assisted Learning*, *26*(1), 53–64.
Saqr, M., Fors, U., Tedre, M., & Nouri, J. (2018). How social network analysis can be used to monitor online collaborative learning and guide an informed intervention. *PLoS One*, *13*(3), e0194777.
Saqr, M., Viberg, O., & Vartiainen, H. (2020). Capturing the participation and social dimensions of computer-supported collaborative learning through social network analysis: which method and measures matter?. International Journal of Computer-Supported Collaborative Learning, 15(2), 227-248.
Schunk, D. H. (2014). *Learning theories: An educational perspective*. Harlow.
Schwendimann, B. A., Rodriguez-Triana, M. J., Vozniuk, A., Prieto, L. P., Boroujeni, M. S., Holzer, A., & Dillenbourg, P. (2016). Perceiving learning at a glance: A systematic literature review of learning dashboard research. *IEEE Transactions on Learning Technologies*, *10*(1), 30–41.
Sclater, N., Peasgood, A., & Mullan, J. (2016). *Learning analytics in higher education*. Jisc.
Scrimsher, S., & Tudge, J. (2003). The teaching/learning relationship in the first years of school: Some revolutionary implications of Vygotskya's theory. *Early Education & Development*, *14*(3), 293–312.
Sfard, A. (1998). On two metaphors for learning and the dangers of choosing just one. *Educational Researcher*, *27*(2), 4–13.
Shaffer, D. W. (2017). *Quantitative ethnography*. Lulu. lulu.com.
Shook, J. R., & Paavola, S. (Eds.). (2021). *Abduction in cognition and action: Logical reasoning, scientific inquiry, and social practice* (Vol. 59). Springer Nature.
Siegel, E. (2013). *Predictive analytics: The power to predict who will click, buy, lie, or die*. John Wiley & Sons.
Siemens, G. (2013). "Learning analytics: The emergence of a discipline." *The American Behavioral Scientist*, *57*(10), 1380–1400.

Siemens, G., & Long, P. (2011). Penetrating the fog: Analytics in learning and education. *EDUCAUSE Review*, *46*(5), 30.
Sinclair, J., & Aho, A. M. (2018). Experts on super innovators: Understanding staff adoption of learning management systems. *Higher Education Research & Development*, *37*(1), 158–172.
Singh, S., Meyer, B., & Wybrow, M. (2020, June). UserFlow: A tool for visualizing fine-grained contextual analytics in teaching documents. In *Proceedings of the 2020 ACM conference on innovation and technology in computer science education* (pp. 384–390).
Smith, M. A., Shneiderman, B., Milic-Frayling, N., Mendes Rodrigues, E., Barash, V., Dunne, C., Gleave, E. (2009, June). Analyzing (social media) networks with NodeXL. In *Proceedings of the fourth international conference on communities and technologies* (pp. 255–264).
Scott, J. (2011). Social network analysis: developments, advances, and prospects. *Social network analysis and mining*, *1*(1), 21-26.
Smørdal, O., Rasmussen, I., & Major, L. (2021). Supporting classroom dialogue through developing the Talkwall microblogging tool: Considering emerging concepts that bridge theory, practice, and design. *Nordic Journal of Digital Literacy*, *16*(2), 50–64.
Spikol, D., Ruffaldi, E., Dabisias, G., & Cukurova, M. (2018). Supervised machine learning in multimodal learning analytics for estimating success in project-based learning. *Journal of Computer Assisted Learning*, *34*(4), 366–377.
Stake, R. E., & Trumbull, D. J. (1982). Naturalistic generalizations. *Review Journal of Philosophy and Social Science*, *7*(1), 1–12.
Stahl, G. (2006). *Group cognition: Computer support for building collaborative knowledge (acting with technology)*. The MIT Press.
Tansley, S., & Tolle, K. M. (2009). *The fourth paradigm: Data-intensive scientific discovery* (Vol. 1). In A. J. Hey (Ed.), *Microsoft research*.
Tracy, S. J. (2010). Qualitative quality: Eight "big-tent" criteria for excellent qualitative research. *Qualitative Inquiry*, *16*(10), 837–851.
The Norwegian Government (2022, June 10). *Learning Analytics-some key dilemmas. Sub-report from the expert group for digital learning analysis*. https://www.regjeringen.no/no/dokumenter/laringsanalyse-noen-sentrale-dilemmaer/id2916747/
University of Bergen. (n.d.).*SLATE*. https://www.uib.no/slate
Valle, N., Antonenko, P., Valle, D., Dawson, K., Huggins-Manley, A. C., & Baiser, B. (2021). The influence of task-valuescaffolding in a predictive learning analytics dashboard on learners' statistics anxiety, motivation, and performance. *Computers & Education*, *173*, 104288.
Van den Akker, J., Gravemeijer, K., & McKenney, S. (2006). Introducing educational design research. In J. Van den Akker, K. Gravemeijer, & S. McKenney (Eds.), *Educational design research* (pp. 15–19). Routledge.
Van Harmelen, M., & Workman, D. (2012). Analytics for learning and teaching. *CETIS Analytics Series*, *1*(3), 1–40.
Van Leeuwen, A., Janssen, J., Erkens, G., & Brekelmans, M. (2015). Teacher regulation of cognitive activities during student collaboration: Effects of learning analytics. *Computers & Education, 90*, 80–94.
Van Leeuwen, A., Rummel, N., & Van Gog, T. (2019). What information should CSCL teacher dashboards provide to help teachers interpret CSCL situations? *International Journal of Computer-Supported Collaborative Learning, 14*(3), 261–289.
Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science*, *46*(2), 186–204.
Verbert, K., Duval, E., Klerkx, J., Govaerts, S., & Santos, J. L. (2013). Learning analytics dashboard applications. *American Behavioral Scientist*, *57*(10), 1500–1509.
Viberg, O., Hatakka, M., Bälter, O., & Mavroudi, A. (2018). The current landscape of learning analytics in higher education. *Computers in Human Behavior*, *89*, 98–110.
Vigentini, L., Liu, D. Y., Arthars, N., & Dollinger, M. (2020). Evaluating the scaling of a LA tool through the lens of the SHEILA framework: A comparison of two cases from tinkerers to institutional adoption. *The Internet and Higher Education*, *45*, 100728.
Voigt, P., & Von dem Bussche, A. (2017). The EU general data protection regulation (GDPR). A practical guide (1st ed.). Cham: Springer International Publishing.
Vygotsky, L. S. (1978). Socio-cultural theory. *Mind in Society*, *6*, 52–58.
Walker, D. (2006). Toward productive design studies. In J. Van den Akker, K. Gravemeijer, & S. McKenney (Eds.), *Educational Design Research*, 8–13. London: Routledge.
Wang, F., & Hannafin, M. J. (2005). Design-based research and technology-enhanced learning environments. *Educational Technology Research and Development*, *53*(4), 5–23.
Wasson, B., & Kirschner, P. A. (2020). Learning design: European approaches. *TechTrends*, *64*(6), 815–827.
Watson, W. R., & Watson, S. L. (2007). What are learning management systems, what are they not, and what should they become? *TechTrends*, *51*(2), 29.
Wertsch, J. V. (1991). *Voices of the mind. A sociocultural approach to mediated action*. Harvard University Press.

Williamson, B. (2017). *Big data in education: The digital future of learning, policy and practice*. Sage.
Wise, A. F., Knight, S., & Shum, S. B. (2021). Collaborative learning analytics. In Cress, U., Rosé, C., Wise, A. F., & Oshima, J. (Eds.), the *International handbook of computer-supported collaborative learning* (pp. 425–443). Springer, Cham.
Wise, A. F., & Jung, Y. (2019). Teaching with analytics: Towards a situated model of instructional decision-making. *Journal of Learning Analytics*, *6*(2), 53–69.
Wise, A. F., & Shaffer, D. W. (2015). Why theory matters more than ever in the age of big data. *Journal of Learning Analytics*, *2*(2), 5–13.
Wise, A., Zhao, Y., & Hausknecht, S. (2014). Learning analytics for online discussions: Embedded and extracted approaches. *Journal of Learning Analytics*, *1*(2), 48–71.
Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. *Child Psychology & Psychiatry & Allied Disciplines, 17*(2), 89–100. https://doi.org/10.1111/j.1469-7610.1976.tb00381.x
Xu, L., Ferguson, J., Widjaja, W., Luo, W., Bao, L., & Li, J. (2021). A sociocultural framing of multimodal learning analytics: Potential for formative assessment in primary mathematics. In White, P. J., Tytler, R., Ferguson, J. P., & Clark, J. C. (Eds.). Methodological approaches to STEM education research, 220-242.
Yoo, M., & Jin, S. H. (2020). Development and evaluation of learning analytics dashboards to support online discussion activities. *Educational Technology & Society*, *23*(2), 1–18.

Appendix 1: Coding schemes for articles 1-4

Table A1. Coding schema for article 1.

Categories	Description/Explanation	Examples
LA frameworks (deductively developed based on OrLA framework)		
Design and Planning	The framework provides guidance for teachers (e.g. representations of data to teachers) in choosing and using data to inform learning design decisions.	Learning Analytics-Learning Design Framework (Gunn et al., 2017).
Awareness and assessment	The framework provides teachers with awareness of what is happening in the classroom or learners' mind through tools such as dashboards.	Checkpoint and Process Analytics Framework (Lockyer et al., 2013).
Adaptation, flexibility and intervention	The framework provides insight into students' progress towards the intended learning outcomes being gradually achieved by the learners, thus allowing for adequate adaptations of the learning design and other forms of intervention	The Analytics4Action Evaluation Framework (Rienties et al., 2016).
LA challenges (inductively developed)		
Technical	An article makes reference to LA adoption challenges related to the technical aspects of LA such as interpretation of algorithms, design of LA tools, infrastructure etc.	Shortage of guidance for developing tools, limited LA expertise (Tsai et al., 2017)
Pedagogical	An article makes reference to LA adoption challenges related to pedagogically related issues such as teachers' lack of data literacy, lack of connection between LA and theory etc.	Limited connection between LA and theory, visual literacy, (Wasson et al., 2016; Rogers et al., 2016; Shibani et al., 2020).
Institutional	An article making reference to LA adoption challenges related to institutional challenges e.g. lack of a LA policy, inadequate support to teachers etc.	Insufficient training opportunities, limited financial capacity to facilitate LA, (Macfadyen et al., 2014).
Ethics	An article making reference to ethics related challenges that affect teachers' adoption of LA	Lack of ethical guidelines for LA affect teachers from using LA in their practice (Slade & Prinsloo, 2013; Tsai et al., 2017)
Workload	An article making reference to workload related challenges that affect teachers' adoption of LA	Teachers are concerned about additional workload LA might impose (Howell et al., 2018).

Table A2. Coding schema for article 2

Categories	Description/Explanation	Examples
Deductive codes based on TAM		
LA perception-based referencing	Teachers highlight the perceived benefits of LA but not based on their own experience of using LA	'If you ask students, they may not give you right [adequate] responses, but LA can be helpful regarding knowing what exactly happens' (R9)
LA concerns referencing	Teachers make reference to the possible challenges of using LA (e.g. emotional and cognitive attitudes)	'I need a way of ensuring that the analytics in question are suitable for qualitative teaching because the kind of materials LA uses are poorly suited to my teaching' (R10).
Inductively developed codes		
LA understanding	Teachers describe or give examples of what they think LA is about	'I have a very poor idea of LA. I probably should know more, but it is not something I have encountered very much, I have to say' (R10).
LA needs	Teachers highlighting what needs to be done, and the nature of LA they need to support their practice	I need a metric on the quality of the language used by the students and some sophistication of their ideas; I think that could be huge regarding being able to tailor the course (R1).
Learning design practices/strategies	Teacher describes how they are currently designing courses and factors behind their decisions	'When interacting with the students, you get a feeling if they are interested or bored and use it to improve on the courses' (R2)
Learning design challenges	Teachers describe the challenges associated with learning design	'We are busy people, writing articles, etc. … so I don't have time to keep changing things. No one pays for this' (R4)
LA for learning design referencing	Teachers describe their expectations of how LA can support learning design	It would be an interesting proxy for how your learning material is perceived' (R14)

Table A3. Coding schema for article 3

Categories	Explanation	Examples
Value of LA visualizations	References related to the value of LA visualizations for teachers' learning design practices	"The visualizations highlight very high presentation, of course, content knowledge and provide a benchmark for gaining a comprehensive picture of students' online learning processes" (T1)
Challenges of LA visualizations	References related to the challenges of using LA visualizations	"The text networks are so dense and contain so many links so I cannot interpret them well" (T2)

Table A4. Coding schema for Article 4

Category	Explanation	Examples
Deductively developed based on Kirkpatrick and Few's design principles		
Reaction	Statements referring to teachers' reaction to the dashboard features	'Honestly, the tool is very simple to use in terms of its user interface because it is just pressing a couple of buttons' (T2IT1)
Usability	Statements referring to the usability of the CADA dashboard	'I sometimes looked at the tool before the lecture and skimmed through all the students' submissions on the forum. This was quite demanding, but it was easier with the tool because I could see everything at a glance' (T5IT2)
Understanding	Statements referring to CADA's ability in improving teachers' understanding of students' online learning behaviors	I have used this tool for two terms now, and I can say it has been very helpful in preparing me for seminars. I will continue using it in the future.' (T4IT2).
Usefulness	Statements referring to the usefulness of CADA to teachers 'practice	'When I saw Dysthe, which was one of the articles I had assigned for the readings, that proved to me that they had read the assigned readings and tried to integrate them into the discussion' (T3IT2).
Behavior	Statements referring to teachers' change of teaching practices (e.g. lesson plan, assessments, feedback to teachers) based on the feedback from CADA.	'When I looked at the discourse analytics, I realized that the students had not gone much into the key concepts. For example, they were talking a lot about "Zoom" instead of collaborating, as I expected, and later, I said, "These are things we will examine deeper later in the class" (T1IT1).
Inductively developed codes		
Improvement	Statements referring to how the dashboard can be improved	The dashboard should go beyond beyond generating key concepts used in discussions to provide semantic interpretations showing the relationship between concepts
Design lessons	Statements referring to ways to improve the design of LA tools	'I think having video tutorials and screenshots to guide teachers could be helpful' (T5IT2).
Implementation lessons	Statements referring to lessons or suggestions for successful implementation of LA tools	'I understand getting the teachers to commit is an issue, but once you find the teachers who are envisioning a new thing and they understand the value of the analytics tool, then it is easy' (T3IT2).

Appendix 2: Interview guide for teacher interviews

The purpose of this interview is to understand the views of the teachers who have used CADA to help get an overview of what is happening in the online discussion forums. The experiences from teachers will help researchers to improve CADA and to better support teachers in using it in their practice. The interview will be fairly unstructured but guided by some sample questions given below. The interview will be recorded and transcribed for research purposes.

1. Motivation, experience, and expectations

We want to understand a little about the learning context, and your involvement in the project, so we have a few questions about that

- Can you tell me briefly about your course design practices?
- How do you normally go about designing your courses and course activities?
- How and when do you normally make changes to your course designs?
- What is your prior experience in the use of technological innovations in your classroom?
- How do you normally use them?
- Have you used online discussions before as part of your teaching? If yes, how? Any challenges associated with online discussions?

2. Implementation and usage

To introduce CADA in your course, you worked with researchers to implement a learning design, so we have a few questions about the design and implementation.

- Can you tell me a bit about how you designed and implemented the use of CADA? Can you tell me a bit, about how you designed the tasks to fit the intervention context? How did they evolve in the many iterations overtime (if any)?
- Can you tell us abit about how you adopted and adapted the learning design based on the feedback from CADA?
- What limitations are associated with the use of feedback from LA tools such as CADA to make changes in courses?
- Is there any other information you think such a tool could provide?
- How did you find the process of working with researchers?
- Did you face any problems or constraints during the implementation?
- How easy was this process of working with researchers and implementing a technological tool in your class?
- How much time did you spend preparing for it?
- How much effort did it require to implement the intervention?
- Did you feel like you had enough agency/power in how the intervention was designed for your class?

3. Findings, value added and future usage.

The next few questions are focused on the impact of the intervention, and how effective the CADA tool is

- What impact do you think the intervention has had on your teaching practice?
- Did CADA help you to become more aware of and reflect on your own teaching?
- What value did you think it added to your teaching?
- Did the tool and/or intervention encourage you to reflect on your previous and subsequent course designs?
- Do you think CADA improved the efficiency of your teaching?

- Did you learn anything new from this intervention?
- How do you see the role of student data and analysis in supporting course designs?
- Do you have any concerns e.g. about how the CADA tool analyses student data?
- Can you see any improvements that could be made to the tool or/and intervention?
- What changes would you make in the future?
- Will you use CADA again in future semesters? (if yes why, and if no why)
- What could we do to support other teachers to adopt the tool?

Appendix (3): LA visualization/vignette used for interviews (Article 2)

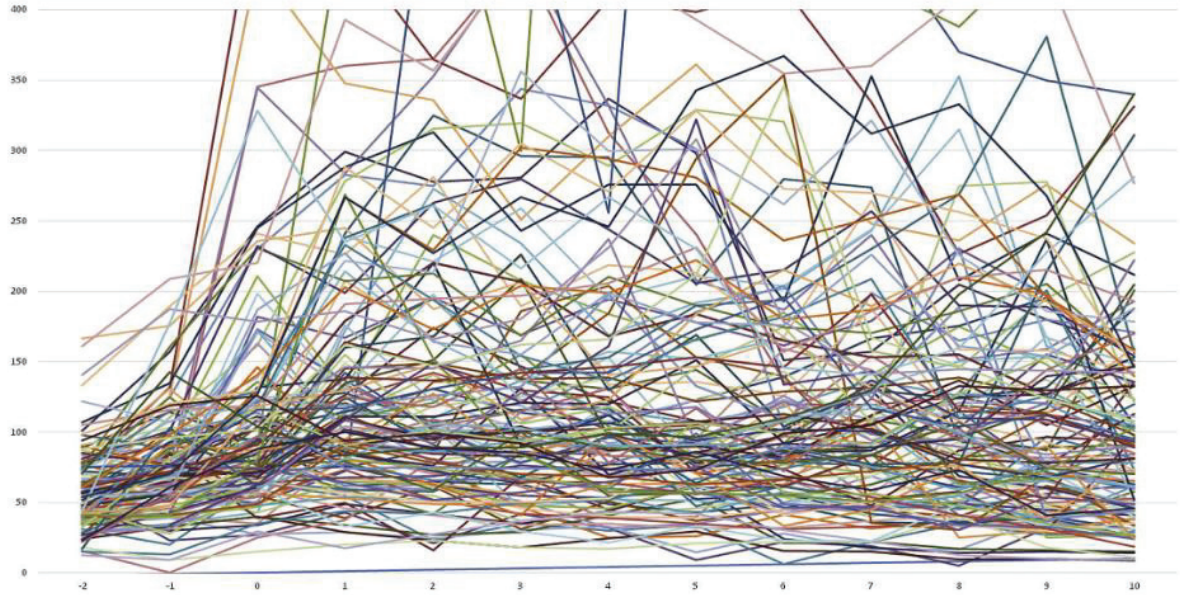


Fig. 1. VLE average time spent per week in minutes per module (n = 140).

Appendix 4: Informed consent information letter (Teachers)

Request for participation in research project

Using Learning Analytics to Support Learning Design

My name is Rogers Kaliisa; I am a Doctoral research student under the Department of Education, University of Oslo. I would like to invite you to take part in a research study as part of my doctoral studies. Before you decide you need to understand why the research is being done and what it would involve for you. Please take time to read the following information carefully. Ask questions if anything you read is not clear or would like more information. Take time to decide whether or not to take part.

Background and Purpose

Despite the early results showing areas where there is a positive relationship between learning analytics and learning design, its implementation in practice is still limited. Questions of how learning analytics are best deployed by instructors in their teaching practice to improve learning processes such as learning design and personalized student support continue to be under-represented in the literature. With this in mind, this doctoral study seeks to bridge the current disconnect between research and practice by conducting a thorough evaluation to explore how learning analytics support teachers to make good design decisions and personalized student support. This study will involve an intervention with selected course and instructors at the University of Oslo; using data extracted from Canvas and a third-party analytics tools called Canvas social analytics, which extracts and turns Canvas discussions into socio-grams and word clouds for teachers. It is from this background that your participation is sought.

What is learning analytics?

For the purpose of this survey, learning analytics is viewed as the use of any system, application, program etc. to assist with understanding, integrating or analyzing data related to **learning and teaching** in an **automated** manner. This can include programs or applications within a learning management system (e.g. Canvas; a data warehouse; or, a stand-alone learning analytics program but is not limited to these examples.

What does participation in the project imply?

Should you choose to participate in the project, your participation in this study would involve two steps. First, allowing to use your course as part of an intervention to trial a Canvas social analytics tool. Second, accepting to take part in an interview (approx. 30-40 mins) at the end of the intervention (e.g. end of autumn semester) where you will give your experience about the Canvas social analytics tool. There is no direct benefit from your participation but learning analytics and learning design being emerging fields with a mix of technical, administrative and ethical issues, this study offers benefit because it will produce important information for stakeholders at multiple levels particularly at the University of Oslo while planning to implement learning analytics to support learning design and other learning and teaching activities. There are no specific risks associated with your participation in this study.

What will happen to the information about you?

All the data you provide will be collected and reported anonymously and where necessary pseudonyms will be used in publications to protect your identity. The interview will not collect personal information such as names to avoid respondents being associated with the particular set of responses. Only the researcher and supervisors will have access to the interview data. The intervention study is expected to be completed by January 2021. After the project completion, data will be stored in locked file or password protected computers with access only by the immediate research team for at least six years. The study results will be presented at conferences and written up in journals.

Voluntary participation

It is voluntary to participate in the project, and you can at any time choose to withdraw your consent without stating any reason. If you decide to withdraw, all your personal data will be made anonymous

Your rights

- So long as you can be identified in the collected data, you have the right to:
- access the personal data that is being processed about you
- request that your personal data is deleted
- request that incorrect personal data about you is corrected/rectified
- receive a copy of your personal data (data portability), and
- send a complaint to the Data Protection Officer or The Norwegian Data Protection Authority regarding the processing of your personal data

What gives us the right to process your personal data?

We will process your personal data based on your consent. Based on an agreement with the University of Oslo, NSD – The Norwegian Centre for Research Data has assessed that the processing of personal data in this project is in accordance with data protection legislation

If you would like to participate or if you have any questions concerning the project, please contact

- Rogers Kaliisa (Doctoral student) Email: rogers.kaliisa@iped.uio.no Telephone (22845318)
- Anders Kluge (Supervisor) Email: anders.kluge@iped.uio.no Telephone (22840710)
- Anders Mørch (Co-supervisor) Email: anders.mørch@iped.uio.no Telephone (22840713)
- NSD – The Norwegian Centre for Research Data AS, by email: (personverntjenester@nsd.no) or by telephone: +47 55 58 21 17.
- Roger Markgraf-Bye: Data protection officer at UiO (personvernombud@uio.no)

The study has been notified to the Data Protection Official for Research, NSD - Norwegian Centre for Research Data.

Consent for participation in the study

I have received and understood information about the project */***LEVERAGING LEARNING ANALYTICS TO SUPPORT LEARNING DESIGNS***/* and have been given the opportunity to ask questions. I give consent:

☐ To participate (i.e., for my interview responses to be processed for research purposes)

☐ For the anonymised data to be processed until the end date of the project, approx. *[Approx. March 2022]*

(Signed by participant, date)

Appendix 5: Informed consent information letter (Students)

Are you interested in taking part in the research project

LEVERAGING LEARNING ANALYTICS TO SUPPORT LEARNING DESIGN

My name is Rogers Kaliisa; I am a Doctoral Research student under the Department of Education, University of Oslo. I would like to invite you to take part in a research study as part of my doctoral studies. Before you decide you need to understand, why the research is being done and what it would involve for you. Please take time to read the following information carefully. Ask questions if anything you read is not clear or would like more information. Take time to decide whether to take part.

Background and purpose of the project

My doctoral study seeks to conduct a thorough evaluation to explore how learning analytics (i.e. data about students' learning) support teachers to make good learning design decisions. This study will involve an intervention with teachers at the University of Oslo; using data extracted from the Canvas learning management system (LMS) in selected courses (e.g., discussion forum content).

Who is responsible for the research project?

This is a doctoral research project conducted under the Department of Education, Faculty of Educational Sciences at the University of Oslo, Norway.

Why are you being asked to participate?

The study intends to utilize students' course analytics data from the Canvas LMS, in form of content posted in course discussion forums. Since you are participating in one of the courses with a component of online discussions, this is why you are being requested to take part of the study.

What does participation in the project imply?

Your participation in this study would only involve providing consent to use your discussion forum content for PED2802/PED4505 course during the spring semester 2021. There is no direct benefit from your participation but the study might produce important information for teachers at the University of Oslo to inform their learning designs, thus improving students' learning experience. There are no specific risks associated with your participation in this study.

Participation is voluntary

It is voluntary to participate in the project, and you can at any time choose to withdraw your consent without negative consequences. If you decide to withdraw, all your personal data will be deleted from the collected data.

What will happen to the personal data?

All the data you provide will be collected and reported anonymously and where necessary pseudonyms will be used in publications to protect the identities of the participants. We will process your personal data confidentially and in accordance with the data protection legislation (the General Data Protection Regulation and Personal Data Act). Only the course teachers and the researcher will have access to your data. The data collection and analysis process is expected to be completed by August 2021 but the overall project is expected to end by March 2022. After the data collection and analysis process (August 2021) all the collected data will be made anonymous (i.e. it will not be possible to link the data back to individual students) and will be stored in a locked file or password-protected computers with access only by the immediate research team for at least six years. The study results could be presented at conferences and written up in journals but participants will not be recognizable.

Your rights

- So long as you can be identified in the collected data, you have the right to:
- access the personal data that is being processed about you
- request that your personal data is deleted
- request that incorrect personal data about you is corrected/rectified
- receive a copy of your personal data (data portability), and
- send a complaint to the Data Protection Officer or The Norwegian Data Protection Authority regarding the processing of your personal data

What gives us the right to process your personal data?

We will process your personal data based on your consent. Based on an agreement with the University of Oslo, NSD – The Norwegian Centre for Research Data has assessed that the processing of personal data in this project is in accordance with data protection legislation.

