Supporting teachers as designers with community and learning analytics: a framework, technology, and case studies

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DOCTORAL THESIS UPF / 2019

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"Inquiry… indicates a stance toward experiences and ideas —a willingness to wonder, to ask questions, and to seek to understand by collaborating with others in the attempt to make answers to them. At the same time, the aim of inquiry is not "knowledge for its own sake" but the disposition and ability to use the understandings so gained to act informedly and responsibly in the situations that may be encountered both now and in the future… Inquiry, then, is rooted in the understandings gained in the past as these are embodied in the culture's practices and artifacts and, at the same time, situated in the specific present of particular classrooms and oriented to the construction of new understandings."

(Wells, 1999, p.121)

Acknowledgments

This work would not have been possible without the help and support of several people who I met during my PhD journey. I am very thankful to all of them!

Firstly, I am very grateful to my supervisor Dr. Davinia Hernández-Leo for giving me the opportunity to pursue a PhD. Davinia was always there for me to provide her expertise, support, and assistance. Davinia, thank you for all the things we have achieved together!

My sincere thanks also goes to all the members of the GTI-learning and later TIDE research group for their help and encouragement. Thanks, Jonathan for assisting me even in the last period of your PhD. Thanks, Kalpi and Laia for your insightful comments and our collaborations. Your great support and pieces of advice were very important during these years. Special thanks to Pablo for being always there to support and discuss with me all the technical implementations. Ishari, I appreciate all your comments and encouragement. Thanks, Marc and Patricia for your thoughtful feedback and help. I am especially grateful to new members of the group for our active discussions about PhD and life. Thank you, Roman, Milica, Nicolas, Judit. I would also like to thank Sebastian for being a great friend from the first moments of the PhD.

During my PhD years, I was lucky to participate in very interesting research projects (RESET, CoT, MDM), to gain professional experiences and learn from great researchers and teachers. I would like to thank and mention several members of the GSIC-EMIC research group from Universidad de Valladolid and GAST research group from Universidad Carlos III de Madrid. Thanks to Professor Yannis Dimitriadis, Dr. Juan I. Assensio-Pérez, Dr. Sara Villagra Sobrino, Dr. Eduardo Gómez-Sanchez and Dr. Juan Alberto Muñoz Cristobal for their feedback during our project meetings and our collaboration in designing and implementing a MOOC. Thanks to Professor Carlos Delgado-Kloos, Dr. Pedro Muñoz-Merino and Dr. Carlos Alario-Hoyos for the stimulating discussions and feedback.

This work would not have been achieved without the support of many teachers who participated in the CoT project. My sincere thanks to all teachers in Dolmen and Ginebró school for their active

participation and support. I especially admire their enthusiasm, dedication and continuous interest in the objectives of the project. Their insightful comments and feedback during several workshops and our project communications were a key part of this research work.

Besides, I am grateful to all the members of the ETIC UPF Department. They all created a great work atmosphere and I was lucky enough to meet many inspiring people. Thanks to Professor Josep Blat and all the members of this department.

I am also greatly appreciative of the constructive comments and helpful suggestions provided by reviewers during the different stages of this thesis and their interest in our research work.

It is also important to mention Bakala Brothers