Where can I find out more?

If you have questions about the project, or want to exercise your rights, contact:

- Rogers Kaliisa (Doctoral student) Email: rogers.kaliisa@iped.uio.no Telephone (22845318)
- Anders Kluge (Supervisor) Email: anders.kluge@iped.uio.no Telephone (22840710)
- Anders Mørch (Co-supervisor) Email: anders.mørch@iped.uio.no Telephone (22840713)
- NSD – The Norwegian Centre for Research Data AS, by email: (personverntjenester@nsd.no) or by telephone: +47 55 58 21 17.
- Roger Markgraf-Bye: Data protection officer at UiO (personvernombud@uio.no)

The study has been notified to the Data Protection Official for Research, NSD - Norwegian Centre for Research Data.

Consent form

I have received and understood information about the project **/LEVERAGING LEARNING ANALYTICS TO SUPPORT LEARNING DESIGNS/** and have been given the opportunity to ask questions. I give consent:

- To participate (i.e., for my discussion forum data to be processed for research purposes)
- For the anonymized data to be processed until the end date of the project, approx. *[Approx. March 2022]*

(Signed by participant, date)

PART 2: THE ARTICLES

I

Article 1

Kaliisa, R., Kluge, A., & Mørch, A. I. (2021a). Overcoming challenges to the adoption of learning analytics at the practitioner level: A critical analysis of 18 LA frameworks. *Scandinavian Journal of Educational Research*, 1–15. https://doi.org/10.1080/00313831.2020.1869082

Article 2

II

Kaliisa, R., Mørch, A. I., & Kluge, A. (2021b). 'My point of departure for analytics is extreme skepticism': Implications derived from an investigation of university teachers' learning analytics perspectives and design practices. *Technology, Knowledge and Learning*, 1–22. https://doi.org/10.1007/s10758-020-09488-w

Technology, Knowledge and Learning
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ORIGINAL RESEARCH

'My Point of Departure for Analytics is Extreme Skepticism': Implications Derived from An Investigation of University Teachers' Learning Analytics Perspectives and Design Practices

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Abstract

The literature until 2020 has forecasted a significant uptake of learning analytics (LA) to support learning design in higher education. However, there remain only a few investigations into teachers' course design practices and their perspectives on LA as a tool to support their design practices. This paper presents findings from an examination of 16 university teachers' design practices and perspectives on LA at two Norwegian universities (The University of Oslo and Oslo Metropolitan University). On one hand, findings identified situational factors, feedback sources and teachers' intuition as key influencers of teachers' course design decisions. On the other hand, guided by principles of the technology acceptance model, this study identified mixed reactions amongst teachers regarding the awareness, understanding and potential use of LA to support course design practices. In particular, most teachers appreciated the formative and normative value of LA to provide more objective evidence about students' learning patterns and to shape learning trajectories, but some were skeptical about the evaluative role where LA is used to evaluate teachers' and students' performance based on unnuanced data (e.g. no theory guidance) with limited depth in observation. This article contributes to the understanding of factors fundamental to linking LA to teachers' course design practices by synthesizing findings to propose a 'bi-directional LA-course design' conceptual framework that clarifies key elements that influence teachers' design practices and highlighting their implications for LA integration.

Keywords Learning analytics · Learning design · Higher education · Teachers

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1 Introduction

The need to improve the quality of higher education has fostered an interest in integrating technology tools to support teachers' pedagogical practices (Bennett et al. 2015). Over the past decade, this interest led to the development of tools to help create improved online learning experiences, specifications to underpin designs of educational systems and repositories to share examples (Bennett et al. 2015). A more recent strand of research, learning analytics (LA), is receiving increased attention, partially because of its promising potential to assist educational institutions and teachers to improve their design practices (Rienties and Toetenel 2016). Emerging from educational technology, artificial intelligence, educational data mining and related fields, LA concerns the collection, measurement, analysis and reporting of data about learners and their context to optimize learning and teaching (Siemens 2013). LA systems use and analyze learners' behavioral and interaction data mainly from online learning systems, which enables ecologically more valid research since no interruptions to authentic student learning processes are necessary to collect LA data (Berland et al. 2014). From this perspective, the promises of LA are timely, given the increasing spread and use of online learning environments (e.g. learning management systems) for teaching and learning within higher education institutions for purposes like identifying low performing students (Saa et al. 2019), monitoring students' online social learning behaviors (Kaliisa et al. 2019) and supporting course design practices (e.g. planning, sequencing, feedback, assessment and redesigning of learning activities) (Rienties and Toetenel 2016).

The research reported herein was conducted with 16 teachers at two Norwegian universities (The University of Oslo and Oslo Metropolitan University) by the use of semi-structured interviews. The aim is to advance our understanding of teachers' course design practices and perspectives towards LA as a potential tool to support course design practices. As a constructive contribution, this study proposes a conceptual framework that clarifies key elements for the proper alignment of LA with design practices based on views expressed by teachers. Next, we provide relevant literature on teachers' LA experiences and design practices. We then state the aim and study research questions, followed by a brief description of the study's conceptual framework, including the technology acceptance model (TAM). Subsequently, we present the methodology and findings, before discussing the findings and presentation of the proposed bi-directional LA–LD model and an exemplary case study detailing its application in practice. The paper ends with a conclusion highlighting key implications and suggestions for future research.

2 Background

2.1 Teachers' Learning Analytics Perspectives

Research investigating teachers' experiences with LA has garnered mixed reactions (Howell et al. 2018; Ifenthaler and Yau 2019). In a mixed-methods study conducted among 276 academics in Australia and New Zealand, West et al. (2016) found 37% of participants reported LA as a potential tool to assist teachers' decision-making. Other empirical studies have shown that teachers found LA reports useful for diagnosing and intervening during student activities (van Leeuwen 2019). Research has shown that the deeper analysis of summative reports generated by LA tools helps teachers to understand individual and

collaborative students' learning behaviors and domain-specific effects of courses (Ifenthaler 2017). More recently, Muljana and Luo (2020) explored the perception of instructors regarding the intent and actual practice of LA, and the majority admitted that LA had great potential (e.g. gaining insights into students' learning behaviors), even though adoption was limited.

Nonetheless, other studies have reported negative experiences regarding LA from the teachers' perspective. For instance, Corrin et al. (2013) in studying staff associated with teaching and learning at the University of Melbourne noted teachers found the accurate tracking of students' online engagement (e.g. counting the number of times students visited course pages for learning purposes) was challenging. The same concern was reported in a large-scale longitudinal study of 1159 teachers using LA over four years, wherein most teachers found that, although the LA system was relatively easy to use, the more difficult decision was how to act on the provided analytics to effectively intervene (Herodotou et al. 2019).

Teachers have also noted insufficient support (e.g. training) and communication as a challenge to implementing LA (Tsai and Gasevic 2017). For example, Rienties et al. (2018) in an embedded case study amongst 95 teachers at a large distance-learning university found teachers indicated a need for training and follow-up support to use LA tools. In the same vein, adequate time to learn and implement LA has been reported as another challenge with teachers having insufficient time to review LA visualizations (Herodotou et al. 2019). This implies teachers may demand extra resources and peer support to adopt LA, as noted by Ifenthaler and Yau (2019) in their study that involved 37 German higher education teachers. Similarly, Muljana and Luo (2020) concluded that teachers' adoption and perception of LA is largely affected by social influences and facilitating conditions.

2.2 Teachers' Design Practices

Early studies identified several factors influencing teachers' course design practices. For instance, researching the design context of 30 Australian university teachers, Bennett et al. (2011) found institutional policies and practices were key factors determining the way teachers plan, assess and revise courses. Similarly, Nguyen et al. (in press) conducted a mixed-method study into how teachers design for learning in online and distance education. The findings showed that institutional policies and management are important factors affecting teachers' course design processes. Other research has reported teachers to rely on insights from summative and formative assessments (e.g. mid- and end-of-term assessments) as well as the different assumptions about students, to make necessary design changes (Bakharia et al. 2016; Black and Wiliam 2009; Lockyer et al. 2013). However, as identified in previous studies (Lockyer et al. 2013; Berland et al. 2014), such approaches provide limited support to teachers concerning real-time course adaptation since they are less precise and take much longer to compile. This calls for a rethinking of the design process by use of appropriate mechanisms (e.g. LA) to support teachers in making timely and pedagogically informed course design decisions.

To address concerns in teachers' design practices, recently, researchers have begun to align course design with LA to enable a reciprocal relationship between the two elements (Nguyen et al. 2018). Several authors have argued that, in an effective teaching practice, course design establishes learning objectives and pedagogical plans, which can be evaluated against outcomes captured through LA in contexts where relevant technological tools (e.g. LMS) are used for course design purposes. Simply put, LA can help inform teachers

on the success and outcomes of their course designs by providing real-time evidence of design impact, such as engagement patterns, learning paths and time consumed to complete activities (Mor et al. 2015; Nguyen et al. 2018). If taken advantage of, teachers can act accordingly with adaptive teaching and micro-interventions (Ifenthaler et al. 2018).

2.3 Aims and Research Questions

Although research suggests the potential of combining LA and course design practices, before this integration is fully realized, it is necessary to understand teachers' course design practices, because the failure to understand teachers' practices and constraints is a hallmark of many educational technology innovations' failure to achieve success at the practitioner level (Shibani et al. 2019). More precisely, unanswered questions remain about what shapes university teachers' course design practices, what stage of the design process LA supports would be most helpful, and the factors that should be considered to support this integration. This would support the integration of LA and course design based on empirical evidence, not presumptions about the design process (Bennett et al. 2015). The need for accounts of teachers' course design practices aligns with Bennett et al.'s (2011) argument for understanding teachers' challenges and their scope before suggesting the implementation of new ideas into teaching practices. A recent systematic literature review concerning learning design tools found that, even though teachers are the final users of the proposed methods and tools, out of the 20 reviewed studies, only three (e.g. Bennett et al 2015; Arpetti et al. 2014; Laurillard 2013) explored teachers' actual design practices and needs (Dagnino et al. 2018). At the same time, Sergis and Sampson (2017) concluded that few LA studies have addressed the aspect of supporting teachers' reflections on course design. The lack of studies specifically dedicated to understanding teachers' design practices and needs can be considered a gap in the field. Therefore, the first research question will contribute to this gap, focusing on identifying driving factors that shape university teachers' design decisions.

RQ1: What are the driving factors behind university teachers' course design practices?

Besides, to enable greater opportunities for LA integration into teachers' practice, it is important to unpack teachers' LA perspectives, particularly to support course design practices. It is also important to uncover why some teachers might be more willing and able to adopt LA for course design purposes than others, and the kind of LA they perceive as important to support course design practices. Simultaneously, as noted by Howell et al. (2018) and Ifenthaler (2017), LA's successful implementation and maintenance depends on involving intended end-users (e.g. teachers and students). However, very little attention has been devoted to understanding what teachers think about LA, what their practice is and how LA could address everyday pedagogical challenges (e.g. making informed design decisions, giving timely feedback). More importantly, there is a need to examine teachers' contextual pre-conditions for using LA in everyday practices. It is particularly important to advance research work seeking to align LA to course design and to guide the vast number of institutions exploring whether to start using LA (Ferguson et al. 2016). Consequently, by considering these important but underrepresented views, our second and third research questions explore teachers' LA perspectives and derive their implications for LA to support design practices.

RQ2: What is the current university teachers' state of awareness, acceptance, needs and perspectives about LA?
RQ3: What are teachers' expectations for using LA to support course design?

We employed the technology acceptance model (TAM) (Venkatesh and Davis 2000) as the theoretical lens to interpret teachers' beliefs about LA. TAM distinguishes perceived ease of use (e.g. perceived effort needed to use LA) and perceived usefulness of technology (e.g. extent a teacher believes LA use will, for example, enhance their teaching quality) as key drivers for teachers' adoption. TAM's influence was shown in previous LA-related research (Rienties et al. 2018), hence being a suitable model to use in this study. By using TAM, we expect to gain unique insights into potential reasons for teachers' beliefs and needed implementation requirements to support LA's successful adoption.

3 Methodology

3.1 Research Design, Context, Participants and Demographics

This study used a qualitative approach to elicit context-rich teacher-focused perspectives and practices of LA and course design. The sample consisted of 16 university teachers (male, n = 10, female, n = 6) from different disciplines and academic levels at two campus-based Norwegian universities (one research-The University of Oslo- and one profession oriented-Oslo Metropolitan University). The two institutions are both at the initial stages of exploring possibilities of implementing LA, with small-scale implementation (e.g. piloting scales by individual researchers at a course level) but without institution-wide scale uptake. We assumed teacher norms and practices could vary between educational institutions and disciplines. Thus, participants were selected from different universities and disciplines to enrich our analysis, as previous studies recommended (Howell et al. 2018). Participants were strategically selected (Bryman 2016) through institutional networks based on discipline, affiliation, and teaching experience. Table 1 summarizes teachers' profiles. Potential participants were emailed a letter explaining the study's purpose and seeking their informed written consent. From the 20 teachers invited, 16 accepted and were interviewed. All interviews were face-to-face. Written informed consent approved by the Norwegian National Center for Research Data was gained before interviews started. All personal information was anonymized.

3.2 Methods of Data Collection and Analysis

3.2.1 Interviews

Data were collected using a semi-structured interview protocol structured around four sections (supplementary material Appendix 1). Teachers were initially asked about their role and teaching experience to establish rapport. Later, teachers were asked about their course design practices, followed by questions about teachers' LA perspectives. The fourth section stimulated discussions about the ways teachers perceived LA as a potential tool to support design practices. The interview protocol was devised based on the prior review of research on teachers' design practices (Bennett et al. 2015) and LA (Howell et al. 2018). The protocol was piloted with two teachers based at the authors' department before interviews. The

Table 1 Demographic characteristics of participating teachers

No	Institution	Discipline	Teaching method	Years of teaching experience
R1	Research intensive	Education	Face-to-face	< 5
R2	Research intensive	Education	Both face-to-face and online	> 20
R10	Research intensive	Education	Face-to-face	< 15
R14	Research intensive	Education	Face-to-face	< 8
R15	Research intensive	Education	Face-to-face	< 10
R16	Research intensive	Education	Face-to-face	< 15
R3	Research intensive	Computer science	Both face-to-face and online	> 30
R6	Research intensive	Computer science	Face-to-face	> 20
R7	Research intensive	Computer science	Both face-to-face a online	< 10
R8	Research intensive	Computer science	Face-to-face	> 30
R9	Research intensive	Mathematics	Both face-to-face and online	> 20
R4	Profession-oriented	Education	Both face-to-face and online	> 25
R11	Profession-oriented	Education	Both face-to-face and online	< 15
R12	Profession-oriented	Education	Both face-to-face and online	< 5
R13	Profession-oriented	Technology	Both face-to- face and online	> 28
R5	Profession-oriented	Business	Face-to-face	< 8

interviews were audio-recorded and transcribed verbatim. The first author conducted all interviews, which lasted between 30 and 60 min (median: 35 min). As LA is an emerging area of research and practice, we introduced visual mediating artefacts (e.g. LA visualizations) during interviews to encourage in-depth discussion and reflection about this field. Visualizations shown to participants depicted an example of LA visualizations adapted from empirical studies (Rienties and Toetenel 2016). Vignettes were evaluated by an LA expert who judged their suitability for the study. After transcribing, member validation (Bryman 2016) was conducted by seeking additional input during the processes of analyzing data. In this case, we shared interview transcripts with individual participants to provide opportunities for questions, critique, feedback and affirmation. Through this process, six participants freshly illuminated and provided new data on some questions, which provided an opportunity for reflexive elaboration (Bryman 2016). The remaining 10 participants approved the transcripts as true and accurate with no further additions or subtractions, which ensured the qualitative credibility of findings (Bryman 2016).

3.2.2 Mini-Survey

We administered a mini-survey to explore teachers' beliefs about the ease of use and usefulness of LA tools on five-point Likert scales (Table 2). The survey was administered after each interview, enabling us to capture teachers' LA perceptions using TAM, a well-researched model reported as reliable in predicting technology use (Rienties et al. 2018). As most TAM questionnaires have focused on users and students, not teachers, we adapted the mini-survey in line with Rienties et al. (2018). Consequently, we rephrased items to fit our teacher context. A think-aloud approach was used; participants were asked to explain their thoughts as they reviewed each survey item. This process helped clarify questions

Table 2 LA ease of use and usefulness survey

Item	Statements	Frequencies (n = 16)				
		SD	D	NAD	A	SA
Perceived ease of use of LA/data tools						
a	Learning to operate data tools is easy for me		2	1	9	4
b	I find it easy to get the data tools to do what I want them to do	2	2	5	5	2
c	I find the data tools easy to use		3	3	6	4
d	I expect most staff will need formal training on the data tools			2	3	11
Perceived usefulness of LA						
e	Using the data tools will potentially improve the delivery of the module/course			6	9	1
f	Using the data tools will potentially enhance the effectiveness of the teaching on the course	1	1	4	8	2
g	Using learning analytics will assist in making timely and informed educational decisions			3	9	4

7 statements; 5-point Likert scale with strongly Disagree (SD), Disagree (D), Neither Agree nor Disagree, (NAD) Agree (A) Strongly Agree (SA)

some participants found challenging to interpret, thus ensuring construct validity (Bryman 2016).

3.2.3 Data Analysis

Interviews were transcribed by the first author and coded through a deductive thematic analysis approach (Braun and Clarke 2012). The development of codes was theoretical and structural, meaning they were formulated according to study research questions and TAM. The three researchers familiarized themselves with data and repeatedly examined raw data to determine how to reduce raw information into smaller units, like categories and themes. The initial categorization was performed by the first author using qualitative analysis software (NVivo). Later, all three authors discussed codes and themes with close reference to raw data until a consensus was reached. The unit of analysis in our coding system was one paragraph (i.e. one full response to an interview question). Paragraphs could be given multiple codes if the essence presented differed. Altogether, our thematic analysis identified six themes. The codebook is available as supplemental material. The mini-survey, which sought to capture teachers' beliefs about LA, was analyzed using descriptive statistics (Table 2).

4 Findings

4.1 Teachers' Course Design Practices

The first research question explored teachers' course design practices, which fell into two themes: (1) course design influences and (2) limitations. Tables 3 and 4 summarizes these findings, supported by illustrative quotes that represent common perspectives and alternative views from participants.

4.1.1 Theme 1: Course Design Influences

The theme 'course design influences' includes three sub-themes: situational factors, teachers' beliefs and experience, and feedback and peer influence. Table 3 illustrates sub-themes and sample excerpts of quotes as exemplifications of themes identified.

4.1.2 Theme 2: Course Design Limitations

The theme 'course design limitations' includes two sub-themes: institutional limitations and unreliable feedback mechanisms. Table 4 illustrates sub-themes and sample excerpts of quotes to exemplify themes.

Table 3 Theme 1: course design influences, sub-themes and sample excerpts

Sub-themes	Sample excerpts
Situational factors (e.g. course structure, teaching mode, class size, student characteristics and learning objectives)	'Online courses take a lot of time to design as compared to face-to-face courses' (R4)
	'What I always start with is to consider the target group and what we want to achieve' (R15)
Teachers' beliefs and experience	'When interacting with the students, you get a feeling if they are interested or bored and use it to improve on the courses' (R2)
	'When I teach a course for more than three years, I have a good sense of what works and does not' (R6)
Feedback (e.g. summative assessments, course evaluations) and peer influence	'One part of it is evaluation and feedback from students, and sometimes, that happens in a very formal way but sometimes informally' (R10)
	'The quality of the essay at the end of the course will usually tell me what topics have been processed and understood and which ones have not been, and that helps to see where I need improvement' (R10)
	'I am co-teaching now with a colleague, so when one is teaching, the other one takes notes. Was it problematic? And then we discuss how we can improve it' (R14)

Table 4 Theme 2: course design limitations sub-themes and sample excerpts

Sub-themes	Sample excerpts
Institutional limitations (e.g. assessment and instructional policies, lack of incentives to support innovative teaching, course structures)	'In case we need to make changes, we usually follow the guidelines coming from above' (R6)
	'We are busy people, writing articles, etc. … so I don't have time to keep changing things. No one pays for this' (R4)
	'Considering the nature of the intensive courses with 16 h contact in a week we normally have, there is no flexibility to make adaptive changes' (R1)
Unreliable and untimely feedback mechanisms	'The problem with student evaluations is that you only get the outliers with the most dissatisfied ones not showing up, and the satisfied ones will tell you everything is going on well and others in between will not tell you anything'(R10)
	'If you get the evaluations at the end of the course and [are] thinking about changes for the next semester, it is sometimes forgotten and takes time to refresh and figure out which kind of changes to make' (R15)

4.2 Teachers' LA Perspectives

The second research question focused on teachers' LA perspectives. Three themes emerged from this topic: (1) teachers' awareness of LA; (2) LA challenges and (3) teachers' LA needs.

4.2.1 Teachers' Awareness of LA

Teachers expressed mixed familiarity with LA. Out of 16 teachers, 12 reported some awareness of what LA is about, while a modest number of teachers (four) claimed no idea about what LA is until visual examples were provided. For example, 'I have a very poor idea of LA. I probably should know more, but it is not something I have encountered very much, I have to say' (R10). 'No idea' (R7). Teachers who knew about LA described LA as context-dependent. Teachers highlighted LA can be conceptualized at the macro (institutional), micro (course, teacher, student) and societal levels or from a research and teaching perspective. Hence, its application will depend on the desired level of application. 'If you separate it by micro, macro, societal level and course level, then it is a very different thing' (R3). Another teacher stated, 'I think LA can be as simple as knowing how much time do students use online in one course compared to other courses and up to knowing specific details' (R8).

4.2.2 LA Challenges

Teachers highlighted several challenges to LA's potential use. First, all 16 teachers agreed using LA daily is a time-consuming imposition with the potential of an extra workload. Teachers reported they work under considerable pressure with many demands from their employers, making it hard to implement LA, which requires teacher follow-ups. Teachers claimed they lack the motivation and incentives to implement LA besides the big workload they already have, as illustrated by the following quote: 'What is the motivation for me? There is no incentive from the perspective of, like, doing the analytics' (R1). However, it is unsurprising such comments were especially prominent among teachers from the more research-oriented university, who usually perceived teaching as an extra workload on top of their normal research activities.

Privacy and data ownership concerns were raised as obstacles to LA's application. Teachers mentioned a lack of clarity at many institutions concerning data ownership, how this data can be used and if students' property rights are violated. For example, 'Here at XX, we are not very comfortable with using systems hidden in the cloud—not very clear what happens to the information stored, so control is really an important thing' (R3). To deal with privacy concerns, one teacher stated, 'We have to be able to anonymize students' data so they are not worried' (R2).

Some teachers disagreed with using LA to follow up with students especially in higher education, where students are expected to be self-driven. R10 used the 'big-brother effect' metaphor to illustrate this concern. R3 further echoed this view by stating, 'If you're responding to students based on the analytics, maybe you're cultivating a new culture of running after the students. … I do not want to run after the students, so that is the drawback' (R3) and 'Maybe with primary children, but these adults, I am not their mother, so they do what they want' (R6).

Teachers acknowledged LA's evaluative nature is an additional concern. This is particularly serious when LA is viewed as capable of evaluating teachers/students' performance based on unnuanced data with limited depth in observation. According to R15, this view

of using LA might lead to incorrect educational decisions and be a reason for teachers and students to resist LA.

Last, five of 16 teachers expressed extreme skepticism about LA's potential to provide meaningful interpretations of the learning process. Teachers from the arts and social science disciplines (7), who claimed LA was incongruent with their teaching style, mainly emphasized this claim. According to the teachers, these LA data validity issues could potentially result in inaccurate, incomplete evaluations of students' learning processes. 'I need a way of ensuring that the analytics in question are suitable for qualitative teaching because the kind of materials LA uses are poorly suited to my teaching' (R10). Teachers claimed that, unless different sources of information are utilized, LA alone cannot account for processes behind the numbers. Another teacher attributed the challenge of getting meaning from LA to the lack of theorizing of LA, claiming the field is 'highly data-driven' (R15). Other representative quotes to express these concerns are highlighted below:

> My point of departure for analytics is extreme skepticism. … I am not confident if Canvas analytics and some plugins can provide me with reliable findings about the quality of the text produced by students (R1).
>
> Until we have sensors in the heads to tell us what they are learning, I think LA will always be based on data but not giving the whole picture of what is happening (R13).
>
> No real scope for the automation of assignments, as it will provide dictionary meanings to the text (R10).

This skepticism was corroborated by the mini-survey's results: six out of 16 teachers neither agree nor disagree about LA's potential to enhance their teaching's effectiveness.

4.2.3 LA Needs

Teachers were asked about the kind of data, pre-conditions and environment they would need to facilitate LA's use in their everyday professional practice. This question provoked a range of responses from teachers, with their needs spanning practical and technical considerations.

From the practical perspective, throughout the interviews was the call for incentives regarding increased time allocation to account for the time and extra effort involved in LA's use to improve course designs. Teachers noted that, if they were to take a dynamic approach to embrace LA, they would demand extra teaching resources. For example, 'I think I would make a cynical point, but it is going to be a very important point. What you are talking about here is a massive time investment on the side of the teachers. Are you aware of that?' (R10). R2 added, 'It is important to have a preparation count attached to LA application. For example, at least five hours can be suggested to have a better account for the time teachers use to apply the LA'. In this regard, the institution is making it visible that course design is important, so teachers can put more effort into leveraging LA in everyday practice. Teachers also demanded rewards for quality teaching and the need to improve a teacher's status to make teaching lucrative and enforce the use of innovative approaches like LA. One teacher stated, 'I think that half of the lecturers don't like to lecture, but they have to do it, so they don't really care. … Now, employees are set to teach, instead of them wanting to teach, and that is not good' (R8).

Technically, teachers were interested in different forms of LA outputs to enable them to capture and gain an overview of students' learning processes. The kind of analytics demanded by teachers can be categorized as social analytics (e.g. student participation and interaction patterns), feedback analytics (e.g. automated feedback to students), process

analytics (e.g. time spent on the task, access and submission metrics), discourse analytics (e.g. language used by students), text analytics (e.g. topics discussed), peer analytics (e.g. their comparison with other students in class and previous years) and temporal analytics (e.g. when materials are downloaded). The need for these analytic forms is illustrated in the following statements:

> I need a metric on the quality of the language used by the students and some sophistication of their ideas; I think that could be huge regarding being able to tailor the course (R1).
>
> It is important to know what they talked about, and maybe the machine can tell me what the topics discussed were. Was the discussion heated at some point? (R13).
>
> I would like to know how quickly students download the slides (R5).

Finally, teachers saw the need for data analytics courses for all university teachers to provide them with the right LA competencies to deal with data interoperability issues. 'Not everybody is into statistics; most people cannot relate to a graph and cannot read or understand it because they do not have the mindset' (R8). This argument was supported by survey responses, where 11 teachers, irrespective of LA acceptance level, strongly agreed and three agreed that teachers need the training to use LA in everyday practice.

4.2.4 Teachers' Expectations of LA to Support Course Design Practices

The third research question explored teachers' expectations of using LA as a tool to support course design practices. The benefits highlighted by participants are categorized broadly into two forms: normative and formative perspectives.

From the normative perspective, teachers highlighted LA would signal an opportunity to generate descriptive information about students' learning, which could be used to inform timely course design interventions by recommendations. For example, teachers viewed LA use to identify non-active students, difficult assignments, students' attendance, submissions and page views, among other indicators, providing an opportunity to intervene and make necessary adjustments.

From a formative perspective, teachers viewed LA as a baseline tool to understand and shape learning processes (e.g. to check the quality of learning materials and design and to provide feedback in the form of visualizations). Teachers perceived LA as capable of providing quality checks regarding learning materials, activities and overall design. 'It would be an interesting proxy for how your learning material is perceived' (R14). Another teacher commented: 'I also see the potential of using such inputs as a baseline to understand certain processes, at least in quantitative terms, and perhaps guide some learning and teaching activities based on that input' (R15).

Also welcomed was LA's potential to provide temporal statistics about students' online engagement and how this relates to performance. 'It would be interesting to ask whether there is any relationship between time spent and the quality of the text which would lead to potential interventions like reminding students, for example, the more time you spend on the assignment, the better the quality of your assignment can be' (R1). Another teacher said, 'If I see something like this [pointing to vignettes during the interview] and can see that the student has been online very often, then I start thinking, why hasn't the student handed in, yet always online? And then I can send them an email' (R11).

The teachers also perceived LA as a tool that can identify differences in students' learning processes, which could inform personalized, adaptive teaching. 'You can do more data mining of what they have handed in and try to share them beautifully and help others who have not been able to perform at the same level, so it is a huge benefit for feedback purposes' (R3).

More importantly, LA's ability to provide less biased assessments of students' learning processes were deemed important by teachers. As commented by one teacher: 'If you ask students, they may not give you right [adequate] responses, but LA can be helpful regarding knowing what exactly happens' (R9). These claims are supported by mini-survey findings: Out of 16 teachers, nine agree and four strongly agree that LA can potentially assist with making timely, informed educational decisions. A snapshot of themes and sub-themes from RQ2 and three are illustrated in Fig. 2 (appendix).

5 Discussion and Implications

This work's objective was to explore and better understand current university teachers' course design practices and perspectives of LA as a tool to support course design practices. Within the context of this objective, exploring RQ1 revealed that teachers' course design practices are underpinned by situational factors (e.g. nature of the course, size of the class); feedback sources (e.g. course evaluations, summative assessments, informal reflections and discussions with students and fellow teachers) and teachers' intuition and experience (e.g. based on in-classroom assessments and personal beliefs about the learning process). These findings align with evidence in related work asserting teachers' course design practices closely relate to their experience, expectations and practical issues like student characteristics (Nguyen et al. in press; Bennett et al. 2015; Arpetti et al. 2014), which prompt adjustments in course areas. However, as previous studies noted (Bakharia et al. 2016) and teachers emphasized during interviews, such approaches are prone to personal bias, fail to capture students' learning behavior in online learning environments and cannot provide timely feedback to teachers. Thus, it affects teachers' possibility of real-time design adjustments due to the time lag between receiving feedback and using it to modify a course. This finding suggests a context in which there could be opportunities for further scaffolds (e.g. using LA) to support the way teachers approach their normal practice (Laurillard 2012) and get insights about students' learning outside the classroom, and promptly to support design adaptations on the 'fly'.

RQ2 targeted teachers' awareness, needs and beliefs about LA. Some teachers admitted during interviews that they did not fully know what LA is about until visual examples were introduced. This finding raises complications about the extent LA implementation will soon be a reality in university teachers' course designs. This suggests that efforts to promote LA implementation at scale should involve increasing LA awareness among relevant stakeholders (e.g. teachers, HE administrators, educational policy-makers), since extensive research in the field has shown that LA implementation is a multifaceted process, which involves multiple stakeholders (Ifenthaler 2017). Conversely, some teachers were skeptical about LA's possibilities. For example, even though there is promising research on how LA can provide insights about students' online discourse (Kaliisa et al. 2019), teachers were concerned about the evaluative role of LA, which one teacher called 'unnuanced', and whether it captures the most reliable predictors of student learning and teacher performance. This concern was mostly observed by teachers from the arts and social science

disciplines and those who indicated lower perceived usefulness of LA scores in the survey. These teachers claimed LA was incongruent with their teaching style and could not reliably explain students' learning behaviors. This concern is not just unique to this study, but a common challenge raised across the LA field (Ifenthaler and Yau 2019). Efforts to reduce this concern have included contextualizing LA within learning theory to help teachers interpret LA outputs according to well-grounded learning theories (Shibani et al. 2019).

Besides, building from TAM's perceived ease of use principle, teachers worried about the increased workload, training and time demands LA may impose a concern especially prominent among teachers from the more research-oriented institution. Implied within these findings, and explicit in LA literature is the importance of considering the institutional context, provision of incentives and training of teachers to enable the effective, easy utilization of LA in everyday practice (Rienties et al. 2018). Moreover, building on previous findings (e.g. Corrin et al. 2013), the concerns raised by teachers confirm the assertion that effective adoption of LA in higher education will depend on the ability of universities to provide the necessary institutional infrastructure and remuneration (Howell et al. 2018). Thus, motivating teachers to integrate LA into their everyday practice with no reservations and to be explicit about the purpose of collecting student data to teachers and students.

RQ3 analyzed teachers' perception of LA as a tool to support course design practices. Thus, building on the theoretical lenses of TAM (e.g. LA's perceived usefulness), teachers highlighted LA's potential from a normative and formative perspective. Taking a normative perspective, teachers saw LA as a tool to provide more objective and timely evidence about students' learning behavior, which could be used in design adjustments. This finding supports the narrative that LA might support teachers' design practices by addressing the limitations of traditional feedback approaches (e.g. summative assessments and course evaluations) which research has identified as less precise and take much longer to compile (Berland et al. 2014; Ifenthaler et al. 2018; Nguyen et al. 2018). However, underlying LA's theme as a formative tool was an emphasis that LA can be used as a tool to support personalized learning based on evidence collected from students' online trajectories. This finding identifies that teachers would like to use LA as a diagnostic tool to understand individual students' learning processes, hence providing customized educational experiences to students during the course (e.g. personalized feedback), as also noted in previous research (van Leeuwen 2019). To support these processes, teachers demanded different forms of LA, like automated feedback, metrics on students' participation and engagement with the implemented design, among others. The nature of LA highlighted by teachers has important implications for the nature of LA support to be provided to teachers. Currently, though, few LA tools offer course design subject-specific support, which calls for the development of relevant tools to provide the kind of analytics required by the teachers. Arpetti et al (2014) who reported that teachers need systems that can provide simple and quickly visible instructions to support course designs also noted this.

Overall, given the identified teachers' current course design practices, several opportunities exist to leverage LA, especially due to recognized challenges concerning current influences of course design practices, such as summative assessments and student evaluations, which, according to teachers, cannot provide timely feedback and an objective assessment of students' learning behaviors. Accordingly, using LA to inform course design decisions could result in a better understanding of students by the teachers before and during the course, which could lead to more informed, timely course design decisions. Moreover, the integration of LA and teachers' course design practices addresses the known concern that LA is highly data-driven and lacks an explicit pedagogical approach (Shibani et al. 2019). Yet, if integrated, LA could provide the lens to interpret the pedagogical assumptions

embedded within a course design (Shibani et al. 2019). This answers our third RQ, as it shows the potential value of linking course design with LA to overcome such barriers. This is through providing teachers with more objective evidence concerning students' learning behaviors that currently teachers cannot determine in any concrete way, other than basing on their observations and less objective, untimely students' evaluations. Thus, the findings indicate that LA could form the basis of an important reflective tool for improving teaching practices and allow an adaptive, rather than reactive, teaching practice (Howell et al. 2018).

Meanwhile, for LA to effectively guide teachers' course design practices, the teachers need a framework to guide this integration. Thus, to unpack how these two components can work together, we synthesize the findings from teachers' interviews and related literature to propose the 'Bi-directional LA—course design conceptual model' (Fig. 1), which is presented in the next section.

5.1 The Bi-directional LA—Course Design Conceptual Framework

The study's findings revealed that the necessary conditions for connecting LA to course design are broad and revolve around several factors and issues. Thus, to contribute to this alignment, we propose the 'Bi-directional LA—course design conceptual framework' (Fig. 1) to support and guide teachers, researchers, administrators and technology developers with a usable model to make informed decisions about the nature of the analytics needed and the requirements to inform the connection between LA and course design. The name '*Bi-directional'* was chosen to convey that both LA and course design can reciprocally determine each other, and therefore, both need to be equally considered while planning an LA—course design implementation. For instance, the data captured from learning environments may not only affect course design adaptation but also the design informing the type of data to collect and how it is to be structured and captured (i.e. data capturing, sense-making etc.). Taking this perspective, the bi-directional LA-course design conceptual framework emphasizes that an outcome within one element (e.g. LA) precipitates changes in outcomes within another element (e.g. course design). The proposed 'Bi-directional LA—course design conceptual model' operationalizes the connection between LA and course design through four interconnected dimensions: context, digital tools, technical/functional requirements and stakeholders. These dimensions are informed by both the empirical findings of the current study with teachers as well as existing LA literature and frameworks (e.g. Seufert et al. 2019; Kaliisa et al. 2021; Muljana and Luo 2020). Next, a conceptual description and theoretical rationale of these dimensions is given.

Dimension 1: *Context.* This dimension emphasizes the learning context (e.g. online, blended or face-to-face), the specific course context (e.g. course objectives, discipline) and course design influences (e.g. class size, student characteristics, teacher experience). These elements are important to consider beforehand since these will affect the nature of LA that can be gathered and the conclusions made. Moreover, the meaningful interpretation of LA outputs depends on understanding the pedagogical context in which data is being collected (Shibani et al. 2019; Ifenthaler and Widanapathirana 2014; Hernández-Leo et al. 2019; Muljana and Luo 2020). In this regard, defining/understanding the context before designing, collecting and interpreting LA is necessary because different pedagogical practices could imply particular epistemological and pedagogic assumptions (Knight et al. 2014).

Dimension 2: *Digital Tools*. This dimension considers the need to have the necessary technologies/tools (e.g. LMS, LD technologies, multimodal LA technologies such as sensors and eye scanners) that will support course enactment and to log machine-readable

course data (e.g. access reports, page views, discussion analytics, eye movements) for LA purposes and regarding the intentions of a given course. Thus, digital tools represent an important element to support the connection between LA and course design, especially within blended learning (BL) contexts where teachers tend to deliver course designs with the limited use of technology (Rodríguez-Triana et al. 2015).

Dimension 3: *Technical and Functional Requirements.* This dimension highlights the necessary resources and support mechanisms (e.g. LA institutional regulations, training, policy on LA ethics) to support the integration of LA and course design practices. The teachers revealed that they need training in the use of LA tools, which implies that institutions should provide the necessary support in form of training as well as local policies about ethics. This dimension also highlights the need for LA tools and approaches that could support the analysis of course analytics needed by teachers, for example, Epistemic Network Analysis (ENA). A recent review of existing LA adoption frameworks revealed that a large number of frameworks are not concretized into technological artefacts and concrete data streams, which could make it hard for teachers to use them in making pedagogically informed learning, and teaching decisions based on the analytics (Kaliisa et al. 2021). Thus, the technical and functional requirements dimension represents an important element to support teachers' use of LA for course design.

Dimension 4: *Stakeholders.* This dimension recognizes the mediating role of different players (e.g. teachers, students, institutional managers, IT personnel, among others) to support the LA-course design adoption in practice. As noted by Rienties et al. (2016) and Seufert et al. (2019) and emphasized by teachers during the interviews, LA implementation requires the involvement of different stakeholders. In particular, institutional leaders should be at the forefront of LA adoption since teachers expressed concern that institutional structures and guidelines limit them from implementing the necessary innovations and design adjustments on a needs basis. Moreover, integrating LA tools requires institutional multilevel approval due to security and ethical related issues (e.g. securing student privacy). At the same time, in this framework, a teacher and a student are both placed in the middle of the LA—course design process, as both play a key role. For example, students are involved as proactive stakeholders throughout the whole LA adoption process, so that the analytics systems do not run the risk of diminishing the ability of students to exercise judgment (e.g. who is using my data?). As emphasized by Wise et al. (2016) the teachers should position students' analytics as an integral part of the learning process, and create an environment where LA outputs are discussed between the teacher and students.

5.2 An Illustrative Example for Application of the Bi-directional LA-course Design Conceptual Framework

The following section includes the description of a use case (Armour and Miller 2000) that illustrates how the dimensions of the Bi-directional LA-course design framework can be translated into practice. In this case, we illustrate how a teacher can design relevant activities and make use of the different elements depicted in the framework to make timely data-informed decisions.

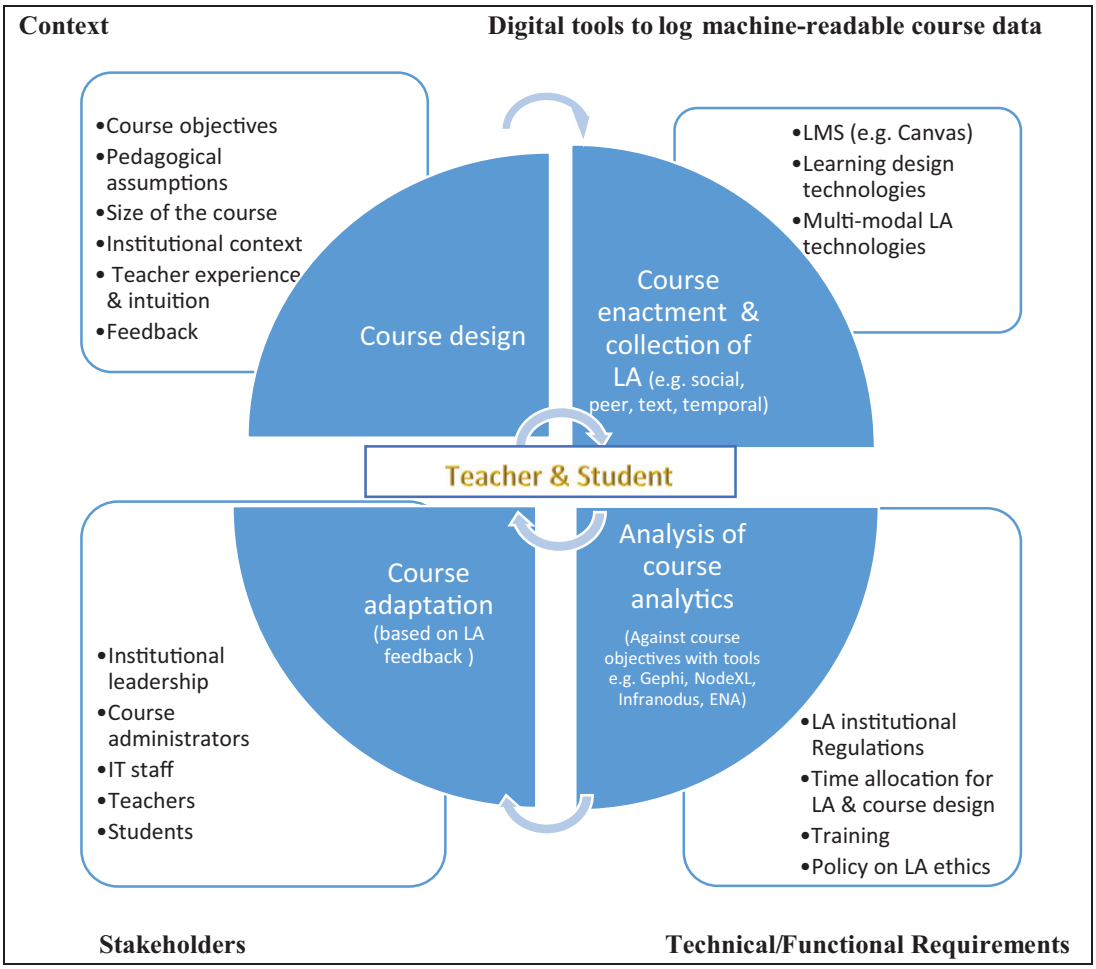

Fig. 1 The Bi-directional LA-Course design conceptual framework for linking LA and course design

5.2.1 Use Case: Using Social Learning Analytics to Support Course Design

This use case illustrates an example of a teacher using social learning analytics (SLA), which involves the collection and analysis of students' learning behaviors and traces gathered from online social interaction activities and contexts (Buckingham Shum and Ferguson 2012). The context of this case is a blended learning environment using a learning management system such as Canvas to support the instruction process and logging of machine-readable data. To connect LA and course design, the teacher begins with identifying design features or designing relevant course activities based on their context and related factors (e.g. course size, course objectives, student characteristics), and theoretical or pedagogical perspectives (e.g. behaviorist, constructivist). It is also important for the teacher to consider the LA indicators (e.g. the number of logins, discussion contributions) that can be used to monitor if the planned learning activities are going as intended or not, according to a metric or model. For example, a teacher can design online discussions to be completed through the Canvas LMS, with a socio-constructivist assumption that students that are more active in the discussion imply better learning, and that active students require a certain number of postings, of a certain length, and depth of discourse. Once the course is enacted, the collection of relevant LA begins. As highlighted in Fig. 1, the teacher needs a tool to capture students' digital traces and in line with the pedagogical needs (e.g. students' interactions and content posted). In this case, relevant social network analysis tools such as NodeXL (Smith et al. 2009) and discourse analysis tools such as Infranodus (Paranyushkin

2019) could be used to analyze students' online interactions and contributions. However, to support timely course adaptation, these tools should provide timely feedback before the unit or lesson is completed to enable the teacher to generate quicker insights into the topics discussed by students and areas where they are struggling. In this regard, a teacher could make some modifications into the course design based on the feedback from the LA or make targeted interventions for specific individual students. This implies a shift from the traditional summative approaches (e.g. end of semester course evaluations), which, according to teachers, cannot provide timely feedback and an objective assessment of students' learning behaviors. However, for this process to be successful, several stakeholders need to be involved as emphasized in the Bi-directional LA-course design framework. For example, the teachers who are at the center of the design and redesign experience, the students who are the data subjects, course administrators and technical people to assist with the design or installation of relevant LA tools. Thus, for the LA-course design process to be successful, it should be a dynamic, continuous, and holistic process covering all stakeholders involved in the learning and teaching process (Conole 2012, p. 33).

6 Limitations

This study is restricted to the specific university cases and a sample of teachers, which limits the generalizability of the findings. A potential limitation is that we did not interview other stakeholders, such as administrators, researchers and IT staff. It may be worthwhile to expand future multi-stakeholder analyses to include perspectives from additional stakeholders. Thus, insights should be treated as preliminary and beginning to shed light on teachers' perceptions of LA and its potential to support teaching practices in higher education. Besides, the self-reported nature of the interview's results implies that sometimes what participants say may not represent what they do. Another limitation is that the empirical validation of our proposed framework and how the intended users (e.g. teachers) perceive it is missing. Towards this direction, the focus of follow-up studies is to design different interventions with teachers to examine the relevancy of the framework in supporting teachers' practice.

7 Conclusion

This paper began by making a case for research into teachers' design practices and beliefs about LA as a tool to support these practices. The findings revealed the prominence of situational factors, feedback systems and teachers' personal experiences as key influences of teachers' course design practices. Moreover, teachers reported their course design practices were challenged by institutional regulations, as well as biased and untimely sources of feedback. These findings imply that supporting tools such as LA could have the most potential to improve teachers' course design practices by engaging with the key influences and challenges that shape teachers' course design practices.

Simultaneously, findings revealed that teachers recognize the potential value of LA to support course design practices (e.g. normative and formative perspectives). Meanwhile, skepticism over the evaluative role of LA, the failure to meaningfully represent students' learning behavior and a perceived increased workload LA may impose were common issues identified by the teachers.

Based on these findings, we suggest that the issues raised by LA skeptics and documented in the existing literature such as time, motivation and LA relevance should be considered if the field of LA is to make a significant step in impacting teachers' practices. For example, to support the meaningful interpretation of students' learning behaviors through LA, it is important to employ pedagogically driven rather than data-driven LA interventions so teachers can make meaningful and contextualized interpretations and conclusions about LA data and suggest relevant actionable insights/interventions. This also implies that the teacher/learning designer should play an active role in re-designing elements of the course based on the feedback provided by the LA, as illustrated by the proposed bi-directional LA—course design conceptual framework (Fig. 1).

We also suggest the need to include all stakeholders (e.g. administrators, technology developers, teachers and students) at all levels of LA implementation to ensure transparency, fairness and the ethical use of student data. Similarly, the study identified differences between teachers' course design practices and perceptions towards LA based on institutional and disciplinary affiliations. As an implication, it is important to recognize the different constraints and conditions within which teachers work and to consider LA context-specific approaches. In this study, we contribute to this direction by proposing the 'Bi-directional LA—course design conceptual framework', which might offer institutions and teachers an easy tool to clarify the necessary conditions and guide discussions about how LA can be implemented to support teachers' course design practices. An exemplary case has also been included to illustrate how the four-dimensional framework can be operationalized in authentic practice. We regard this framework as the main contribution to the LA and course design integration knowledge base from a social cultural perspective.

The findings reported in this paper are part of a large project seeking to explore how teachers can leverage LA to support their course design practices. The findings extend our understanding of factors that are fundamental to teachers' course design practices, with important implications for the nature of analytics that are needed by teachers based on their current practices. Thus, this study will inform the next phases of our research by particularly addressing some of the LA needs and course design challenges highlighted by the teachers. The proposed framework will also be further examined and refined through empirical cases during the next phases of research. We hope that the results and the proposed conceptual framework have significant theoretical and practical insights into the understanding and application of LA, which teachers, researchers and higher education managers can leverage as they try to promote excellence in teaching, learning and curriculum planning.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical Approval All procedures performed in this study were in accordance with the ethical standards and guidelines of the institutional and national center for research data. Informed written consent was received from all participants**.**

Appendix

See Fig. 2..

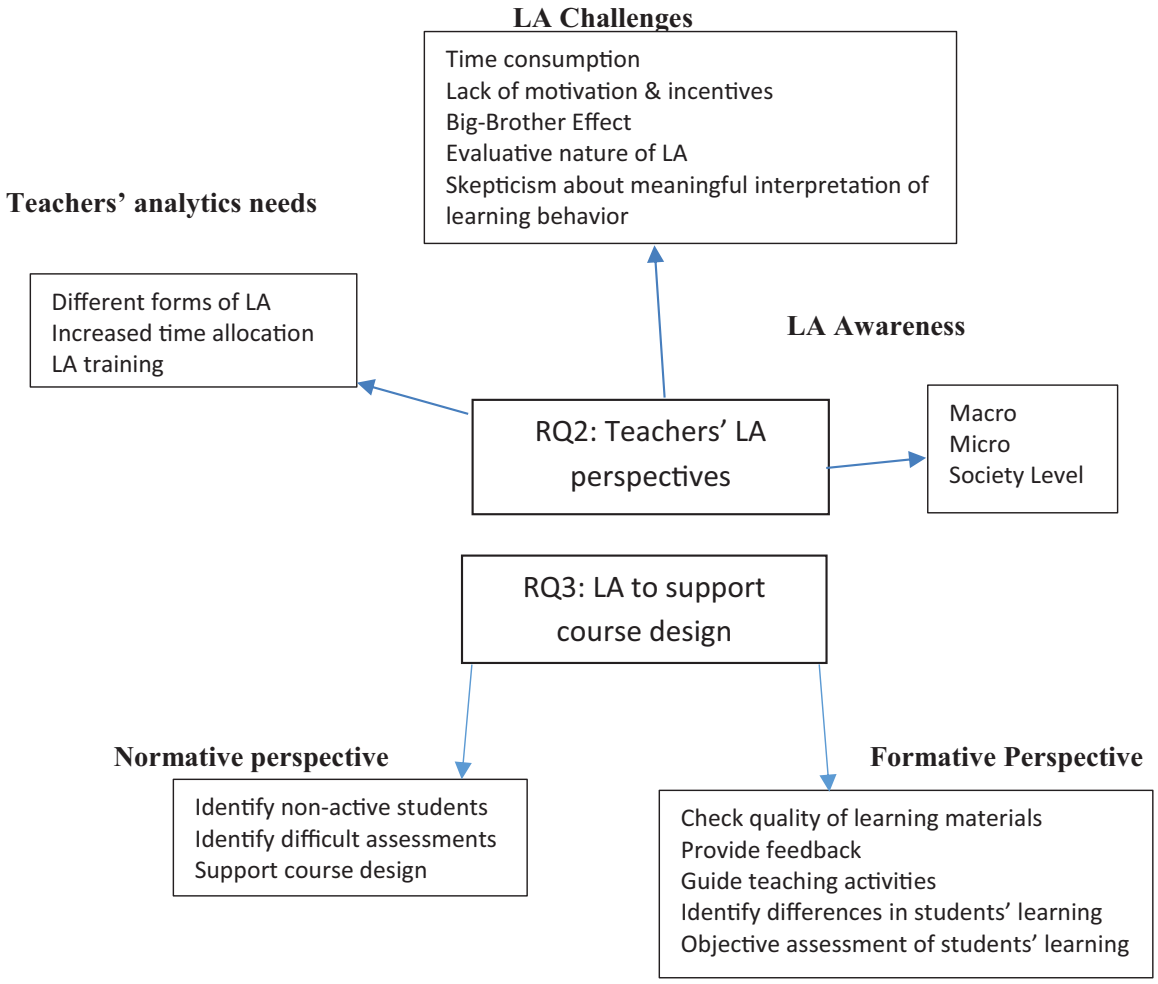

Fig. 2 A snapshot of themes and sub-themes from RQ2 and three are illustrated

References

Armour, F., & Miller, G. (2000). *Advanced use case modeling: Software systems*. Retrieved from https://books.google.no/books?id=V5eER53NWJYC.

Arpetti, A., Baranauskas, M. C. C., & Leo, T. (2014). Eliciting requirements for learning design tools. In *European conference on technology enhanced learning* (pp. 1–14). Cham: Springer.

Bakharia, A., Corrin, L., de Barba, P., Kennedy, G., Gašević, D., & Mulder, R. (2016). A conceptual framework linking learning design with learning analytics. In *Paper presented at the proceedings of the sixth international conference on learning analytics and knowledge*. http://doi/pdf/https://doi.org/10.1145/2883851.2883944.

Bennett, S., Agostinho, S., & Lockyer, L. (2015). Technology tools to support learning design: Implications derived from an investigation of university teachers' design practices. *Computers and Education, 81,* 211–220. https://doi.org/10.1016/j.compedu.2014.10.016.

Bennett, S., Thomas, L., Agostinho, S., Lockyer, L., Jones, J., & Harper, B. (2011). Understanding the design context for Australian university teachers: Implications for the future of learning design. *Learning, Media and Technology, 36*(2), 151–167. https://doi.org/10.1080/17439884.2011.553622.

Berland, M., Baker, R. S., & Blikstein, P. (2014). Educational data mining and learning analytics: Applications to constructionist research. *Technology, Knowledge and Learning, 19*(1–2), 205–220. https://doi.org/10.1007/s10758-014-9223-7.

Black, P., & Wiliam, D. (2009). Developing the theory of formative assessment. *Educational Assessment, Evaluation and Accountability (formerly: Journal of Personnel Evaluation in Education), 21*(1), 5. https://doi.org/10.1007/s11092-008-9068-5.

Braun, V., & Clarke, V. (2012). *Thematic analysis*. https://doi.org/10.1191/1478088706QP063OA.

Bryman, A. (2016). *Social research methods*. Oxford: Oxford University Press.

Buckingham Shum, S. B., & Ferguson, R. (2012). Social learning analytics. *Journal of Educational Technology and Society, 15*(3), 3–26.

Conole, G. (2012). *Designing for learning in an open world* (Vol. 14). Berlin: Springer.

Corrin, L., Kennedy, G., & Mulder, R. (2013). Enhancing learning analytics by understanding the needs of teachers. In *Paper presented at the ASCILITE-Australian society for computers in learning in tertiary education annual conference*. https://www.learntechlib.org/p/171128/.

Dagnino, F. M., Dimitriadis, Y. A., Pozzi, F., Asensio-Pérez, J. I., & Rubia-Avi, B. (2018). Exploring teachers' needs and the existing barriers to the adoption of learning design methods and tools: A literature survey. *British Journal of Educational Technology, 49*(6), 998–1013. https://doi.org/10.1111/bjet.12695.

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.

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. https://doi.org/10.1111/bjet.12645.

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. https://doi.org/10.1007/s11423-019-09685-0.

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. https://doi.org/10.1007/s10758-017-9329-9.

Ifenthaler, D. (2017). Are higher education institutions prepared for learning analytics? *TechTrends, 61*(4), 366–371. https://doi.org/10.1007/s11528-016-0154-0.

Ifenthaler, D., & Widanapathirana, C. (2014). Development and validation of a learning analytics framework: two case studies using support vector machines. *Technol Knowl Learn*, *19*(1–2), 221–240.

Ifenthaler, D., Gibson, D., & Dobozy, E. (2018). Informing learning design through analytics: Applying network graph analysis. *Australasian Journal of Educational Technology, 34*(2), 117–132. https://doi.org/10.14742/ajet.3767.

Ifenthaler, D., & Yau, J. Y. K. (2019). Higher education stakeholders' views on learning analytics policy recommendations for supporting study success. *International Journal of Learning Analytics and Artificial Intelligence for Education (iJAI), 1*(1), 28–42. https://doi.org/10.3991/ijai.vlil.10978.

Kaliisa, R., Mørch, A. I., & Kluge, A. (2019). Exploring social learning analytics to support teaching and learning decisions in online learning environments. Proceedings of the 14th European Conference on Technology Enhanced Learning (EC-TEL 2019), 16–19 September 2019, Delft, The Netherlands. *Lecture notes in computer science* (Vol. 11722, pp. 187–198). Cham, Switzerland: Springer. https://doi.org/10.1007/978-3-030-29736-7_14.

Kaliisa, R., Kluge, A., & Mørch, A. I. (2021). Overcoming the challenges to learning analytics adoption at the practitioner level: A critical analysis of 18 learning analytics frameworks. *Scandinavian Journal of Educational Research*.

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.

Laurillard, D. (2013). *Teaching as a design science: Building pedagogical patterns for learning and technology*. Routledge. https://books.google.no/books?hl=en&lr=&id.

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

Mor, Y., Ferguson, R., & Wasson, B. (2015). Learning design, teacher inquiry into student learning and learning analytics: A call for action. *British Journal of Educational Technology, 46*(2), 221–229. https://doi.org/10.1111/bjet.12273.

Muljana, P. S., & Luo, T. (2020). Utilizing learning analytics in course design: Voices from instructional designers in higher education. *Journal of Computing in Higher Education*. https://doi.org/10.1007/s12528-020-09262-y.

Nguyen, Q., Huptych, M., & Rienties, B. (2018). Linking students' timing of engagement to learning design and academic performance. In *Paper presented at the proceedings of the 8th international conference on learning analytics and knowledge*. https://doi.org/10.1145/3170358.3170398.

Nguyen, Q., Rienties, B., & Whitelock, D. (in press). A mixed-method study into how instructors design for learning in online and distance education. *Journal of Learning Analytics*.

Paranyushkin, D. (2019). InfraNodus: Generating insight using text network analysis. In *Paper presented at the the world wide web conference*. https://doi.org/10.1145/3308558.3314123.

Rienties, B., Herodotou, C., Olney, T., Schencks, M., & Boroowa, A. (2018). Making sense of learning analytics dashboards: A technology acceptance perspective of 95 teachers. *International Review of Research in Open and Distributed Learning, 19*(5), 1. https://doi.org/10.19173/irrodl.v19i5.3493.

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. https://doi.org/10.1016/j.chb.2016.02.074.

Rodríguez-Triana, M. J., Martínez-Monés, A., Asensio-Pérez, J. I., & Dimitriadis, Y. (2015). Scripting and monitoring meet each other: Aligning learning analytics and learning design to support teachers in orchestrating CSCL situations. *British Journal of Educational Technology, 46*(2), 330–343. https://doi.org/10.1111/bjet.12198.

Saa, A. A., Al-Emran, M., & Shaalan, K. (2019). Factors affecting students' performance in higher education: A systematic review of predictive data mining techniques. *Technology, Knowledge and Learning, 24*(4), 567–598. https://doi.org/10.1007/s10758-019-09408-7.

Sergis, S., & Sampson, D. G. (2017). Teaching and learning analytics to support teacher inquiry: A systematic literature review. In A. Peña-Ayala (Ed.), *Learning analytics: Fundaments, applications, and trends* (pp. 25–63). Cham: Springer. https://doi.org/10.1007/978-3-319-52977-6_2.

Seufert, S., Meier, C., Soellner, M., & Rietsche, R. (2019). A pedagogical perspective on big data and learning analytics: A conceptual model for digital learning support. *Technology, Knowledge and Learning, 24*(4), 599–619. https://doi.org/10.1007/s10758-019-09399-5.

Shibani, A., Knight, S., & Shum, S. B. (2019). Contextualizable learning analytics design: A generic model and writing analytics evaluations. In *Paper presented at the proceedings of the 9th international conference on learning analytics and knowledge*. https://doi.org/10.1145/3303772.3303785.

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

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

Smith, M. A., Shneiderman, B., Milic-Frayling, N., Mendes Rodrigues, E., Barash, V., Dunne, C., & Gleave, E. (2009). Analyzing (social media) networks with NodeXL. In *Proceedings of the fourth international conference on Communities and technologies* (pp. 255–264). https://doi.org/10.1145/1556460.1556497.

Tsai, Y.-S., & Gasevic, D. (2017). Learning analytics in higher education-challenges and policies: A review of eight learning analytics policies. In: *Proceedings of the seventh international learning analytics and knowledge conference* (pp. 233–242).https://doi.org/10.1145/3027385.3027400.

van Leeuwen, A. (2019). 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, 67*(5), 1043–1064. https://doi.org/10.1007/s11423-018-09639-y.

Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science, 46*(2), 186–204. https://doi.org/10.1287/mnsc.46.2.186.11926.

West, D., Huijser, H., Heath, D., Lizzio, A., Toohey, D., Miles, C., & Bronnimann, J. (2016). Higher education teachers' experiences with learning analytics in relation to student retention. *Australasian Journal of Educational Technology*. https://doi.org/10.14742/ajet.3435.

Wise, A. F., Vytasek, J. M., Hausknecht, S., & Zhao, Y. (2016). Developing learning analytics design knowledge in the" middle space": The student tuning model and align design framework for learning analytics use. *Online Learning, 20*(2), 155–182.

Article 3

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III

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Combining Checkpoint and Process Learning Analytics to Support Learning Design Decisions in Blended Learning Environments

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Abstract

Learning analytics (LA) constitutes a key opportunity to support learning design (LD) in blended learning environments. However, details as to how LA supports LD in practice and information on teacher experiences with LA are limited. This study explores the potential of LA to inform LD based on a one-semester undergraduate blended learning course at a Norwegian university. Our findings indicate that creating valuable connections between LA and LD requires a detailed analysis of student checkpoints (e.g., online logins) and process analytics (e.g., online content and interaction dynamics) to find meaningful learning behaviour patterns that can be forwarded to teachers in retrospect to support the redesign of courses. Moreover, the teachers in our study found the LA visualizations to be valuable for understanding student online learning processes, but they also requested the timely sharing of aggregated LA visualizations in a simple, easy-to-interpret format, yet detailed enough to be informative and actionable. We conclude the paper by arguing that the potential of LA to support LD is improved when multiple levels of LA are considered.

Notes for Practice

- The effective use of learning analytics to support learning design requires a combination of different levels of learning analytics to provide richer insight into student online learning processes.
- The specific learning analytics visualizations should consider the pedagogical intentions of the course (i.e., to make learning design decisions based on theory) and the needs of the teachers, rather than specific analytics or other technical considerations.
- For learning analytics visualizations to meet the intended purpose of supporting learning design, they should be provided in a timely and simplified manner.

Keywords

Learning analytics, learning design, blended learning, teachers, Canvas, social network analysis, text network analysis

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1. Introduction

The dynamics between learning analytics (LA) and learning design (LD) have garnered interest among educational technology researchers and practitioners (Michos, Hernández-Leo, & Albó, 2018; Nguyen, Rienties, Toetenel, Ferguson, & Whitelock, 2017). This has been in part due to the increasing demand from higher education providers for teachers to apply evidence-informed approaches and to provide better quality and tailored learning experiences to their students (Alhadad & Thompson, 2017; Bennett, Agostinho, & Lockyer, 2015; Dobozy & Cameron, 2018). Teachers' usual practice is to rely on insights from summative assessments, course evaluations, and personal experience to make pedagogical decisions (Bakharia et al., 2016). However, LA can potentially provide teachers with timely feedback about student learning, which can contribute to informed pedagogical decisions and improved student performance in educational programs (Macfadyen & Dawson, 2010). Consequently, there is an imperative among educational technology researchers to explore the possibilities of combining LA

and LD to support teachers with timely and informed teaching and learning decisions (Griffiths, 2017; Law et al., 2017). However, despite substantial progress and interest in connecting these two areas of research, there is still much to explore about the potential of LA to support LD. One major methodological limitation within existing studies is the use of aggregated activity metrics (i.e., page views, logins, and time spent on tasks) to analyze LD; little emphasis has been placed on the process and the actual learning content. Moreover, little attention has been given to how teachers perceive and use the insights generated from LA data and visualizations to inform their LD decisions. The research reported in this paper investigates the potential of leveraging multiple LA sources to help teachers make informed LD decisions. Using the example of LD in a university course, we investigate how multiple levels of LA can lead to a richer understanding of student online learning processes and how these insights can be used by teachers to make informed LD decisions.

As for our contribution to the current research in this area, we propose that creating valuable connections between LA and LD requires a detailed analysis of student checkpoints and process analytics, as doing so adds scope for a more holistic and deeper understanding of the teaching and learning process. In this study, we use quantitative data (e.g., social network analysis), and in-depth interviews with teachers to enable a qualitative interpretation of our claims. The rest of the paper is organized as follows. We start with a brief overview of LA and LD and the relationship between them. We then present the existing research connecting these two areas. Next, we present the methodology and report the results and discussion. In the interests of space, the results are presented and discussed concurrently with the existing research. The paper concludes by discussing the key implications of combining LA and LD as well as suggestions for future research.

2. Background

The growing adoption of educational technologies (e.g., learning management systems or LMSs) and online learning approaches (e.g., massive open online courses [MOOCs] and content-based learning environments) have led to a greater quantity of data about students and their contexts. For example, student interactions with course content (e.g., tasks, resources, and forums) can be captured, stored, analyzed, and used as indicators of teaching quality (e.g., how the enacted teaching approaches align with learning outcomes; Lockyer, Heathcote, & Dawson 2013; Gašević, Dawson, Rogers, & Gašević, 2016) and to create predictive models of student learning (Macfadyen & Dawson, 2010). Lockyer et al. (2013) suggested two different classes of analytics: 1) checkpoint analytics, which is concerned with tracing student access to necessary course content and pages (e.g., page views, online course logins, file downloads, and time spent on tasks); and 2) process analytics, which looks at the way students complete learning tasks (e.g., online discussion interactions). Such data can be provided to teachers in the form of visualizations, tables, and reports to support them with retrospective insight into teaching and learning outcomes (Ifenthaler, Gibson, & Dobozy, 2018) and to reveal student cognitive and social learning processes (Kaliisa, Mørch, & Kluge, 2019). This data can be used by teachers to generate predictive insights and to use as a benchmark for providing adaptive feedback at a fine-grained level, thus supporting personalized interventions (Law et al., 2017; Rienties, Cross, & Zdrahal, 2017) and fully integrating curricular decision-making into the digital learning experience (Ifenthaler, Gibson, & Dobozy, 2018).

Nonetheless, the digital footprints captured by LA tools are not without shortcomings. For example, LA cannot solely explain the success or failure of a particular learning activity through algorithms alone since numbers (i.e., quantitative approaches) do not provide context (Macfadyen & Dawson, 2012) and do not speak for themselves (Wise & Shaffer, 2015). Moreover, LA offers teachers and researchers limited insight into the systematic understanding of learner behaviour (Knight, Shum, & Littleton, 2014) and productive learning processes. We argue that to make sense of and to identify meaningful patterns, an explicit theory that illustrates pedagogical information is needed. In this respect, LD has been suggested as a potential pedagogical framework through which to bridge the gap between the information provided by LA and the pedagogical designs created by teachers.

To delimit the scope of this paper, we adopt Conole's definition, which conceptualizes LD as a structure that supports teachers in their preparation and describes the course objectives, activities, assessments, and resources that students and teachers undertake in the context of a unit of learning (Conole, 2012). Consequently, LD creates the conditions for a learning environment that could potentially support teachers in making pedagogically informed decisions while planning, preparing, and writing about the later enactment (Agostinho, 2011). However, although LD has the potential to highlight pedagogical intentions, it fails to consider student learning processes and engagement in an ongoing course at a fine-grained level of analysis (Lockyer et al., 2013). In other words, few built-in best practices exist to evaluate the effects of the designs in comparison to the intended learning and teaching objectives. The connection between LA and LD is thus gaining momentum, with the expectation that the former can support inquiries into student learning activities (Bakharia et al., 2016; Mor, Ferguson, & Wasson, 2015) and assessments of LD in context (Shibani, Knight, & Shum, 2019).

3. Related Research and Identified Gaps

3.1. Blended Learning and Learning Analytics

Blended learning (BL) is a pedagogical structure that combines traditional face-to-face instruction with computer-mediated/online delivery of content and instruction (Bonk & Graham, 2012). In BL structures, due to the variety of online and face-to-face activities, it may be challenging for teachers to maintain awareness of certain aspects of the learning process (e.g., student progress, and whether class activities in practice deviate from the original plan in theory), particularly for online learning components (Hernández-Leo, Martinez-Maldonado, Pardo, Muñoz-Cristóbal, & Rodríguez-Triana, 2019). One possible way to support teachers in dealing with the complexity of BL structures is the use of LA to help make certain aspects of the online learning components visible to support teachers' LD decisions. In the next section, the possible role that LA could play to support teachers' LD decisions in BL contexts is discussed.

3.2. The Interplay Between Learning Analytics and Learning Design

The interplay between LA and LD has gained considerable interest among educational technology researchers over the past few years (Mangaroska & Giannakos, 2018). For example, Rienties et al. (2017) evaluated the weekly LD data of 2,111 learners in four language studies classes and found that individual course design explained 55% of the variance in weekly online engagement. In another study, Rienties and Toetenel (2016) linked 151 modules taught at The Open University (OU), in which 111,256 students were enrolled, and found that LD was a strong predictor of student satisfaction. Nguyen et al. (2017), who studied 74 modules to examine the impact of assessment design on student engagement, focusing on fine-grained weekly LD data, took a similar approach. Their study indicated that the course workload for other activities diminished after assessment activities were introduced. Additionally, Nguyen et al.'s (2018) work complement previous studies by linking the timing of student engagement to LD and academic performance. The findings revealed a mismatch between how instructors designed activities for learning and how students studied in reality. Moreover, Haya, Daems, Malzahn, Castellanos, and Hoppe (2015) demonstrated the value of an approach that combines social networks and content analysis to support LD decisions by providing indicators that support teachers in their assessment of their LDs.

In another example, Melero, Hernández-Leo, Sun, Santos, and Blat (2015) used a case study of location-based games and presented an LD dashboard that provided teachers with the necessary data to make evidence-based LD decisions. As with Haya et al. (2015), the study illustrated how alignment between LA and LD can support effective pedagogical decision-making. Rodríguez-Triana et al. (2015) proposed a monitoring-aware, pattern-based design process that allows teachers to benefit from the outputs of LA to improve their LD. Similarly, using examples of computer-based support tools, McKenney and Mor (2015) argued that the retrospective analysis of LA can support pedagogy-driven data collection and analysis, which could in turn offer insight into learning and teaching practices. This claim is corroborated by Fritz (2016) who found that the data generated by an LMS can be used by teachers and students as a real-time proxy to support effective course design practices. Meanwhile, Kaliisa, Kluge, and Mørch (in press b) more recently explored university teachers' LA–LD perspectives at two Norwegian universities. Findings revealed that teachers appreciated the formative and normative value of LA to provide more objective evidence about students' learning patterns which could lead to timely course design decisions.

Recent research has begun to synthesize the corpus of existing studies that explores the connection between LA and LD. For instance, Mangaroska and Giannakos (2018) reviewed 43 empirical studies on LA for LD; they depicted ongoing design patterns and detected learning phenomena (i.e., moments of learning or misconception) arising from the connection between LA and LD. Moreover, to aid LA–LD alignment, a review of 18 LA frameworks (Kaliisa, Kluge, & Mørch, in press a) found that research has focused on providing tools and conceptual frameworks to inform the connection between LA and LD (Bakharia et al., 2016; Eradze, Rodriguez Triana, & Laanpere, 2017; Hernández-Leo et al., 2019; Lockyer et al., 2013; Persico & Pozzi, 2015; Gunn, McDonald, Donald, Nichols, Milne, & Blumenstein, 2017) within online and BL settings.

While the research and interest in exploring the dynamics between LA and LD is increasing, few empirical studies have demonstrated how this alignment between LA and LD happens in practice. Most of the existing studies that combine LA and LD are based on aggregated data from large datasets — for example, from MOOCs and other distance learning programs (Nguyen et al., 2017) — and system logs (i.e., course logins, page views, and resource access). As noted by Mangaroska and Giannakos (2018), little attention has been paid to the analysis of content data (i.e., teaching and learning concepts) and how these elements can be used to define and identify meaningful learning behaviour patterns and interactions that can be retrospectively forwarded to teachers to support the redesign of their courses. An even smaller amount of research (see Michos, Hernández-Leo, & Albó, 2018; Rienties & Toetenel, 2016) has examined how LA visualizations illustrate the impact of LD activities (i.e., data from student interaction with content) for teachers or sought information about teacher experiences with aligning LA and LD based on their generated outputs (Rodríguez-Triana, Martínez-Monés, Asensio-Pérez, & Dimitriadis, 2015). The apparent scarcity of studies that use content data and teacher experiences to acquire a holistic understanding of the

connection between LA and LD seems contrary to the documented evidence of utilizing different datasets (e.g. online discussions) to offer comprehensive insights and practical comments to support informed future course improvements (Kaliisa, Kluge, & Mørch, in press b; Samuelsen, Chen, & Wasson, 2019).

Thus, motivated to address these research problems, we aim to contribute to the literature with an empirical study on LA and LD linkages by considering multiple levels of analysis (i.e., course activity metrics, content data, and interaction dynamics data, hereafter referred to as checkpoint and process analytics) and how this could offer deeper insight to inform LD decisions. Besides, we aim to better understand teacher experiences with connecting LA and LD by sharing LA visualizations with them to spark discussions about LD. The objective of our study is to explore the relevance of LA for informing LD by answering the following research questions (RQ):

RQ1. Do LA visualizations generated from different sets of process and checkpoint analytics provide informative insights to support LD decisions?

RQ2. What are the teachers' perceived value of using LA visualizations as tools to evaluate and make timely and informed LD decisions?

With reference to the review of 18 existing LA–LD frameworks (Kaliisa et al., in press a), we employed the checkpoint and process analytics framework as the lens through which to select, present, interpret, and discuss our results. This framework highlights the different levels of data (e.g., checkpoint and process analytics) that are the basis of the current study. We argue that such data is relevant for a meaningful understanding of student learning behaviour especially in BL environments, where teachers may lack cues to understand student online learning behaviours.

4. Methods

4.1. Research Design and Participants

We used a mixed-methods approach by integrating quantitative information (i.e., social network analysis and automated discourse analysis) and qualitative interviews with teachers. We argue that the combination of different sets of data and analytical approaches is a valuable tool to enable the validation of data gathered and claims made from different approaches (i.e., using text network analysis to investigate the implicit meanings from page views and social network interactions). The study's main data source stems from the discussion forum contributions posted via the Canvas LMS for a bachelor-level, blended-learning technology course offered at a Norwegian University. The course included 36 enrolled students and four teachers. The researchers received ethics approval from the national review board, and informed consent was gained from 30 students and four teachers whose data informed the analysis presented in this paper.

4.2. Learning Design and Course Context

The studied course focused on technology-enhanced learning at the bachelor level. It included compulsory weekly online discussions on eight topics (see Table 1) and face-to-face lectures over eight weeks. The discussions were conducted asynchronously, and all the subsequent messages in the thread were text only. Each week, the teachers initiated a new discussion thread based on the topic of the next lecture. Each student was expected to make two contributions, including at least one response to another student, every week. The course materials included videos and required reading.

4.3. Data Collection and Analysis

We extracted checkpoint analytics such as individual students' weekly action logs (e.g., page views and participation/entries) from Canvas's analytics. This data represented student visits to elements within a course (i.e., curriculum content or tools) and the nature of their participation in the online activities (e.g., a discussion forum). We used this data as a lens through which to review the process analytics. We performed a Pearson correlation analysis (Benesty, Chen, Huang, & Cohen, 2009) to determine whether there was a significant correlation between the Canvas page views and student participation, as measured by their entries in the discussion forum (see Figure 2). Later we extracted process analytics by aggregating scores and counted activities such as discussion forum posts and the modelling of concepts through text network analysis (TNA) and social network analysis (SNA). This was intended to identify the interaction dynamics that evolved over the course of the collaborative online activities and the topics explored by the students within the networks.

4.4. Social Network Analysis

We extracted discussion forum data from the institutional LMS and reconstructed social network relationships based on student–student, student–teacher, and teacher–student interactions. This study involved the manual extraction of student discussions and interaction data (399 posts) from the LMS into a third-party social network visualization tool called NodeXL (Smith et al., 2009). Discussions were coded as vertices and edges using a Canvas link labelled "reply/go to theme." In this context, a vertex is defined as an engaged user, and an edge is defined as a connection between users. The coding process in

NodeXL included all students who posted in the discussion forum. For example, if student S10 posted a message in response to the main discussion question (DQ), we coded it as (S10➔DQ). Then, if student S8 posted a message in response to S10's post, we coded it as (S8➔S10). Following the SNA measures used in previous studies (Andersen & Mørch, 2016), we used degree centrality measures to determine the number of ties an individual student actor had with other student actors in the network (Smith et al., 2009). Moreover, we used betweenness centrality to identify the students occurring within the shortest path between other nodes, which represented other students, who thus facilitated the spread or control of information within the network.

4.5. Text Network Analysis

Discourse analysis was used to unveil and categorize key concepts and topics that emerged from the students' weekly discussion posts and how they were connected to the course design (Haya et al., 2015). The analysis was performed through text network analysis, which converts textual artefacts into a network of topics based on the proximity of their representatives in a given text (Haya et al., 2015). We used InfraNodus, a web-based, open-source automation tool, which relies on a text network analysis algorithm to identify influential words and topical clusters (Paranyushkin, 2019). Prior to the analysis, we preprocessed the data in three key steps. First, the student contributions from each week were combined into one corpus file. Second, we performed text normalization or stemming, by which all the words in the text were converted into their lemmas to reduce redundancy and to bring different variations of certain words under the same common denominator. We also removed all the syntax information (e.g., "?") but maintained the paragraph structure. Last, we conducted Stop words removal for commonly used words (i.e. "as," "the," and "is") that do not carry additional meaning, as well as for numbers, pictures embedded in postings, user avatars and information, headers, and punctuation. Following these procedures, we performed a text analysis for each week, which produced directed network graphs (see Figure 1) in which the normalized words were nodes and the edges between them described the regularity with which they co-occurred in the analyzed documents. The unit of analysis was the weekly discussion theme or topic (see Table 1), which was used as a benchmark to identify relevant topics that connect to the pedagogical intent of the respective discussion.

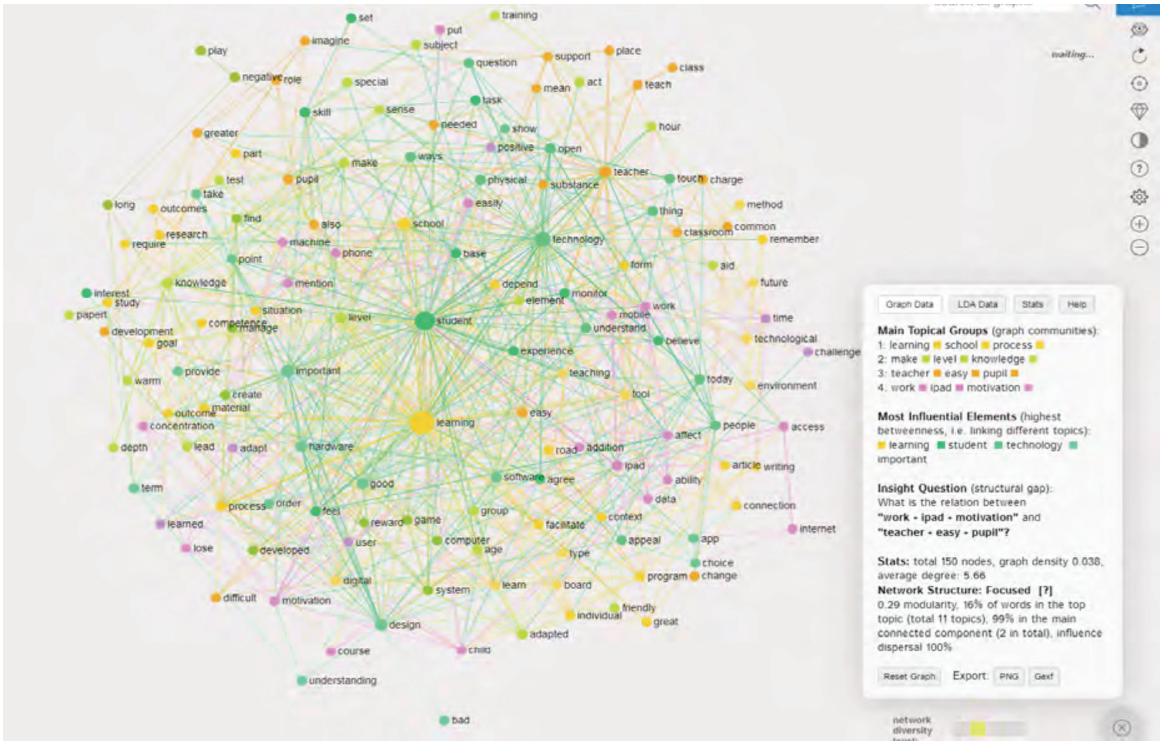

Figure 1. InfraNodus interface visualizing the main topics inside, and discourse structure of Week 7

4.6. Interviews

We conducted individual semi-structured interviews with the four teachers (three male, one female) who taught the course and stemming from the education faculty. Two of the teachers had more than 30 years of teaching experience in higher education, while the remaining two had a teaching background ranging between 5 and 10 years. None of the teachers had experience with

using LA as part of their teaching. The interviews allowed us to identify feelings and perceptions of the participating teachers and to validate and assess the usability of the visualized checkpoint and process analytics for LD purposes. The four interviews, which lasted between 30 and 45 minutes, were conducted in person. Each of the teachers were shown visualizations from the online modules they had facilitated (e.g., Figure 1). This means that all interviewed teachers had a clear understanding of the module structure, the activity schedules, and the expected pedagogical outcomes. In other words, during the interviews, the teachers could bring contextual knowledge to the review of the LA visualizations since, as noted by Lockyer et al. (2013), the interpretation of such visualizations highly depends on the user's understanding of the context and the goals of the teacher. The interview protocol, devised based on the research questions and prior research on teachers' LA adoption (Rienties & Toetenel, 2016), began with questions related to the teachers' general experiences of their LD throughout the semester. The main portion of the interview asked instructors to 1) critically study the provided LA visualizations, 2) make sense of them, 3) give their opinion on what they found useful or not useful, 4) discuss how such visualizations could inform their LDs, 5) explain when they would like to receive such visualizations, and 6) discuss the challenges associated with such visualizations. All interviews were audio-recorded and later transcribed.

5. Results and Discussion

5.1. Descriptive Statistics of Checkpoint Analytics

Figure 2 shows the student checkpoint analytics (i.e., page views and entries) over the course of the semester. The statistical analysis showed that the correlation between Canvas page views and participation (expressed as entries) was close to zero and hence not significant ($p > .05$) ($r = .06$, $p = .760$). For instance, as illustrated in the scatterplot, students S5, S30, S33, and S13 had the highest number of page views (1053, 1108, 1072, and 845, respectively), while students S1, S20, S23, and S34 recorded the lowest number of page views (332, 295, 250, and 361, respectively). However, concerning entries in the discussion forum, S17, S28, S29, S22, S14, S3, S9, and S34 recorded the highest number of entries (between 17 and 20), which is equivalent to the average number of posts (16) expected as per the LD. An interesting finding was that there was no overlap between the students with the most entries in the online discussion forum and the students with higher Canvas page views. Moreover, three of the students who recorded low participation in the discussion forum activities (S27, S7, and S6) had a slightly higher presence in Canvas, with their total page views amounting to 741, 755, and 745, respectively. These results suggest no clear pattern between average page views and participation rate. One potential explanation could be that some students made effective use of the Canvas environment, but that this use was not adequately represented by the total page views. Some students could have also used Canvas to submit an assignment without interacting with their classmates or accessing all the material made available by the teachers.

These results support the claims from previous studies that some learning traces, especially total time spent online, relate only weakly to student participation and their contributions to the online discourse (Macfadyen & Dawson, 2010). However, this finding does not imply that checkpoint analytics is useless in understanding student online learning processes; rather, even though it could be an invaluable proxy for student engagement with the course content, researchers and practitioners need to acknowledge the caveats of using such data in isolation of more interpretive process analytics (Lockyer et al., 2013; Nguyen et al., 2018).

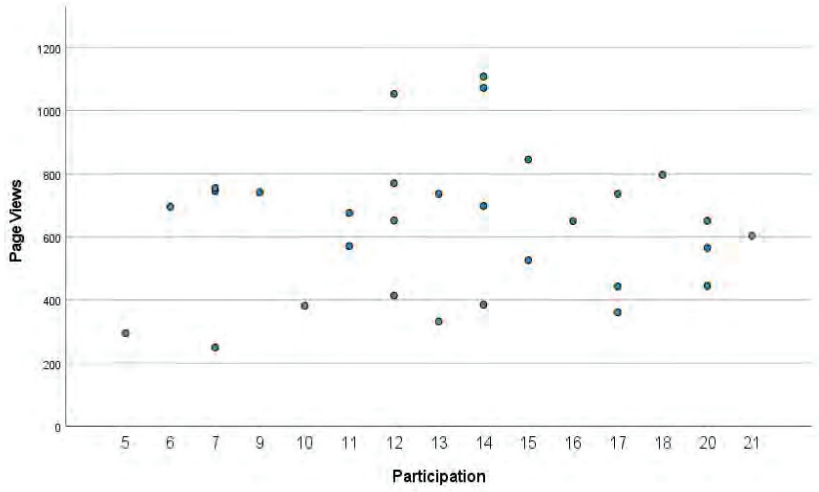

Figure 2. Scatter plot of students' Canvas page views and discussion entries during the semester

5.2. Social Network Analysis Findings

We analyzed student interactions in the online discussion forum, as illustrated in the sociograms in Figure 3. The layout of the figures is based on the Harel-Koren Fast Multiscale algorithm, which produces undirected graphs with straight-line edges (Harel & Koren, 2001). The figure provides an aggregated visual representation of the unweighted and undirected graphs, connecting 30 students and four teachers during the eight weeks of online discussion activities conducted on the Canvas platform. The size of the nodes corresponds to their degree centrality or the number of edges connected to them in the network. This means that the bigger a node is, the more messages that the student or teacher represented by that node sent and received. Furthermore, betweenness centrality was measured by the extent to which a node was more central to the main discussion question (DQ), which was very dense with numerous edges. For example, S13, S29, S14, S3, S17, S28, and S4 recorded the highest betweenness centrality between Weeks 1 and 7, respectively. Moreover, the figure also provides useful information about the weakly connected students across the eight weeks of discussion, which could be an early warning sign to help teachers detect students who are not complying with the course instructions.

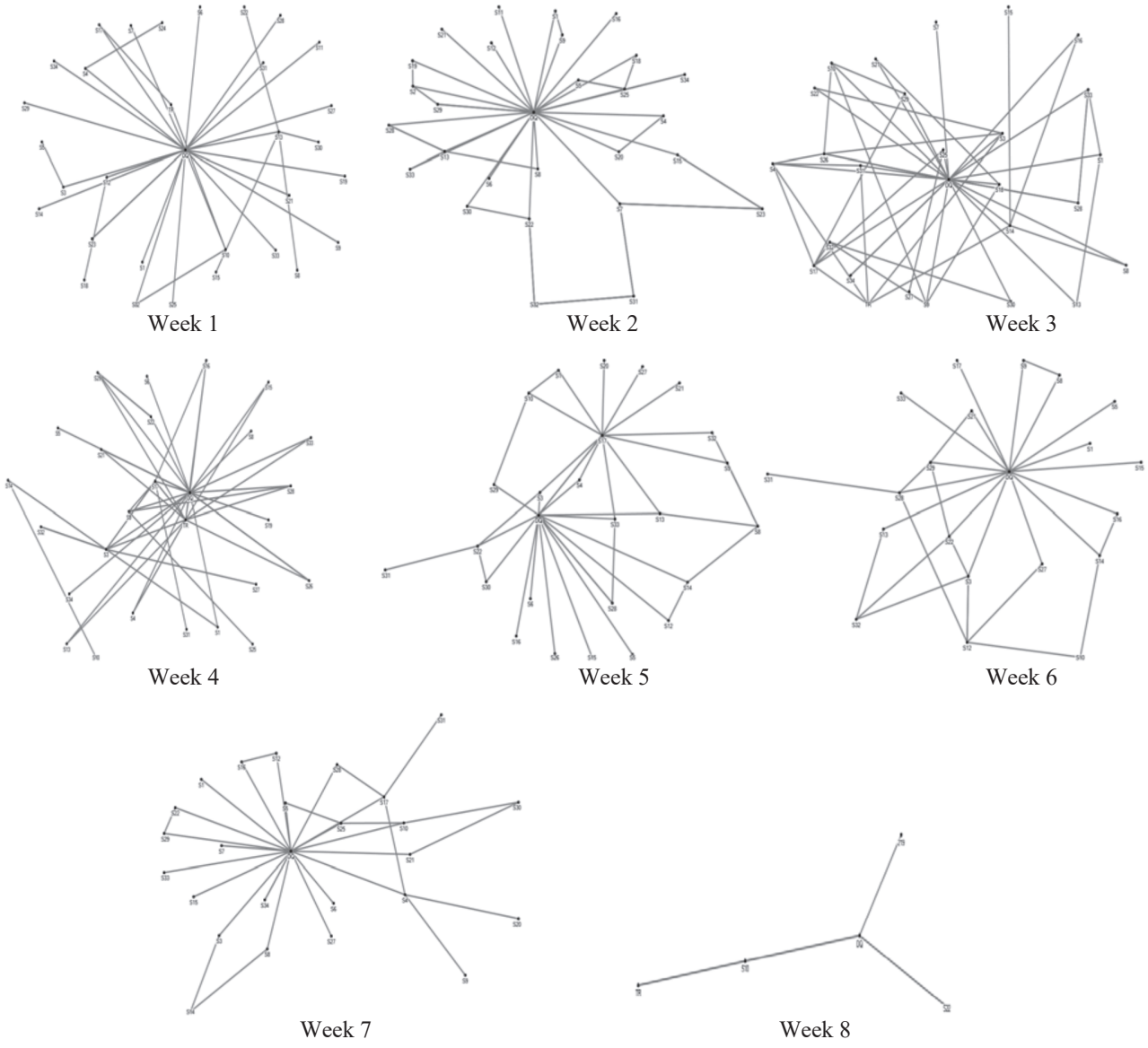

Figure 3. Discussion forum networks across the eight weeks of the course. Each node represents a student who posted at least one contribution or provided at least one reply to another student. The size of each node suggests the quantity of interactions associated with the student.

Conversely, at the group level, the sociograms illustrate students' general interaction (social structure) across the eight weeks. For example, the Week 1 sociogram illustrates limited interaction among students, with most communication directed towards the original discussion question (DQ). This means that this interaction pattern was polarized from the intended LD of student-to-student interaction. However, a higher volume of interactions is observed in Weeks 2–7, with students and teachers interacting more than in Week 1. In Week 4, the average degree of centrality increased, which is depicted by enlarged nodes (e.g., S3, S17, and S9). This is possibly attributed to the teacher-centric pattern observed in Week 4. It is interesting to observe the dramatic drop in network density in Week 8, where only three students posted in the discussion forum. Unsurprisingly, this is attributed to the fact that the discussion during Week 8 was not compulsory, and very close to the end-of-semester examination. Thus, students opted not to post in the discussion forum. In line with previous studies (Rienties et al., 2017), this finding confirms that the teacher's course design could explain the variance in students' weekly online engagement. Such a finding implies that teachers should design courses with the awareness that the scheduling and instructions could affect student VLE behaviour.

Overall from a researcher's perspective, while the findings from the social network visualizations might not be surprising, their strength relies in creating a much easier-to-understand visual representation of large amounts of student information and interactions at a glance, thus enabling teachers to monitor what is happening in their courses and to make quick and informed LD decisions at a structural level. In other words, the social network visualizations could provide teachers with an opportunity to quickly detect early on whether students are complying with the instructional guidelines. Therefore, teachers can use this measure as a benchmark for adapting their teaching practice and for taking action either through whole-class or individual-student scaffolding (Wise & Jung, 2019). Moreover, the visualizations could act as a reflective resource for teachers to assess whether socio-constructivist educational goals (i.e., group discussion) have been accomplished (Macfadyen & Dawson, 2010), since student-to-student interactions in online learning environments are a significant predictor of student success (Macfadyen & Dawson, 2012). As shown in this study, by comparing the LD objectives, teachers can visually analyze the networks depicted in the sociograms to identify students who were highly or less engaged in the discussion forum, as defined by the teachers.

By examining the vertices and edges, teachers can see which students posted at least twice and commented on other student contributions. For example, if students followed the LD instructions provided by the teachers, then each student would have posted at least twice and interacted with at least one other student, obtaining a degree centrality of at least three. By gaining such insights from social network visualizations, teachers can implement strategic teaching interventions (e.g., splitting groups) to manipulate social structures and encourage student participation. Alternatively, the teacher can intervene to change the interaction dynamics by encouraging less central but engaged students to extend their network and thus have more central-focal points to promote liveliness in the discussion. However, as highlighted in previous studies (Lockyer et al., 2013), meaningful interpretations of social network visualizations are only possible if the LD and the intent of the activities are made clear ahead of the analysis.

5.3. Text Network Analysis Findings

Aiming for further informative insight into the potential impact of LA visualizations on the revision of LDs, we performed an automated discourse analysis of student discussion contributions to detect the dominant concepts and terms used. Table 1 depicts the four main topical groups and influential concepts for each discussion theme across the eight weeks. One interesting observation gained from analyzing student discourse through a temporal dimension is that across the eight weeks, the concepts of "learning" and "technology" gained significant attention from the students and were sustained throughout the eight weeks of discussion (i.e., 1, 2, 3, 4, 5, and 7, and 2, 4, 5, and 7, respectively). The frequent presence of these concepts could imply that they are central and form the backbone for meaning circulation and for binding together clusters of terms within the discussion forum (Paranyushkin, 2019). This observation is unsurprising given that the name of the course is "Learning, Design and Technology." Moreover, it is logical that over the weeks, the most influential concepts were closely related to the discussion theme for the respective week. For instance, in Week 4 (see Figure 4), the key concepts of learning, school, knowledge, and technology were closely related to the three sub-questions posed by the teacher, which were related to the characteristics of learning at work, the technologies that support learning at work, and the differences and similarities between learning at work and learning at school or through education. Although such an observation might imply that the frequent presence of topics related to the discussion theme indicates highly relevant and valuable course discussions, we also think that this might have resulted from the LD, as every teacher emphasized the use of the course literature as the basis for the discussion. More precisely, such a finding could imply that the questions set by the course instructors have critical importance for and influence on student learning processes.

Table 1. Weekly Discussion Topics, Topical Groups, Influential Elements, and Graph Density

Weekly Discussion Topic	Topical Groups	Influential Elements (betweenness)	Graph Density
1. The distinctions between "knowledge," "skills," and "dispositions" based on J. S. Brown's video	A. Learning, motivation, perspective B. Knowledge, disposition, Brown C. School, make, experience D. Important, information, believe	Knowledge, learning, information, disposition	0.055
2. Role of technology in classroom experiences	A. Task, solve, test B. Learning, theory, good C. Technology, thing, work? D. Teacher, teaching, class	School, technology, learning? Teacher	0.047
3. Constructivism in practice	A. Meaningful, building, Lego B. Make, work, Minecraft C. Learn, thing, ways D. Learning, process, design	Learning, building, create, game?	0.007
4. Social media and e-learning in working life technologies that support learning at work	A. Knowledge, important, good B. Time, teacher, lot C. School, technology, remember D. Learning, work, tool	Learning, school, knowledge, technology	0.114
5. Difference between mechanical and digital technology	A. Reading, easy, read B. Learning, theory, support C. Technology, learn, digital D. Time, today, book	Learning, technology, learn, reading	0.033
6. Advantages and disadvantages of a digital climate simulator	A. Graph, model, understand B. World, part, interesting C. Student, task, show D. Tool, science, imagine	Simulator, student, climate, graph	0.034
7. Hardware design for the learning process and learning outcomes in schools	A. Learning, school, process B. Make, level, knowledge C. Teacher, easy, pupil D. Work, iPad, motivation	Learning, student, technology, important	0.038
8. Questions regarding the examination (non-obligatory)	A. Lecture, summarize, latest B. Exam, thought, group C. Sensible, penitent, grasp D. Answer, template, institute	Group lecture, exam, thought	0.023

Thus, from an LD perspective, by examining the textual discourse and network structure, teachers may have an early signal by quickly identifying the text's main agenda, especially in connection to the intended pedagogical intent. In particular, the text networks could enable teachers to acquire an overall understanding of the discussion topics and specific, representative points. Consequently, the teacher can get a signal regarding the kinds of topics provoked by the instructional content of a lesson, thus supporting future instructional decisions for the course and providing a basis for adaptations and scaffolding students (Haya et al., 2015). Such possibilities are not feasible through traditional assessment and evaluation practices, which usually take place at the semester's end (Bakharia et al., 2016).

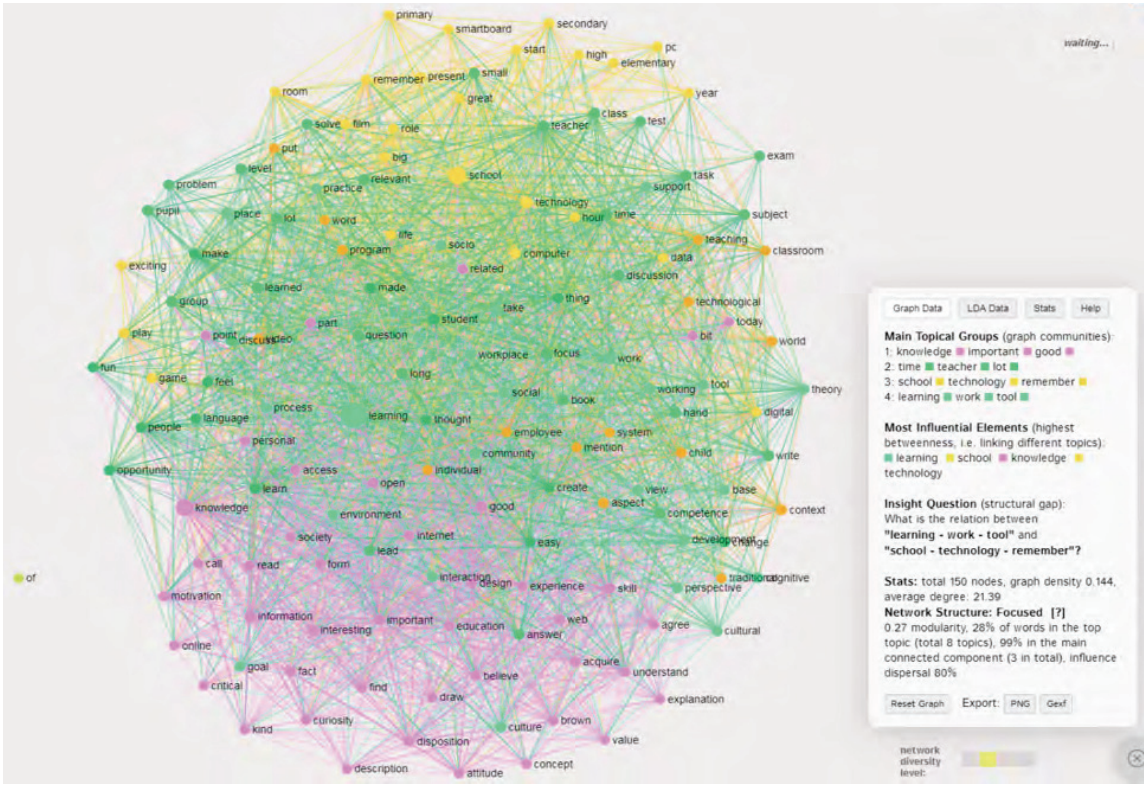

Figure 4. InfraNodus interface visualizing Week 4's main topics and graph metrics

5.4. Teachers' Interview Results

The four teachers were invited to reflect on the perceived value of using LA visualizations. Two broad themes surfaced across these interviews: 1) the value of LA visualizations; and 2) challenges concerning LA visualizations. These are further discussed below.

5.4.1. Theme 1: Value of LA Visualizations

The value of LA visualizations perceived by the teachers were categorized broadly into the three sub-themes of supporting LD, detecting the quality of online discourse, and facilitating teacher–student discussions. Table 2 illustrates the themes and sample extracts of the quotes as exemplifications of themes identified.

Table 2. Perceived Value of LA Sub-Themes, Sample Extracts, and Interview Questions

Sub-Themes	Sample Extracts	Interview Questions
Supporting LD decisions	"The networks can tell me if students responded to the discussion forum as asked by my looking at the nature of the networks or number of nodes" (T4)	What is your impression about these visualizations?
Detecting the quality of online discourse	"The visualizations highlight very high presentation, of course, content knowledge and provide a benchmark for gaining a comprehensive picture of students' online learning processes" (T1)	How do they link to the intended discussion activities?
Facilitating teacher–student discussions	"For example, for this week, I don't see the word 'skills,' yet I expected it to be central to the discussion; I can then ask students if they found the term hard to conceptualize and then build a discussion around that" (T2)	How would you use these visualizations to inform your design practice?

Supporting Learning Design Decisions: The teachers found that the information provided by the LA visualizations could be used to inform the redesign of their courses and face-to-face lectures. For example, two teachers expressed that the

visualizations could be useful in understanding how students responded to the tasks provided and how their responses related to the pedagogical intentions of the task. For instance, one teacher denoted the importance of text and social network visualizations in identifying the most and least active students as well as student knowledge of the course content ahead of the classroom meetings. In addition, on the checkpoint analytics provided by Canvas, one teacher said that these kinds of analytics can provide information about the design of the course that could support the modification of in-classroom lectures. Similarly, T4 mentioned that according to the text network visualizations (Week 3), some key concepts from the required readings such as "lego" were detected under the main topical groups, which means that the students had utilized the required course literature. In particular, teachers thought that such visualizations are handy for very large courses. As T3 noted, "In a course of about 200 students, where it is unrealistic to read through all the comments, the visualizations could be absolutely very productive."

Facilitating Teacher–Student Discussions: Teachers valued the potential of LA visualizations (e.g., text and network analysis) to prompt discussions between students and teachers. For example, T2 mentioned that during the lectures, the text network analysis outputs could be used to create a discussion around the structural gap identified by the text network analysis tool InfraNodus (see Table 1). In this regard, the teachers expressed that to achieve the best outcome of the LA visualizations, they would need to share the outputs with the students throughout the course. One representative comment came from T1 who pointed out, "I think it could be interesting to show them to students, tell them that this represents what they think, and then have a discussion around it." Another teacher stressed the same point: "I find the visualizations useful for me as a teacher, but it is necessary that the students are also presented with the same output" (T3).

Detecting the Quality of Online Discourse: LA visualizations could help teachers understand student online learning processes and how they are connected to the LD. As one teacher commented, social network visualizations could provide insight into which topics and questions generate debate among students. More so, T3 stated, "In theory, the importance of something like this is to identify a thread that most of the students responded to and then take a close look at that thread."

5.4.2. Theme 2: Challenges of LA Visualizations

The teachers highlighted some challenges associated with the potential use of LA visualizations. These challenges were categorized broadly into two sub-themes: 1) sophisticated LA visualizations; and 2) unclear demonstration of student knowledge construction processes (see Table 3).

Table 3. Challenges of LA Visualizations Subthemes, Sample Extracts, and Interview Questions

Sub-Themes	Sample Extract	Interview Questions
Sophisticated LA visualizations	"The text networks are so dense and contain so many links so I cannot interpret them well" (T2)	What are the challenges associated with the use of these LA visualizations?
Unclear demonstration of student knowledge construction processes	"What I still miss from the visualizations is the actual excerpts from students' discussions and tracking of student knowledge-building processes" (T3)	What kind of visualizations would you like to receive to inform your practice?

Sophisticated LA Visualizations: While teachers found the LA visualizations interesting, three of them were concerned about their sophisticated nature, which made their potential use in practice difficult. For example, T1 felt that the text networks were so dense and contained so many links that the detail impeded the extraction of meaningful insights, especially for LA novices. In this regard, T2 expressed the need for aggregated metrics for easy interpretation.

Demonstrating Student Knowledge Construction Processes: Another challenge concerned the failure of the visualizations to demonstrate student knowledge development processes. Thus, teachers voiced concerns about their utility in understanding student learning processes and informing LD. In this regard, teachers asked for additional and more in-depth information to support the meaningful translation of the visualizations into relevant pedagogical actions.

Overall, despite some reservations, teachers explicitly expressed the value of the LA visualizations in several ways. For example, the teachers found them to be informative about the flow of the course, which could be used to make necessary modifications throughout the process. According to the teachers, the visualizations raised their awareness of the quality of the student online discourse by identifying the main themes and their magnitude in online discussions. The LA visualizations could also facilitate discussions between teachers and students. However, for LD decisions to be made based on these outputs, the teachers emphasized the need to share the LA visualizations in real time while the course is running. For example, in the current study, the presentation of the visualizations at the end of the course limited the ability to make changes to the course during the semester. Some teachers felt that if they had received the visualizations earlier, they could have made changes to the design of their courses. While the regular provision of data to the teachers might be overwhelming or require a lot of work

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for the researcher, using automated approaches could address the challenge. Moreover, teachers suggested the need to keep LA visualizations simple but with enough details to gain a richer understanding of student learning processes. Such insights from the teachers validate and confirm what Rienties and Toetenel (2016) found regarding the need to present LA visualizations in a pedagogically meaningful manner to allow teachers to make connections between them and their LDs. Moreover, as emphasized in previous research (Rodríguez-Triana et al., 2015), it is important to keep the visualizations simple so that teachers can derive meaning from them. In this regard, researchers and LMS designers should not provide data to teachers for them to interpret but instead provide them with answers to the questions they seek to answer about the teaching and learning processes (Buckingham Shum, Ferguson, & Martinez-Maldonado, 2019). This can be achieved through LA plugins that provoke simple but productive sense-making by the teachers (Martinez-Maldonado, Kay, Yacef, & Schwendimann, 2012).

6. Limitations and Future Work

Some limitations affect the generalizability and interpretation of the findings of this exploratory study. First, the conclusions of the study are limited by its focus on data collected from a single course, with a small sample size of 30 students and four teachers from the same academic discipline. LA needs do, of course, vary between different disciplines. Second, the lack of consent from the six students limited the ability to have a full network. Nonetheless, the non-consenting students never participated in all discussions and were not part of the central discussion actors. Lastly, presenting the visualizations at the end of the course limited the teachers' ability to make changes to the LD during the course. These limitations will inform the next phase of our LA–LD research. Several further research lines have been identified:

1. Sharing LA visualizations with teachers and students during the course to support timely LD adaptations
2. Integrating teacher-user friendly LA visualization tools (e.g., Quantext [quantext.org]) in the Canvas LMS to provide simple and pedagogically relevant visualizations of checkpoint and process analytics, which would support easier application by the teachers
3. Providing visualizations representing student knowledge networks to both teachers and students
4. Using larger samples to validate these initial findings

7. Conclusion

In this study, we examined the potential of LA as a means to provide important insights to help teachers improve their LDs. To do so, we analyzed Canvas activity metrics, discussion forum content, and interactions from a semester-long bachelor-level course at a Norwegian University. The first research question investigated whether LA visualizations generated from different sets of process and checkpoint analytics could provide informative insights to support LD decisions. The findings reveal that analyzing different levels of analytics (e.g., process and checkpoint) could provide important information about student online learning processes (i.e., course access, course performance, discussion forum activities, and topics discussed), which can be used as a reflective resource by teachers to make informed LD decisions. Some of our findings indicated a discrepancy between checkpoint analytics (e.g., the total time spent online and actual student participation). This finding demonstrates that it is important to complement checkpoint analytics with a more focused analysis (i.e., process analytics) that considers the student's actual information processing and knowledge application (Lockyer et al., 2013).

The second research question explored teachers' perceived value of using LA visualizations as tools to evaluate and make productive, timely, informed LD decisions. The findings indicate that teachers perceive LA visualizations as important for gaining insight into the flow of the course, identify which LD elements should be revised, initiate teacher–student interactions, and assess the quality of the online discourse. Teachers argued that such insights could support inquiry into student learning activities and improve the relevance of in-class lectures. The teachers also voiced concerns about the LA visualizations; in particular, they were concerned about the sophisticated visualizations and the failure to demonstrate student knowledge construction processes. Thus, they suggested providing clear, more in-depth information (e.g., knowledge development networks) and simplified LA visualizations, which would hide unnecessary complexity but be detailed enough to be informative and still leave opportunities for teacher interpretation.

We extended the existing research on LA and LD in four ways. First, from a research perspective, this study provides detailed descriptions of how researchers can simultaneously use multiple levels of analytics to provide insights into the status of student online learning activities and enable relevant interpretations of the results. The combination of different approaches in this study supports the general claim that the most benefit can be expected from combining different types of analytics data and techniques since doing so provides a richer basis for understanding the connection between LA and LD (Haya et al., 2015). Second, from a teacher perspective, this study demonstrates how teachers can generate valuable insight into student learning activities based on LA visualizations (i.e., social and text network diagrams), which provides them with an opportunity to reflect on their practice and make timely adaptations to their LDs. Third, we provide teacher perspectives on LA visualizations

and their impact on LD. The issues highlighted by instructors (i.e., the need to keep visualizations simple) offer useful, practical guidelines to researchers and LA tool designers regarding the nature of the outputs and tools needed by teachers. Finally, we used the checkpoint and process analytics framework as a guide for the collection and analysis of relevant analytics data and how it connects to pedagogical objectives. While this framework is at a high descriptive level, suggesting no tools to support the collection and analysis of relevant analytics, we found it useful in providing a lens through which to select, interpret, and gain actionable insights for the refinement and redesign of learning activities. In this regard, we have contributed towards the limited validation of LA frameworks in practice. The aim is that this research and the implications derived from it will be a step towards informed LD by teachers and the design of relevant LA tools to support the alignment between LA and LD.

Declaration of Conflicting Interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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References

Agostinho, S. (2011). The use of a visual learning design representation to support the design process of teaching in higher education. *Australasian Journal of Educational Technology, 27*(6). https://https://dx.doi.org/10.14742/ajet.923

Alhadad, S. S., & Thompson, K. (2017). Understanding the mediating role of teacher inquiry when connecting learning analytics with design for learning. *Interaction Design and Architecture(s) Journal, 33*, 54–74. Retrieved from https://eprints.qut.edu.au/202493/1/62149001.pdf

Andersen, R., & Mørch, A. I. (2016). Mutual development in mass collaboration: Identifying interaction patterns in customer-initiated software product development. *Computers in Human Behavior*, *65*, 77–91. https://dx.doi.org/10.1016/j.chb.2016.08.005

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. *Proceedings of the 6th International Conference on Learning Analytics and Knowledge* (LAK '16), 25–29 April 2016, Edinburgh, UK (pp. 329–338). New York, NY: ACM. https://dx.doi.org/10.1145/2883851.2883944

Bennett, S., Agostinho, S., & Lockyer, L. (2015). Technology tools to support learning design: Implications derived from an investigation of university teachers' design practices. *Computers & Education, 81*, 211–220. https://dx.doi.org/10.1016/j.compedu.2014.10.016

Benesty, J., Chen, J., Huang, Y., & Cohen, I. (2009). Pearson correlation coefficient. In I. Cohen, Y. Huang, J. Chen, & J. Benesty (Eds.), *Noise reduction in speech processing* (pp. 1–4). Berlin, Germany: Springer. https://dx.doi.org/10.1007/978-3-642-00296-0_5

Buckingham Shum, S., Ferguson, R., & Martinez-Maldonado, R. (2019). Human-centred learning analytics. *Journal of Learning Analytics, 6*(2), 1–9. https://dx.doi.org/10.18608/jla.2019.62.1

Bonk, C. J., & Graham, C. R. (2012). *The handbook of blended learning: Global perspectives, local designs.* Hoboken, NJ: John Wiley & Sons. Retrieved from https://books.google.no/books?hl=en&lr=&id=2u2TxK06PwUC&oi=fnd&pg=PT14&dq=

Conole, G. (2012). *Designing for learning in an open world* (Vol. 4). Leicester, UK: Springer Science & Business Media. Retrieved from https://dl.uswr.ac.ir/bitstream/Hannan/130952/1/9781441985163.pdf https://dx.doi.org/10.1007/978-1-4419-8517-0

Dobozy, E., & Cameron, L. (2018). Special issue on learning design research: Mapping the terrain. *Australasian Journal of Educational Technology, 34*(2). https://dx.doi.org/10.14742/ajet.4390

Eradze, M., Rodriguez Triana, M. J., & Laanpere, M. (2017). Semantically annotated lesson observation data in learning analytics datasets: A reference model. *Interaction Design and Architecture(s) Journal, 33*, 75–91. Retrieved from http://www.mifav.uniroma2.it/inevent/events/idea2010/doc/33_4.pdf

Fritz, J. (2016). LMS course design as learning analytics variable. In J. Greer, M. Molinaro, X. Ochoa, & T. McKay (Eds.), *Proceedings of the 1st Learning Analytics for Curriculum and Program Quality Improvement Workshop* (PCLA 2016), 25 April 2016, Edinburgh, UK (pp. 15–19). Retrieved from https://www.semanticscholar.org/paper/LMS-Course-Design-As-Learning-Analytics-Variable-Fritz/be7e8fe65384513355467e56cc84b36829669482

Gašević, D., Dawson, S., Rogers, T., & Gasevic, D. (2016). Learning analytics should not promote one size fits all: The effects of instructional conditions in predicting academic success. *The Internet and Higher Education, 28*, 68–84. https://dx.doi.org/10.1016/j.iheduc.2015.10.002

Griffiths, D. (2017). The use of models in learning design and learning analytics. *Interaction Design and Architecture(s) Journal, 33*, 113–133. Retrieved from http://ubir.bolton.ac.uk/1330/1/Griffiths%20D%20IxD%26A%20article.pdf

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*. Wellington, Australia: Ako Aotearoa – The National Centre for Tertiary Teaching Excellence. Retrieved from https://ako.ac.nz/assets/Knowledge-centre/NPF-15-008

Haya, P. A., Daems, O., Malzahn, N., Castellanos, J., & Hoppe, H. U. (2015). Analysing content and patterns of interaction for improving the learning design of networked learning environments. *British Journal of Educational Technology, 46*(2), 300–316. https://dx.doi.org/10.1111/bjet.12264

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. https://dx.doi.org/10.1111/bjet.12645

Harel, D., & Koren, Y. (2001). A fast multi-scale method for drawing large graphs. In J. Marks (Ed.) *Graph drawing. GD 2000. Notes in computer science* (Vol. 1984). Berlin, Germany: Springer. https://dx.doi.org/10.1007/3-540-44541-2_18

Ifenthaler, D., Gibson, D., & Dobozy, E. (2018). Informing learning design through analytics: Applying network graph analysis. *Australasian Journal of Educational Technology, 34*(2), 117–132. https://dx.doi.org/10.14742/ajet.3767

Kaliisa, R., Mørch, A. I., & Kluge, A. (2019). Exploring social learning analytics to support teaching and learning decisions in online learning environments. In M. Scheffel, J. Broisin, V. Pammer-Schindler, A. Ioannou, & J. Schneider (Eds.), *Transforming learning with meaningful technologies. Proceedings of the 14th European Conference on Technology Enhanced Learning (EC-TEL 2019), 16–19 September 2019, Delft, The Netherlands. Lecture Notes in Computer Science* (Vol. 11722) (pp. 187–198). Cham, Switzerland: Springer. https://dx.doi.org/10.1007/978-3-030-29736-7_14

Kaliisa, R., Kluge, A., & Mørch, A. I. (in press a). Overcoming the challenges to learning analytics adoption at the practitioner level: A critical analysis of 18 learning analytics frameworks. *Scandinavian Journal of Educational Research.*

Kaliisa, R., Kluge, A., & Mørch, A. I.. (in press b). "My point of departure for analytics is extreme skepticism": Implications derived from an investigation of university teachers' learning analytics perspectives and design practices. *Technology, Knowledge & Learning*.

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. https://dx.doi.org/10.18608/jla.2014.12.3

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) Journal, 33*, 92–112. Retrieved from http://www.mifav.uniroma2.it/inevent/events/idea2010/doc/33_5.pdf

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

Macfadyen, L. P., & Dawson, S. (2010). Mining LMS data to develop an "early warning system" for educators: A proof of concept. *Computers & Education, 54*(2), 588–599. https://dx.doi.org/10.1016/j.compedu.2009.09.008

Macfadyen, L. P., & Dawson, S. (2012). Numbers are not enough: Why e-learning analytics failed to inform an institutional strategic plan. *Journal of Educational Technology & Society, 15*(3), 149–163. Retrieved from https://www.jstor.org/stable/10.2307/jeductechsoci.15.3.149

Mangaroska, K., & Giannakos, M. N. (2018). Learning analytics for learning design: A systematic literature review of analytics-driven design to enhance learning. *IEEE Transactions on Learning Technologies, 12*(4), 516–534. https://dx.doi.org/10.1109/TLT.2018.2868673

Martinez-Maldonado, R., Kay, J., Yacef, K., & Schwendimann, B. (2012). An interactive teacher's dashboard for monitoring groups in a multi-tabletop learning environment. In S. A. Cerri, W. J. Clancey, G. Papadourakis, & K. Panourgia (Eds.), *Proceedings of the 11th International Conference on Intelligent Tutoring Systems (ITS 2012), 14–18 June 2012, Chania, Greece,. Lecture notes in computer science* (Vol. 7315) (pp. 482–492). Berlin, Germany: Springer. https://dx.doi.org/10.1007/978-3-642-30950-2_62

McKenney, S., & Mor, Y. (2015). Supporting teachers in data-informed educational design. *British Journal of Educational Technology, 46*(2), 265–279. https://dx.doi.org/10.1111/bjet.12262

Michos, K., Hernández-Leo, D., & Albó, L. (2018). Teacher-led inquiry in technology-supported school communities. *British Journal of Educational Technology, 49*(6), 1077–1095. https://dx.doi.org/10.1111/bjet.12696

Mor, Y., Ferguson, R., & Wasson, B. (2015). Learning design, teacher inquiry into student learning and learning analytics: A call for action. *British Journal of Educational Technology, 46*(2), 221–229. https://dx.doi.org/10.1111/bjet.12273

Melero, J., Hernández-Leo, D., Sun, J., Santos, P., & Blat, J. (2015). How was the activity? A visualization support for a case of location-based learning design. *British Journal of Educational Technology*, *46*(2), 317–329. https://dx.doi.org/10.1111/bjet.12238

Nguyen, Q., Huptych, M., & Rienties, B. (2018). Linking students' timing of engagement to learning design and academic performance. *Proceedings of the 8th International Conference on Learning Analytics and Knowledge* (LAK '18), 5–9 March 2018, Sydney, NSW, Australia (pp. 141–150). New York, NY: ACM. https://dx.doi.org/10.1145/3170358.3170398

Nguyen, Q., Rienties, B., Toetenel, L., Ferguson, R., & Whitelock, D. (2017). Examining the designs of computer-based assessment and its impact on student engagement, satisfaction, and pass rates. *Computers in Human Behavior, 76*, 703–714. https://dx.doi.org/10.1016/j.chb.2017.03.028

Paranyushkin, D. (2019). InfraNodus: Generating insight using text network analysis. *Proceedings of the 28th International Conference on World Wide Web* (WWW '19), 13–17 May 2019, San Francisco, CA, USA (pp. 3584–3589). New York, NY: ACM. https://dx.doi.org/10.1145/3308558.3314123

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

Rienties, B., Cross, S., & Zdrahal, Z. (2017). Implementing a learning analytics intervention and evaluation framework: What works? In D. Kei Daniel (Ed.) *Big data and learning analytics in higher education* (pp. 147–166). Cham, Switzerland: Springer. https://dx.doi.org/10.1007/978-3-319-06520-5_10

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. https://dx.doi.org/10.1016/j.chb.2016.02.074

Rodríguez-Triana, M. J., Martínez-Monés, A., Asensio-Pérez, J. I., & Dimitriadis, Y. (2015). Scripting and monitoring meet each other: Aligning learning analytics and learning design to support teachers in orchestrating CSCL situations. *British Journal of Educational Technology, 46*(2), 330–343. https://dx.doi.org/10.1111/bjet.12198

Samuelsen, J., Chen, W., & Wasson, B. (2019). Integrating multiple data sources for learning analytics: Review of literature. *Research and Practice in Technology Enhanced Learning, 14*(11), 1-20. https://dx.doi.org/10.1186/s41039-019-0105-4

Shibani, A., Knight, S., & Shum, S. B. (2019). Contextualizable learning analytics design: A generic model and writing analytics evaluations. *Proceedings of the 9th International Conference on Learning Analytics and Knowledge* (LAK '19), 4–8 March 2019, Tempe, AZ, USA (pp. 210–219). New York, NY: ACM. https://dx.doi.org/10.1145/3303772.3303785

Smith, M. A., Shneiderman, B., Milic-Frayling, N., Mendes Rodrigues, E., Barash, V., Dunne, C., & Gleave, E. (2009). Analyzing (social media) networks with NodeXL. *Proceedings of the 4th International Conference on Communities and Technologies* (C&T '09), 25–27 June 2009, University Park, PA, USA (pp. 255–264). New York, NY: ACM. https://dx.doi.org/10.1145/1556460.1556497

Wise, A. F., & Jung, Y. (2019). Teaching with analytics: Towards a situated model of instructional decision-making. *Journal of Learning Analytics, 6*(2), 53–69. https://dx.doi.org/10.18608/jla.2019.62.4

Wise, A. F., & Shaffer, D. W. (2015). Why theory matters more than ever in the age of big data. *Journal of Learning Analytics, 2*(2), 5–13. https://dx.doi.org/10.18608/jla.2015.22.2

Article 4

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IV

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ORIGINAL RESEARCH

CADA: a teacher-facing learning analytics dashboard to foster teachers' awareness of students' participation and discourse patterns in online discussions

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Abstract

Despite the potential of learning analytics (LA) to support teachers' everyday practice, its adoption has not been fully embraced due to the limited involvement of teachers as co-designers of LA systems and interventions. This is the focus of the study described in this paper. Following a design-based research (DBR) approach and guided by concepts from the socio-cultural perspective and human-computer interaction (HCI), we design, test, and evaluate a teacher-facing LA dashboard, the Canvas Discussion Analytics Dashboard (CADA), in real educational settings. The goal of this dashboard is to support teachers' roles in online environments through insights into students' participation and discourse patterns. We evaluate CADA through 10 in-depth interviews with university teachers to examine their experiences using CADA in seven blended undergraduate and graduate courses over a one-year period. The findings suggest that engaging teachers throughout the analytics tool design process and giving them control/agency over LA tools can favour their adoption in practice. Additionally, the alignment of dashboard metrics with relevant theoretical constructs allows teachers to monitor the learning designs and make course design changes on the fly. The teachers in this study emphasise the need for LA dashboards to provide actionable insights by moving beyond *what things are* towards *how things should b*e. This study has several contributions. First, we make an artefact contribution (e.g. CADA), an LA dashboard to support teachers with insights into students' online discussions. Second, by leveraging theory, and working with the teachers to develop and implement a dashboard in authentic teaching environments, we make an empirical, theoretical and methodological contribution to the field of learning analytics and technology enhanced learning. We synthesise these through practical design and implementation considerations for researchers, dashboard developers, and higher education institutions.

Keywords Teacher facing learning analytics dashboard · Asynchronous online discussions · Learning design · Participation · Discourse

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1 Introduction

Improvements in technology have generated increased interest in gathering data that provide insights into how students engage with learning materials in both online and physical learning settings. By collecting, analysing, and measuring student data—a process known as learning analytics (LA)—teachers and other educational stakeholders aim to use the formative and summative feedback provided by LA to monitor, reflect on, and optimise students' learning and the teaching process (Bodily & Verbert, 2017; Ifenthaler et al., 2018), particularly in technology-mediated learning environments, where teachers tend to struggle to monitor and support students' active learning (van Leeuwen et al., 2019). Part of the LA research effort has been devoted to the development of dashboards, interactive visual displays that summarise and visualise information for teachers based on students' learning patterns and interactions (Verbert et al., 2014; Few, 2013). However, the use of dashboards and the evidence of their impact on teachers' everyday practice remain limited. This shortcoming can partially be explained by teachers' limited involvement in the planning and design processes of LA tools (Martinez-Maldonado et al., 2020), which are typically designed by LA researchers and technology vendors, who tend to focus more on these tools' technical aspects while neglecting their educational and pedagogical aspects (Kaliisa, et al., 2021a). Buckinghum Shum et al. (2019) and Van Harmelen and Workman (2012) argue that for LA implementation to be successful, its technical, social, and pedagogical dimensions require consideration since LA exists as part of a socio-technical system.

The goal of this study was to describe the planning, designing, implementation, and evaluation of a teacher-facing LA dashboard, herein referred to as the Canvas Discussion Analytics Dashboard (CADA). We used a participatory approach—in particular, a design-based research (DBR) methodology and principles of human–computer interaction (HCI)—to iteratively develop the dashboard with teachers based on their pedagogical needs and the LA preferences identified during the problem identification phase. The developed dashboard combines structural and content analysis to inform teachers about students' participation, engagement, and the discourse patterns that arise from online discussions. This study makes several contributions to the technology-enhanced learning and LA literature. First, we introduce CADA, an LA dashboard that can be integrated as a plugin into Canvas and other learning management systems (LMSs) to support teachers with timely insights into students' online discussions. Second, by evaluating CADA with seven teachers and nine courses over one year, we provide empirical, theoretical and methodological insights and lessons gained through the participatory iterative design process of CADA as a set of design and implementation principles for researchers and developers of LA dashboards.

1.1 Background and related literature

1.1.1 Roles and challenges of teachers in online learning environments

The increasing use of digital learning tools and platforms has enabled the transformation of face-to-face courses into blended courses and courses in which all the information is delivered and accessible online (Børte et al., 2020). Learning management systems (LMSs) such as Canvas and Moodle support student learning by providing content online, allowing for online collaborative activities (e.g. asynchronous online discussions) beyond the physical

classroom. As a result, teachers are expected to design learning activities and provide their students with the guidance to stimulate actions necessary for learning (van Leeuwen et al., 2019). However, teachers often struggle to monitor and support active learning among their students online (Damsa & de Lange et al., 2019). This is partially due to the large number of tasks teachers have and the amount of information produced during online learning activities, as this can overwhelm teachers, increase their cognitive load, and lessen their focus on students' specific needs (Van Leeuwen et al., 2019). Thus, supporting tools such as dashboards could be used to inform and empower teachers with quicker insights into students' participation and engagement patterns. This study intends to contribute to this area. In the following section, we provide a brief account of existing research on LA dashboards, paying particular attention to teacher-facing LA dashboards.

1.1.2 Supporting teachers in online learning environments through LA dashboards

LA dashboards combine automated analysis techniques with interactive visualisations for effective understanding, reasoning, and decision-making based on large, complex datasets on student activity (Schwendimann et al., 2016; Jivet et al., 2017). Teachers can use the insights gained from these dashboards as tools for evaluating and reflecting on their teaching practice (Keim et al., 2008), and track students' social and cognitive progress (Van Leeuwen et al., 2015; Bakharia & Dawson, 2011). For example, if a dashboard provides information about the nature and context of students' discussion topics, this information can be used to identify misconceptions and guide students in the right direction. Teacher-facing dashboards can be perceived as technological artefacts that provide indirect support to teachers during online learning activities (Rummel, 2018).

Studies on teacher-facing dashboards include Bakharia and Dawson's (2011) work, which introduced the social network analysis pedagogical platform (SNAPP). SNAPP produces visualisations and metrics to assist with the evaluation of participation and social mode dimensions in online discussions. The Student Relationship Engagement System is another LA dashboard that allows teachers to personalise their engagement with large cohorts of students, using data from those students to inform their teaching decisions (Dollinger et al., 2019). van Leeuwen et al. (2019) developed three teacher-facing dashboards that offer different information layers (mirroring, advising, and alerting), while Herodotou et al. (2019) presented the Early Alert Indicators (EAI) dashboard, which examined the learning outcomes of more than 14,000 students in 15 undergraduate courses. Based on a sample of 559 teachers, the findings showed that most teachers who used the EAI dashboard only logged in occasionally, and their usage was inconsistent over time. This finding is consistent with Dazo et al. (2017), who examined analytic dashboard use by 14 teachers and found that most teachers accessed the analytics for only a very short time, making in-depth exploration difficult. The authors also reported that teachers struggled to interpret the data from the dashboard because the information was not presented in an actionable way, suggesting that most dashboards do not turn the patterns identified from student activities into possibilities for action (Keim et al., 2008). More recently, Martinez-Maldonado et al. (2020) followed a co-design approach to design for the effective use of translucent LA systems in the context of teamwork in a clinical simulation. The findings from four active teachers and subject coordinators showed that the proxy visualisations generated during the process helped teachers reflect on their pedagogical practices, particularly by using the

visualised traces of nurses' activity to revise the learning design. Positive outcomes were also reported by Wise and Jung (2019), who reported that teachers viewed dashboards as an important tool to support their teaching practices by informing relevant interventions and revising course design.

Despite these advances, this line of LA research still has gaps. First, while teacher-facing dashboards are becoming increasingly available, their use in teachers' everyday practice is limited (Vieira et al., 2018). This can be partially explained by the limited involvement of teachers in the design of LA dashboards (Dollinger et al., 2019), with minimal examples of mature and transparent collaboration with stakeholders in the development of LA tools in the literature to date (Buckingham Shum et al., 2019; Wise & Jung, 2019; Holstein et al., 2018; van Leeuwen et al., 2019; Martinez-Maldonado et al., 2020). Yet, the usefulness of this technology should be measured based on its value to actual users (e.g. teachers) (Dollinger et al., 2019). Second, dashboards are only minimally aligned with learning theory (Gasevic et al., 2016), which makes it difficult to choose the nature of the data to collect and visualise to teachers (Jivet et al., 2017). This means that more work is needed to design LA dashboards grounded within the learning sciences, with the hope of increasing their relevance to teachers' pedagogical needs. Lastly, most existing LA dashboards are standalone, meaning that they are not integrated within popular LMSs. This implies that teachers and researchers who are interested in using such tools must export student activity data into third-party tools, which is labour-intensive work. In real practice, given teachers' time constraints, the use of such tools becomes impossible.

1.2 The present study

To help close the abovementioned gaps, this paper presents a participatory DBR study that involves the co-design, implementation, and evaluation of an LA dashboard together with teachers in higher education. This study is guided by the following research questions:

RQ1: What are teachers' experiences using CADA?

This question sought to explore the extent to which the teachers who participated in the design and implementation process of CADA found it useful for supporting their awareness of student learning in online discussions. In particular, we wanted to explore the teachers' motivations, their reactions to and use of the dashboard features, the challenges they faced, and their suggestions for improving the dashboard.

RQ2: How can we design and implement LA dashboards that meet teachers' pedagogical needs and expectations?

With this question, we wanted to reflect on the experiences from the different case studies to understand what works during the participatory development of LA systems with teachers, as well as the nature of design, implementation, and evaluation considerations to learn from the process and inform future research.

2 The Learning analytics dashboard development process: a design-based research approach

The design of the Canvas analytics dashboard (CADA) was informed by a design based research (DBR) framework (Barab & Squire, 2004), which follows an iterative approach to

exploring, designing, implementing, and evaluating innovative artefacts to solve a real educational problem based on collaboration between researchers and practitioners in authentic settings (Van den Akker et al., 2006; Reeves, 2006). DBR is often used in the learning sciences, which, using theoretical constructs as a starting point; iteratively develop the tool with stakeholders by testing it in real settings. The Learning Awareness Tools – User eXperience method (LATUX) (Martinez-Maldonado et al., 2015) also guided the iterative design stages. LATUX structures parts of the DBR process by emphasising the development of interface and awareness tools through five iterative design stages, which are briefly outlined below.

1) Stage 1: Problem identification.

The starting point for the development of CADA was to understand the challenges teachers face in their everyday practice and how LA can be used as a tool to deal with them. To meet this goal, an exploratory study with 16 teachers at two Norwegian universities was conducted. This stage was exploratory, and the results have already been reported elsewhere Kaliisa et al., 2021b). The findings from this stage showed that teachers struggled to make timely learning design changes and to understand students' learning behaviours within online learning environments. Teachers found a need for LA that indicates student participation and discourse with online activities in a timely manner to support timely changes. These insights were used as a starting point from which to explore a range of candidate LA visualisations based on students' online activities that could address the needs and challenges of teachers.

2) Stage 2: Creation of a low-fidelity prototype.

The next stage explored a range of candidate LA visualisations based on both checklist and process LA. These visualisations were shared with teachers as paper prototypes and grounded in theoretical concepts to address the teachers' needs. The results from this stage are beyond the scope of this paper but have been reported elsewhere (Kaliisa, et al., 2020). In summary, the results based on the interviews conducted with four teachers showed that the paper prototypes were perceived by the teachers as informative in terms of students' online behaviours and could provide insights into real-time course design changes. At the same time, the teachers found some of the visualisations too complex to understand and requested that they be presented in a simple and timely manner to support timely course adaptations. It is from this background that a high-fidelity prototype (CADA) that could be integrated into the same teaching environment used by teachers was developed.

3) Stage 3: Creation of a high-fidelity prototype.

Based on the insights from Stages 1 and 2, an automated, high-fidelity prototype (CADA) (illustrated in Fig. 1) that sits within a Canvas course as a module or plugin was developed to automatically analyse the online discussions on Canvas in teacher-facing visualisations. To add authenticity before piloting with actual courses, we used sample data from an online discussion forum to evaluate how the users interacted with the tool. The design process was composed of a team of people with a wide range of skills and perspectives (designers, programmers, engineers, researchers, and learning scientists), as recommended by DBR (Barab, 2006). This enabled the development of a dashboard aligned with the needs of the different stakeholders while maintaining the necessary technical and design requirements. The development process went through several iterations, with changes made to the high-fidelity prototype based on the feedback gained from the teachers who participated in the initial pilot studies. In what follows, we introduce the features and the theoretical grounding

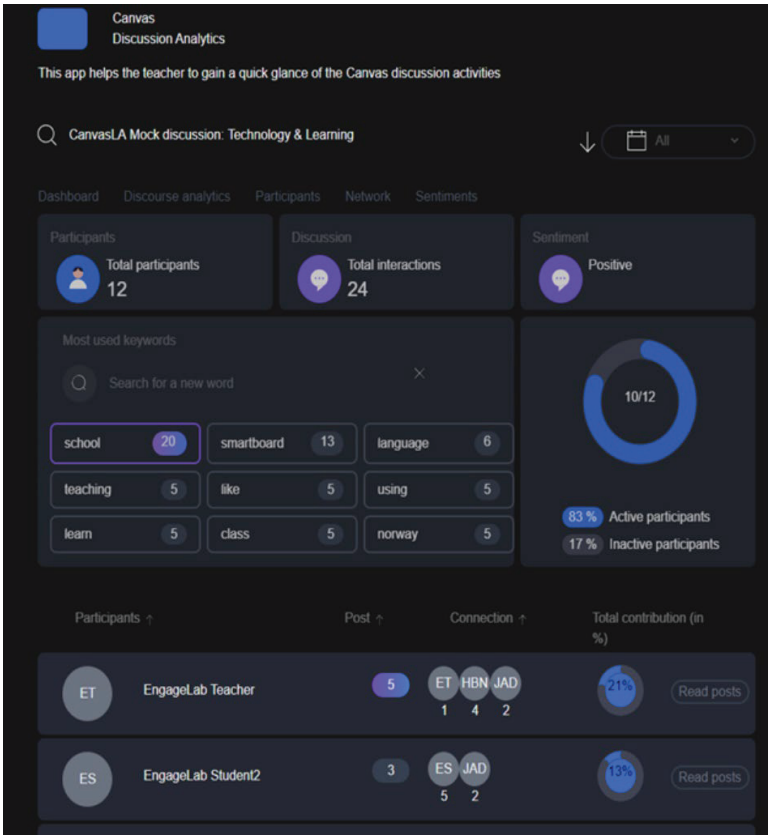

Fig. 1 The CADA interface: General participation analytics (top), summary of the key concepts (middle), and connections between the individual students (bottom)

of CADA, before providing details on how it was implemented and evaluated in authentic university courses.

2.1 Introducing CADA

CADA is an LA dashboard that visualises the participation, social networks, sentiment, and concepts used by students within the Canvas LMS discussion forum on a need-to-know basis. The dashboard, which is based on the automated analysis of the discussion forum posts and interactions patterns, provides an overview for both structural and content-level analytics, which teachers can use to see students' participation in online discussions at a glance through simple visualizations such as sociograms, which illustrate students' discourse structures and how students share knowledge and build on each other's contributions. Besides, the dashboard provides a detailed and fine-grained analysis of discourse, which is summarized in terms of key concepts, individual posts and sentiment. The teachers can then use the insights gained as diagnostic tool to improve their teaching and inform their learning design. The CADA interface is presented in Fig. 1, with data from one of the intervention courses.

2.2 CADA's theoretical grounding

The design of CADA lent itself to principles from the learning sciences and human-computer-interaction (HCI) (Barab & Squire, 2004; Helander, 2014) to satisfy that it had a theoretical foundation and that stakeholders' needs in real life were met (Holstein et al., 2019). Thus, the meanings, interaction opportunities, functions, and attributes associated with the

dashboard were defined together with the teachers (Giacomin, 2014) but at the same time, considering theoretical perspectives. From HCI, we built on the principles of design, such as collaboration with stakeholders, signifiers, constraints, error prevention, and the reduction of cognitive load and decision-making time (Martinez-Maldonado et al., 2015). Further, CADA features elements from strategic and analytical dashboards (Few, 2006), such as the affordance for a quick overview of student engagement, thus enabling the teacher to drill into the underlying details for deeper meaning-making.

From the learning sciences perspective, the design of CADA was informed by a sociocultural perspective which is grounded in the work of the Russian psychologist Vygotsky (1978). In particular, we draw inspiration from Säljö (2002) concept of learning as the participation in, and mastery of, subject-specific discourses and practices mediated by artefacts (such as online discussions) (Säljö, 2002). Researchers in higher education have examined this issue for several decades, and active participation has been recognised as crucial to students' learning (Børte et al., 2020). Students' opportunities to discuss academic topics and issues together through evaluating information, reading, and commenting on fellow students' ideas and work, as well as receiving feedback on their own ideas from fellow students and teachers, are important ingredients for constructing a deeper understanding (Black & William, 2009). Thus, teachers need to be aware of student participation in subject-specific discourses to determine the types of feedback students need to move forward in their learning trajectories (Black & William, 2009; Dolonen & Ludvigsen, 2012). In this regard, drawing on the sociocultural concepts of mediation and artefacts, CADA can be understood as a tool to communicate students' participation and discourse patterns to the teachers and support the teachers' cognitive efforts in understanding these patterns.

Further, the sociocultural conception of language highlights that discourse, understood both as oral and written statements, is considered an important site for understanding individual student's learning through analyzing subject knowledge and student-student interactions (Knight & Littleton, 2015). Hence, these assumptions provided a theoretical rationale for focusing on language (as expressed in online discussions) as a key intellectual artefact, and a proxy for students' learning that together with teachers' pedagogical needs (identified through interviews), laid the foundation for CADA's main learning theoretical constructs of 'participation' and 'discourse.'

2.3 Features of CADA

- *The dashboard*: This feature provides teachers with a quick overview of the discussion activity within the course and access to filtering functions, such as the percentage of active and inactive participants, the total number of interactions, and an aggregated score of sentiments for a particular thread. The information displayed through this function can be customised by the teacher according to a specific week, discussion thread, or time frame.
- *Discourse analytics*: This feature displays the key topics discussed by the students within the selected discussion forum and the context in which they were used (see Fig. 2).
- *Participation*: This function contains information on students' participation metrics. It offers a detailed view of all the students participating on a forum, the number of posts and connections, and the percentage of total contributions for each student, which is

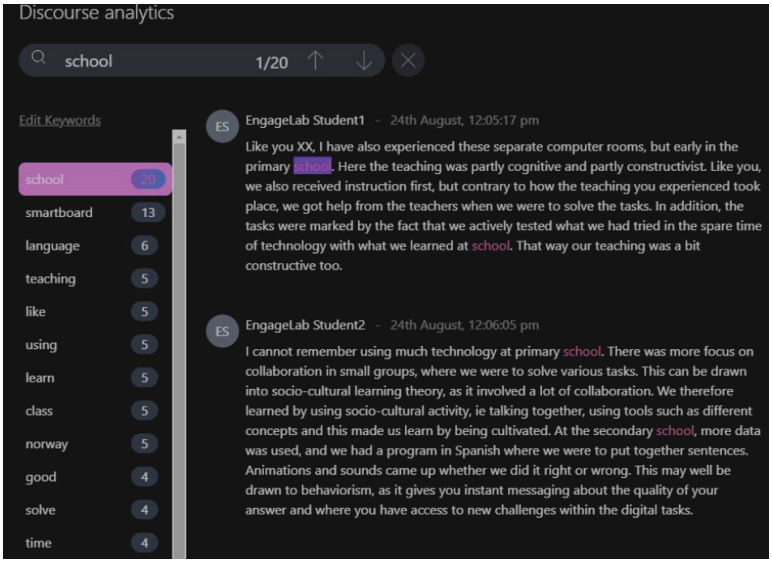

Fig. 2 CADA's discourse analytics showing discussion posts, key concepts and their context of use

calculated based on the size of the post. The teacher can also read all the posts associated with a particular student in one place, with time stamps on when the posts were made. Such insights could provide teachers with information such as whether and to what extent students participated in the discussion.

- *Network*: This function provides details on students' social interactions on a discussion forum, which might be useful for teachers interested in understanding how students relate to one another at the structural level (see Fig. 3).
- *Sentiment analysis*: This function analyses the sentiments attached to each discussion post using document-level sentiment classification granularity (Kagklis et al., 2015). Here, a discussion post—the most basic unit of analysis—is categorised as expressing an overall positive, neutral, or negative opinion. Previous findings indicate that sentiment expressed in online discussions is connected to students' performance and retention (Kagklis et al., 2015), implying that identifying students' sentiments could help to inform the effective design of learning activities.

4) Stage 4: Implementation and evaluation of CADA in pilot and real-world classrooms.

CADA's implementation was based on different courses and teachers' willingness to make design changes in their courses to accommodate the rollout. Before its implementation into authentic classroom contexts, the relevant ethical procedures were completed

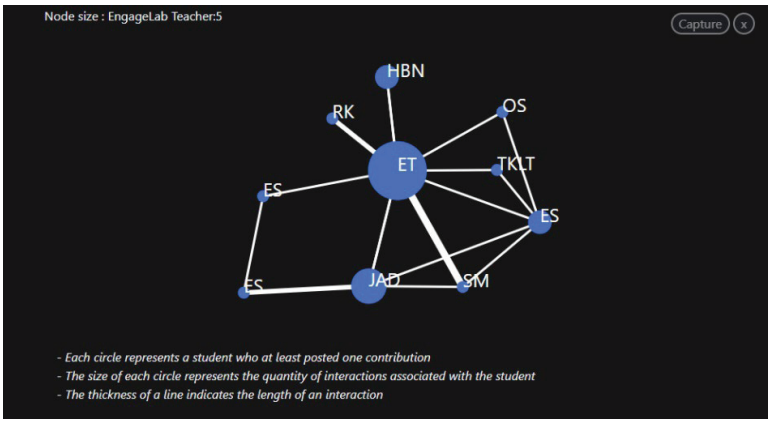

Fig. 3 CADA's social network diagram showing students' interactions in a discussion forum

through the national ethics committee and the university IT services team. Additionally, the researcher met with each of the teachers to introduce them to the dashboard, and instructions were provided to show them all the dashboard's features. The first implementation phase began in fall 2020, with six teachers and five courses. The initial automated dashboard implemented into the first iteration was a simplified version that served as a starting point. This version was later updated based on feedback from the teachers, and the second iteration contained improved design and pedagogical features. For example, some teachers requested an improved interface that was easier to navigate, with clear instructions for users while they selected discussion threads. The teachers also expressed the desire to display not only the key concepts used by students, but also the contexts in which the words were used. Additionally, in our first prototype, we experimented with a variety of chart types and ways of displaying data to teachers. For example, we initially displayed the participating students in the form of a graph; however, the teachers found this overwhelming and uninformative, especially in discussions with large numbers of students (more than 50). The new changes were then built into the revised dashboard, an approach consistent with the cyclic nature of DBR (Barab & Squire, 2004). The second iteration was completed in the spring semester of 2021, with four teachers and four courses. The teachers were interviewed about their user experiences during that time. Further details about the evaluation of CADA in authentic practice are provided below.

3 Study design

This study sought to gain insights into teachers' perspectives of and experiences with the use of CADA in practice. In this regard, a qualitative approach was employed to enable the exploration of teachers' experiences using CADA in authentic courses. Below we present the participants and the methods used to collect and analyse data about CADA's implementation.

3.1 Participants

The implementation of CADA involved seven teachers—four of whom had prior experience with analytics—representing nine different undergraduate- and graduate-level courses. All courses were offered online due to the coronavirus pandemic. Participation was voluntary, and only teachers teaching courses that included online discussions were involved. Three teachers were involved in both the exploratory stage (Stage 1) and the two cycles of CADA implementation; this was particularly helpful for examining how CADA had improved over time. Table 1 outlines the characteristics of the teachers who participated in the implementation and evaluation of CADA.

3.2 Data collection and analysis

3.2.1 Interviews

Cognitive stimulated interviews were conducted with the participating teachers, in which the interviews were held while the teachers ran through CADA's interface. Research shows

that cognitive stimulated interviews help participants to recall and reflect on the experience they are talking about, and provide researchers better insights into the way participants understand and interpret phenomenon (Dempsey, 2010; Wise & Jung, 2019). Each interview started with general questions about the teacher's background, experience, and motivation to participate in the intervention. The main part of the interview included three sections, which were answered while the participant went through the dashboard. These sections were (1) implementation and usage, which covered questions such as how the teacher implemented CADA, how they adopted the course design, constraints during the implementation, and the effort required; (2) value-added and future usage, which included questions such as the impact of the dashboard on their teaching practice, concerns about the dashboard, suggestions for improvement, and willingness to use the tool in the future; and (3) design and implementation considerations, which covered questions such as what did and did not work, how things should be done, and lessons learnt. The development of the interview questions was guided by the study's two research questions (e.g. what are teachers' experiences using CADA? and, how can we design and implement LA dashboards that meet teachers' pedagogical needs and expectations?). In addition, some of the questions were developed based on Kirkpatrick's (2009) evaluation model, which guided the deductive analysis of the interview transcripts. The interviews, which lasted between 25 and 40 min each, were held both online (e.g. via Zoom) and physically on an agreed-upon date. The participants gave their informed consent to participate, and all the interviews were audio-recorded and then transcribed verbatim by the first author.

Table 1 Participants and course profiles for CADA implementation

Teacher ID	Course size and format	Level	Teaching experience (yrs)	Iteration
T1	Seminars (more than 200 students)	Bachelors	< 5	IT1
T2	Lecture & seminar (20 students)	Masters	> 5	IT1
T3	Lecture and seminar (25)	Doctoral/ university staff	> 10	IT 1&2
T4	Lecture and seminar (40)	Bachelors	> 15	IT 1&2
T5	Lecture and seminar (40)	Bachelors	> 25	IT 1&2
T6	Lecture and seminar (70 students)	Bachelors	> 20	IT 1
T7	Lecture & Seminar (20 students)	Masters	< 5	IT2

3.2.2 Data analysis

The analysis of the interview data was guided by an abduction approach which combines deductive and inductive elements of analysis (Linneberg & Korsgaard, 2019). First, the interviews were transcribed verbatim by the first author. They were then coded deductively according to Kirkpatrick's (2009) model, which evaluates the results of programmes against

four levels of criteria (reaction, learning, behaviour, and results). To reduce the data, we sorted the data based on Kirkpatrick's (2009) four levels. Guided by this model, each interview response, which included a set of lines/utterances, was used as the unit of analysis. By doing so, we read the responses to establish whether they fit into the four pre-defined four levels of Kirkpatrick's evaluation model. By following this approach, we were able to focus the analysis on those issues regarded to be important in response to the research questions. Since Kirkpatrick's model was originally developed for evaluating training programmes, some levels were adapted using Few's (2009) design principles for dashboards. The fully adapted evaluation criteria are provided in Appendix A. The other codes were generated inductively through a thematic analysis approach (Braun & Clarke, 2012), where the codes and later themes were developed based on the patterns from the data. While developing the themes, we focused on both the semantic and latent features of the data. This process generated five main themes (see Figs. 2 and 5) relevant to the study's research questions. To ensure the data's validity, the coding was performed with another researcher who was not involved in the project. Social moderation was used to settle the differences in the coding process.

4 Results

4.1 RQ1. What are teachers' experiences using CADA?

Three main themes (see Fig. 4) were generated in response to the first research question.

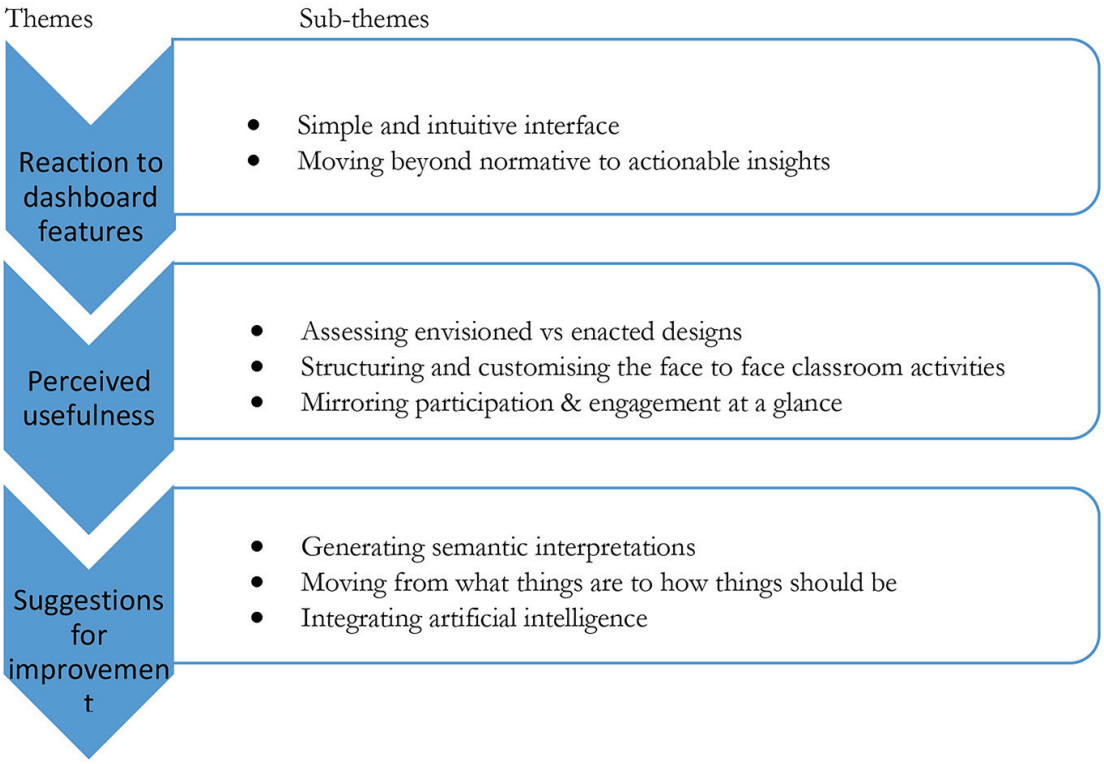

Fig. 4 Themes that emerged from the thematic analysis of the interviews (RQ1)

4.1.1 Theme 1: Reaction to dashboard features

This theme answered RQ1 which sought to explore teachers' experiences of using CADA in authentic practice. The teachers commented on the specific features of the dashboard, particularly the interface, participation, discourse, and social network features. All the teachers stated that the dashboard was very intuitive and easy to use: 'I think this is perfect. It is very intuitive and not very fancy' (T1IT1), and 'It gives me what I need with no need for much data literacy' (T3IT1). Another teacher added, 'Honestly, the tool is very simple to use in terms of its user interface because it is just pressing a couple of buttons' (T2IT1). Three teachers commented on how the social network analytics feature helped them see how their students were interacting. 'The social network feature is very important, as it is related to social learning aspects' (T5IT1). Another feature that the teachers found fascinating was the discourse analytics function (see Fig. 2), particularly the keywords section, which provided a summary of the keywords used by the students during a specific discussion. One teacher noted, 'I think the word cloud is simple, informative, and very nice to share with the students' (T6IT1).

Other teachers, however, questioned several of the dashboard features. For example, one teacher was not convinced about the usefulness of the discourse analytics function: 'I would generally be more interested in phrases than individual words so that I pick out something that shows knowledge development, and this is something that you need AI or machine learning to help with' (T5IT2). The same teacher added that while the dashboard showed how things are in terms of what is being discussed, it provides few insights on what should be done to improve students' learning: 'For example, if I see Student X, she is participating, but what she could do to get better is not clear. Could she use more concepts or interact more with the others?' (T5IT2). Another commented that while the tool provides an overview of the key concepts discussed by the students, the insights do not provide a nuanced understanding of what was being discussed (T3IT1).

4.1.2 Theme 2: Perceived usefulness

Assessing envisioned vs. enacted designs: The teachers commented on the dashboard's potential to provide them with information to assess the envisioned and enacted learning designs. One of them said, 'When I saw Dysthe, which was one of the articles I had assigned for the readings, that proved to me that they had read the assigned readings and tried to integrate them into the discussion' (T3IT2). Another stressed the importance of being able to see how the students were reacting to the intended pedagogical activities: 'This dashboard showed me how students respond to the activities' (T7IT2). A third highlighted that the network analytics provided information about students' interactions with the assigned activity: 'I can say I had to double-check the network diagram and what was in the discussion, and I realised that YES, nobody was commenting on anything, as all contributions were directed towards the original post' (T3IT2).

Structuring and customising face-to-face classroom activities: The teachers stressed the importance of CADA in providing information about students' learning processes through simple visualisations, which they leveraged to structure and customise face-to-face classroom activities. In particular, they noted the positive impact of having information such as students' misconceptions about a topic, as this helps them to make necessary changes in

their lectures and seminars. For example, one teacher noted, 'When I looked at the discourse analytics, I realised that the students had not gone much into the key concepts. For example, they were talking a lot about "Zoom" instead of collaborating, as I expected, and later, I said, "These are things we will examine deeper later in the class" (T1IT1). According to this teacher, the insights from CADA afforded more coherence to the physical lectures. Another teacher raised similar insights: 'The idea for me was that the insights from the dashboard helped me to structure the lesson and customise it to the things they were talking about' (T2IT1). A third teacher added, 'I ended up using the dashboard by summarising and synthesising the issues they had said they knew about at the beginning of the lectures, and I can say the issues visualised in the dashboard were super useful for me ahead of class' (T7IT2).

Mirroring participation and engagement at a glance: A recurring theme from the interviews was the teachers' use of CADA to indicate student engagement with a given discussion thread at a glance, as this facilitated quicker learning design decisions and saved a lot of time: 'I sometimes looked at the tool before the lecture and skimmed through all the students' submissions on the forum. This was quite demanding, but it was easier with the tool because I could see everything at a glance' (T5IT2).

4.1.3 Theme 3: Future use of the dashboard and suggestions for improvement

The teachers were asked whether they were willing and ready to use the dashboard in their everyday practice, and all of them showed interest.

'I can admit it is extra work when it comes to redesigning courses to include elements such as discussions to capture the analytics, but in the end, it is useful for the students and the teacher, so I would consider doing this again.' (T2IT1).

'I have used this tool for two terms now, and I can say it has been very helpful in preparing me for seminars. I will continue using it in the future.' (T4IT2).

'I have seen the value the dashboard provides, such as getting to know what students know ahead of the class, and I don't think I need much pushing to use it in the future.' (T3IT2).

The teachers also suggested improvements to facilitate future use of the dashboard. For example, one of them suggested the need to go beyond generating key concepts used in discussions to provide semantic interpretations showing the relationship between concepts. The teachers also expressed a need for CADA to extend from presenting how things are (how students interact and the concepts that they use) to include actionable insights that can inform the teacher and students how things should be. The teachers asked for predefined interventions to help them provide support to less engaged or struggling students. One of the teachers even suggested integrating artificial intelligence features into CADA as a way to improve CADA's effectiveness.

4.2 RQ2. How can we design and implement LA dashboards that meet teachers' pedagogical needs and expectations?

To answer RQ2, we analyzed comments from the teachers and researchers' own experiences and reflections. The analysis resulted in a set of implications that can be summarised into two main themes (Fig. 5): design and implementation.

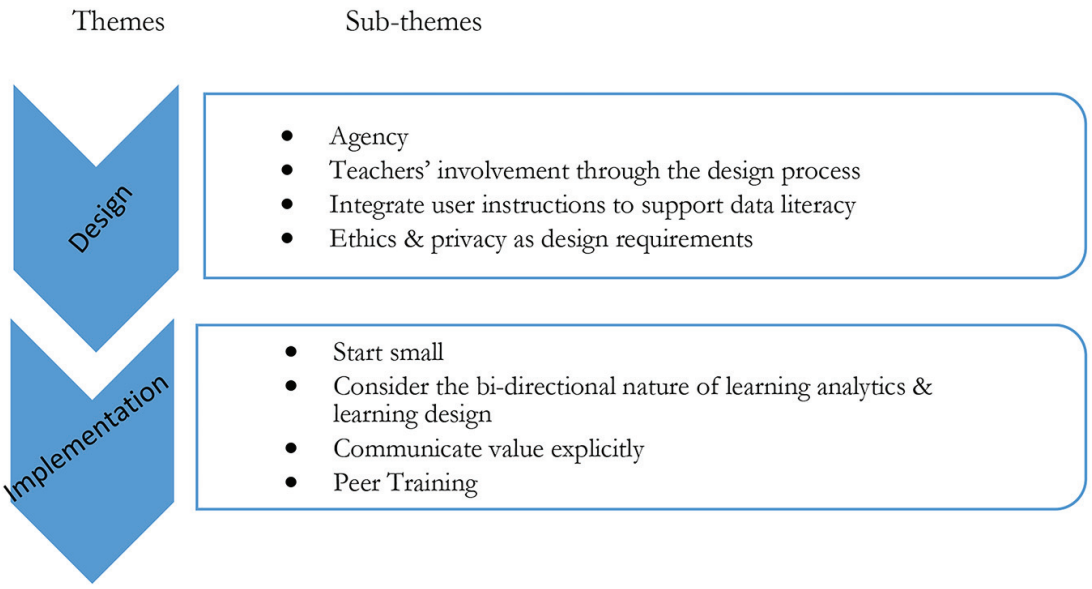

Fig. 5 Themes that emerged from the thematic analysis of the interviews with the teachers and researcher experiences (RQ2)

4.2.1 Theme 1: Design considerations

This theme answered RQ2 which sought to explore how researchers can design and implement LA dashboards that meet teachers' pedagogical needs and expectations.

Agency: The 'Agency' theme reflected how the teachers expressed the need to design LA tools with a high degree of flexibility so that they can customise them to get the kind of feedback they require. Most teachers were against the idea of designing dashboards with strict guidelines. 'I think using strict guidelines does not work because teachers, including myself, all have different ways of and plans for teaching' (T2IT1). Another teacher emphasised the value of agency while designing LA dashboards for teachers: 'I think it is important that, as a researcher, you do not state what should be done with the tool but instead offer options from which the teachers can choose, which is a way of giving them agency' (T3IT2). Another added, 'If there is a way to allow the teacher to edit the ideal state where you would like your students to be at the end of the course, and the tool helps to illustrate this process, that could be very important' (T5IT2).

Teachers' involvement throughout the design process: A critical problem with many LA systems is that their design follows a top-down process in which researchers and developers make decisions without involving the intended users (Dollinger & Lodge, 2018). Our design of CADA was motivated by the challenges the teachers mentioned during the problem identification stage, as well as the feedback received during the different iterations in which the teachers provided feedback on the early prototype. Consequently, the teachers expressed satisfaction with their engagement in the design of the dashboard: 'I remember you interviewed me two times for the first version, and I was surprised to see this much-improved version of the interface with some of the feedback I gave put into consideration in the new designs' (T5IT2).

Integrate user instructions to support data literacy While the teachers were generally happy about the dashboard's interface, they expressed the need for clear instructions to guide them in using the dashboard. 'I think having video tutorials and screenshots to guide teachers could be helpful' (T5IT2). This points to the issue of data literacy, which has been discussed in the LA literature (Kaliisa et al., 2021a). In other words, to favour the wide adoption of LA tools, particularly among non-data experts such as teachers, the tools need to be designed with user-friendly instructions, as teachers may lack data literacy skills and contextualised affordances on how to take advantage of these data.

Ethics and privacy as design requirements To integrate CADA into the intervention courses, we sought clearance from the university's legal team and study administration because in order to implement new plugins into Canvas at our university there is a need to adhere to various privacy and ethical requirements for managing personal information such as a legal basis, secure data storage and correct access privileges. Besides, in light of the increasing datafication of and surveillance in education, as well as general concerns about privacy and ethics, we found no resistance from the teachers in using the dashboard once they were assured that the relevant privacy and ethical considerations had been met.

4.2.2 Theme 2: Implementation considerations

Start small One of the key implementation considerations highlighted by the teachers was the need to conduct case studies with fewer teachers before scaling up the intervention. During the initial pilot stage, as researchers, we started working with only two teachers, who later acted as disseminators and ambassadors by suggesting the dashboard to other teachers. One teacher commended the approach we used in this study, saying, 'It is very smart to start with a few teachers before moving to others to gain some momentum… the few teachers will let others know how the tool works, and this is what you have done already' (T5IT2).

Consider the bi-directional nature of learning analytics and learning design The teachers pointed to the need to consider the connection between LA tools and their learning design practice. Some argued that researchers, as they intend to introduce LA tools such as dashboards, need to plan and work with teachers to ensure that the tools align with the intended course design practices. One teacher commented, 'It is important for teachers to be aware of how the tool plays into their own design process ahead of time. This makes it easier for the teachers to embed the tool into their own teaching' (T3IT2). This was demonstrated in the case studies that were involved in the implementation of CADA; the teachers redesigned some elements of the course to gain insights into specific parts of it and to gather relevant LA. When asked about the future use of the tool, one teacher answered, 'I think I would like to use the tool again, but I will have to make a few changes to the course to allow more posts and better analytics' (T6IT1).

Communicate value explicitly One of the overarching themes across the interviews was the need for explicit communication regarding the value of the proposed LA tools, particularly for improving the teachers' teaching practices. The teachers argued that once the value of

the tool is well communicated, its adoption into practice becomes easier. 'I understand getting the teachers to commit is an issue, but once you find the teachers who are envisioning a new thing and they understand the value of the analytics tool, then it is easy' (T3IT2). Since research has emphasised that the usefulness of the technology should be measured according to its value to actual users (Dollinger et al., 2019), it is critical for LA researchers to communicate the value of dashboards explicitly.

Peer training When asked about the conditions necessary to support the use of CADA in future practice, the teachers pointed out training as a key requirement. In particular, the teachers suggested that the training be done in groups to enable peer support during the implementation. 'The reason why I say it should be in groups is that teachers always learn from each other and ask questions about pros and cons. It is also the interaction and how people think together that could generate useful ideas for further development of LA tools' (T3IT2).

5 Discussion of the findings

The aim of this study was to follow a participatory approach to co-design, implement, and evaluate an LA dashboard with teachers to help gain insights into students' participation and discourse within online discussions. To achieve this aim, we established two research questions: (1) What are teachers' experiences using CADA and (2) How can we design and implement LA dashboards that meet teachers' pedagogical needs and expectations?

Regarding RQ1 on teachers' experiences of using CADA, the teachers who participated throughout the design process were positive about the dashboard features, and they showed interest in using it in their future practice. In particular, they stressed the importance of CADA in providing information about students' learning processes through simple visualisations, which they leveraged to gain a more nuanced understanding of how particular terms were used by the students and, where necessary, how the identified misconceptions were used as a basis on which to structure and customise face-to-face classroom activities. Previous research has reported that very few LA systems, present social learning analytics visualisations (e.g., social networks, discourse analytics) in real-time to support teachers' learning design decisions (Kaliisa et al., 2022). By enabling teachers to make small changes to their physical classroom lectures based on automated social network and discourse analytics visualisations, CADA showed the potential of LA dashboards to improve teachers' learning design practices without solely relying on summative assessments and end-of-semester evaluations, which the literature has reported as untimely and relatively biased (Bennet et al., 2015). Furthermore, the literature on teachers' roles in online learning environments has reported capturing students' participation and discourse as a particularly difficult task for teachers (van Leeuwen et al., 2019; Børte et al., 2020). With CADA, the teachers appreciated gaining insights into students' participation ahead of the physical classes. An important implication for researchers is that well-designed dashboards, aligned with teachers' pedagogical needs, and providing timely and automated visualisations, have the potential to support teachers in their challenging instructional roles, particularly in technology-supported online learning environments (Wise & Jung, 2019).

Although the teachers' overall impressions of CADA were positive, some questioned the usefulness of several of its features. For example, one teacher was not convinced about the usefulness of the discourse analytics function, questioning the value of displaying the key concepts discussed by the students, which did not provide a nuanced understanding of what they were discussing. Others felt that the analytics presented by CADA only showed how things are in terms of what is being discussed, with fewer insights into what should be done to improve students' learning. Meanwhile, CADA's main purpose is to support teachers' awareness of students' participation and discourse at a glance, and teachers use this as a baseline to make pedagogical decisions. However, we also recognise that increased awareness may not be enough for teachers to intervene since information from dashboards is usually presented in a minimally actionable way (Dazo et al., 2017). With this in mind, if we are to support teachers in fulfilling their ethical obligation to act (Prinsloo & Slade, 2017) based on information from dashboards, it is critical that teacher dashboards go beyond the normative to include actionable insights to support teachers' decision-making processes. In other words, to increase the relevance of dashboard analytics, they should be able to provide some hints (Kasepalu et al., 2021) regarding what teachers need to do. This reflection stresses the increasing need to align LA and artificial intelligence (Kasepalu et al., 2021). Holstein et al.'s (2019) work emphasises the power of dashboards by moving beyond descriptive analytics and mirroring dashboards to those that provide teachers and students with timely feedback and recommendations (Camacho et al., 2020).

In relation to RQ2, the findings highlight several design and implementation considerations for LA researchers and technology developers. First, agency and control were identified as key to supporting the adoption of LA by teachers. As reflected under the 'Agency' theme, the teachers expressed the need to be able to configure and choose which indicators and information they need from the system. As stated in earlier studies (Roberts et al., 2017; Shibani et al., 2020), these findings indicate that teachers need control over what LA systems provide, and this can only be achieved by engaging them actively in the design process. Moreover, given the different institutional and disciplinary contexts under which teachers work, designing customisable and adaptable LA systems cannot be overemphasised. In this regard, we plan to add features to CADA that allow teachers to choose the nature of the indicators on which they wish to focus.

In addition, responding to RQ2, the findings showed the value of involving teachers in defining their pedagogical problems and later suggesting LA solutions to deal with the problems. A key challenge identified in LA studies is the design of LA systems that are technically sound but pedagogically weak (Kaliisa et al., 2021a). In this study, we started by identifying teachers' pedagogical challenges (e.g. difficulties in monitoring participation and discourse patterns) and later suggested indicators that could capture participation and discourse together with teachers. We proceeded by identifying relevant LA analytical techniques (e.g. social network and discourse analysis) to analyse the online discussion forums in a way that made sense to the teachers, iteratively evaluating the relevance of the analytics from these techniques with the teachers before they were implemented as features in the CADA dashboard. The teachers reported feeling motivated to use the tool, which they perceived as a product of the participatory process rather than an imposition. Besides, CADA is an example of a practice-oriented system intended to directly impact teachers' everyday practice since it is born within the immediate context of use and co-designed with teachers who are the intended users. In this way, unlike LA systems developed based on experi-

mental studies, CADA and the approach taken in this paper highlights an effort to limit the gap between LA research and practice, and to increase the ownership and relevance of the analytics tools presented to the teachers.

Meanwhile, the process of involving teachers and other stakeholders in the design and implementation of LA systems is without challenges. For example, while some of the participating teachers had some knowledge of LA or other educational technologies (n=4), others had no experience (n=3). Thus, teachers with limited working knowledge of LA struggled to make sense of some of the analytics and provided limited feedback regarding how CADA could be improved. A design challenge posed to LA researchers and designers is to determine how to find negotiated points (Dollinger et al., 2019) when working with multiple stakeholders with varying levels of expertise. Additionally, even though teachers who were well-versed in LA systems and other educational technologies provided suggestions on how to improve CADA, not all the demands were implemented, as some were found to be less technologically and ethically feasible, and beyond the researchers' goals and resources. Again, this finding points towards the dilemma of balancing the needs of different stakeholders in participatory research during the design and implementation of LA tools.

Lastly, the current study showed that it is critical for researchers to consider the introduction of LA tools as new technologies for teachers by providing appropriate support in form of training and exemplars. It is also important that researchers allow enough time for the teachers to learn and decide how to integrate the tools in their everyday practice since LA tools usually come with underlying epistemological assumptions (Knight et al., 2014), which might not align with teachers' own pedagogical needs. In practice, providing the necessary support to teachers might not be simple due to logistical challenges. Thus, we recommend that researchers and institutional leaders interested in LA adoption, start with small initiatives by involving a few teachers who could in turn become the champions and support local communities of practice by spreading the word about an existing tool to other teachers, and subsequently, move towards institutional adoption (Heredotou et al., 2019; Tsai et al., 2018). In the following section, we outline the key recommendations arising from the findings that should be taken into account by researchers, LA developers and higher educational institutional managers.

5.1 Practical recommendations for researchers, LA developers and institutions

- LA dashboard designers and researchers should prioritise giving teachers control while designing LA systems that allow for insights into tool design for local actionability (Wise & Jung, 2019; Buckingham Shum et al., 2019). In particular, it is critical that the design of LA systems align with teachers' conceptualisations of their courses (e.g. presenting analytics based on the course modules), an aspect that underscores the bi-directional nature of LA and course designs.
- Researchers and dashboard designers should integrate automated feedback systems that support the actionability of the insights gained from the dashboards. If this is not done, teachers' cognitive loads might increase while they are trying to interpret the analytics from the dashboard, which might discourage uptake in their everyday teaching practice.

- Researchers should be explicit about their own perspectives and goals, and transparent about certain implementation constraints to avoid challenges resulting from ignoring some of the ideas provided by stakeholders (e.g. teachers, students). One way to achieve this is to maintain close communication and dialogue between different stakeholders throughout the design process.
- In light of the increasing datafication of and surveillance in education, as well as general concerns about ethics and privacy (Howell et al., 2018), we moot the need for LA researchers and designers to not only emphasise the technical aspects of dashboards but also to consider the issues of privacy and ethics while defining the protocols for dashboard designs. To properly ensure the protection of personal information there is a need to adhere to a proper legal basis, secure data storage and proper access privileges to data and visualisations. For example, interfaces can be designed with a possibility to change views, where teachers can hide student identity before sharing LA visualisations in the classroom.
- Researchers and higher education institutions should embrace the fact that developing LA systems is a team effort. CADA was developed with input from researchers, teachers, students, engineers, programmers, study administrators, legal teams and ethical committees. This highlights the need for well-coordinated efforts involving several stakeholders prior to the design of LA systems.

5.2 Limitations and opportunities for future research

One of the limitations of this study was the class sizes used during the evaluation of the dashboard. Most courses had between 20 and 40 students, which means that the teachers did, not easily recognise the actual benefits of CADA, particularly in large courses. Second, while the study included seven different courses and teachers—slightly more than most existing LA studies—this number was not large enough to allow for the generalisation of the user experiences captured. Most teachers wanted assurance on the potential of the dashboard before making design changes in their courses to accommodate the dashboard, which affected the number of teachers at the pilot stage. Third, during CADA's implementation, dashboard updates were ongoing, and features such as sentiment analysis were fully integrated towards the end of the pilot studies. This means that some teachers experienced different functionalities at different points of use. Lastly, the evaluation of CADA was based mainly on user interviews and researcher observations of courses in which this was possible. While user experiences can provide lived experiences, it can be difficult to understand the actual impact and usage of the tool. Thus, we seek to expand this work by engaging with teachers instructing more popular courses and using more fine-grained methods to analyse the actual use and impact of dashboards. Researchers such as Herodotou et al. (2021), for instance, have employed finer-grained methods of data collection, such as eye-tracking, log analysis, and screen capture videos, to gain additional insights into teachers using dashboards in practice. Despite these limitations, this study provides insights into a participatory process among teachers to develop an LA dashboard, as well as relevant design, implementation, and design considerations that other researchers could leverage while developing LA tools. Going forward, we plan to share developer codes to expand the use of CADA across contexts. We also plan to continue developing CADA features based on the feedback from

the pilot studies before CADA is released as a plugin in Canvas and other LMSs; this will allow other researchers, teachers, and institutions to use CADA for their own work.

6 Conclusions

This study's contribution is fourfold. First, from a *practical* point of view, the study offers an artefact contribution in the form of CADA. Teachers have already started using CADA in their everyday teaching practice; thus, CADA is contributing to demonstrable changes among practitioners (Barab & Squire, 2004). CADA is unique in that it can be directly integrated into several LMSs as a plugin. Thus, it represents a step forward in fulfilling the goal of LA to support and inform timely learning design decisions. Second, the study has a *theoretical* contribution by demonstrating how LA researchers and designers can utilise theoretical constructs (sociocultural perspective) to design theoretically sound systems that align with teachers' pedagogical needs. Third, the study has an *empirical* contribution by generating empirically grounded design and implementation considerations that can be utilised by researchers, technology developers and higher education institutions interested in the research, design and adoption of LA dashboards. *Methodologically*, this study has provided a demonstrable and successful process of using participatory approaches (e.g. design-based research and human-centred learning analytics) over two iterations with key stakeholders to improve the value and uptake of LA systems. While we do not advocate for the use of the CADA dashboard developed in this study, we hope that the insights from teachers' use of CADA in authentic practice, as well as the practical design and implementation considerations derived from this series of case studies, could be useful platforms upon which other researchers planning to develop and implement LA tools can build.

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Declarations

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References

Buckingham Shum, S., Ferguson, R., & Martinez-Maldonado, R. (2019). Human-Centred Learning Analytics. *Journal of Learning Analytics*, 6(2), 1–9

Barab, S., & Squire, K. (2004). Design-based research: Putting a stake in the ground. *The journal of the learning sciences*, 13(1), 1–14

Bakharia, A., & Dawson, S. (2011, February). SNAPP: a bird's-eye view of temporal participant interaction. In *Proceedings of the 1st international conference on learning analytics and knowledge* (pp. 168–173)

Black, P., & William, D. (2009). Developing the theory of formative assessment. *Educational Assessment, Evaluation and Accountability*, 21(1), 5–31. https://doi.org/10.1007/s11092-008-9068-5

Bodily, R., & Verbert, K. (2017). Review of research on student-facing learning analytics dashboards and educational recommender systems. *IEEE Transactions on Learning Technologies*, 10(4), 405–418

Børte, K., Nesje, K., & Lillejord, S. (2020). Barriers to student active learning in higher education. *Teaching in Higher Education*. DOI: https://doi.org/10.1080/13562517.2020.1839746

Damșa, C., & de Lange, T. (2019). Student-centred learning environments in higher education. *Uniped*, 42(01), 9–26

Dazo, S. L., Stepanek, N. R., Chauhan, A., & Dorn, B. (2017). *Examining instructor use of learning analytics.* Paper presented at the Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems

Dempsey, N. P. (2010). Stimulated recall interviews in ethnography. *Qualitative sociology*, 33(3), 349–367

Dolonen, J. A., & Ludvigsen, S. (2012). Analyzing students' interaction with a 3D geometry learning tool and their teacher. *Learning, Culture and Social Interaction*, 1(3–4), 167–182.

Dollinger, M., Liu, D., Arthars, N., & Lodge, J. (2019). Working together in learning analytics towards the co-creation of value. *Journal of Learning Analytics*, 6(2), 10–26

Few, S. (2006). *Information dashboard design: The effective visual communication of data*. Sebastopol, CA: O'Reilly Media

Giacomin, J. (2014). What is human centred design? *The Design Journal*, 17(4), 606–623

Helander, M. G. (Ed.). (2014). *Handbook of human-computer interaction*. Elsevier

Herodotou, C., Hlosta, M., Boroowa, A., Rienties, B., Zdrahal, Z., & Mangafa, C. (2019). 'Empowering online teachers through predictive learning analytics'. *British Journal of Educational Technology*, 50(6), 3064–3079. DOI: https://doi.org/10.1111/bjet.12853. [Online]

Herodotou, C., Maguire, C., McDowell, N., Hlosta, M., & Boroowa, A. (2021). The engagement of university teachers with predictive learning analytics. *Computers & Education*, 173, 104285

Holstein, K., McLaren, B. M., & Aleven, V. (2019). Co-designing a real-time classroom orchestration tool to support teacher–AI complementarity.Journal of Learning Analytics, *6*(2)

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

Ifenthaler, D., Gibson, D., & Dobozy, E. (2018). Informing learning design through analytics: Applying network graph analysis.Australasian Journal of Educational Technology, *34*(2)

Jivet, I., Scheffel, M., Drachsler, H., & Specht, M. (2017). *Awareness is not enough: Pitfalls of learning analytics dashboards in the educational practice.* Paper presented at the European conference on technology enhanced learning

Kagklis, V., Karatrantou, A., Tantoula, M., Panagiotakopoulos, C. T., & Verykios, V. S. (2015). A learning analytics methodology for detecting sentiment in student fora: A Case Study in Distance Education. *European Journal of Open, Distance and E-learning*, 18(2), 74–94

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*, 7(3), 33–47. https://doi.org/10.18608/jla.2020.73.4

Kaliisa, R., Kluge, A., & Mørch, A. I. (2021a). Overcoming challenges to the adoption of learning analytics at the practitioner level: A critical analysis of 18 learning analytics frameworks. *Scandinavian Journal of Educational Research*, 1–15. https://doi.org/10.1080/00313831.2020.1869082

Kaliisa, R., Mørch, A. I., & Kluge, A. (2021b). 'My point of departure for analytics is extreme skepticism': Implications derived from an investigation of university teachers' learning analytics perspectives and design practices. *Technology, Knowledge and Learning*, 1–23. https://doi.org/10.1007/s10758-020-09488-w

Kaliisa, R., Rienties, B., Mørch, A. I., & Kluge, A. (2022). Social Learning Analytics in Computer-Supported Collaborative Learning Environments: A Systematic Review of Empirical Studies. *Computers and Education Open*, 100073. https://doi.org/10.1016/j.caeo.2022.100073

Kasepalu, R., Chejara, P., Prieto, L. P., & Ley, T. (2021). Do Teachers Find Dashboards Trustworthy, Actionable and Useful? A Vignette Study Using a Logs and Audio Dashboard.Technology, Knowledge and Learning,1–19

Keim, D., Andrienko, G., Fekete, J. D., Görg, C., Kohlhammer, J., & Melançon, G. (2008). Visual analytics: Definition, process, and challenges. In Kerren, A., Stasko, J., Fekete, J. D., & North, C. (Eds.). *Information visualization* (pp. 154–175). Springer

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

Linneberg, M. S., & Korsgaard, S. (2019). Coding qualitative data: A synthesis guiding the novice.Qualitative research journal

Martinez-Maldonado, R., Elliott, D., Axisa, C., Power, T., Echeverria, V., & Shum, B. (2020). S. Designing translucent learning analytics with teachers: an elicitation process.Interactive Learning Environments,1–15

Martinez-Maldonado, R., Pardo, A., Mirriahi, N., Yacef, K., Kay, J., & Clayphan, A. (2015). LATUX: An iterative workflow for designing, validating and deploying learning analytics visualisations. *Journal of Learning Analytics*, 2(3), 9–39

Prinsloo, P., & Slade, S. (2017, March). An elephant in the learning analytics room: The obligation to act. In Proceedings of the seventh international learning analytics & knowledge conference (pp. 46–55)

Roberts, L. D., Howell, J. A., & Seaman, K. (2017). Give me a customizable dashboard: Personalized learning analytics dashboards in higher education. *Technology, Knowledge and Learning*, 22(3), 317–333

Rummel, N. (2018). One framework to rule them all? Carrying forward the conversation started by Wise and Schwarz. *International Journal of Computer-Supported Collaborative Learning*, 13(1), 123–129

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

Säljö, R. (2002). Learning as the use of tools: a sociocultural perspective on the human–technology link. *Learning with computers* (pp. 158–175). Routledge

Schwendimann, B. A., Rodriguez-Triana, M. J., Vozniuk, A., Prieto, L. P., Boroujeni, M. S., Holzer, A., & Dillenbourg, P. (2016). Perceiving learning at a glance: A systematic literature review of learning dashboard research. *IEEE Transactions on Learning Technologies*, 10(1), 30–41

Tsai, Y. S., Moreno-Marcos, P. M., Jivet, I., Scheffel, M., Tammets, K., Kollom, K., & Gašević, D. (2018). The SHEILA Framework: Informing Institutional Strategies and Policy Processes of Learning Analytics. *Journal of Learning Analytics*, 5(3), 5–20. https://doi.org/10.18608/jla.2018.53.2

van Leeuwen, A., Rummel, N., & Van Gog, T. (2019). What information should CSCL teacher dashboards provide to help teachers interpret CSCL situations? *International Journal of Computer-Supported Collaborative Learning*, 14(3), 261–289

Van Harmelen, M., & Workman, D. (2012). Analytics for learning and teaching. *CETIS Analytics Series*, 1(3), 1–40

Vygotsky, L. S. (1978). Socio-cultural theory. *Mind in society*, 6, 52–58

Wise, A. F., & Jung, Y. (2019). Teaching with analytics: Towards a situated model of instructional decision-making. *Journal of Learning Analytics*, 6(2), 53–69

Vieira, C., Parsons, P., & Byrd, V. (2018). Visual learning analytics of educational data: A systematic literature review and research agenda. *122*,119–135

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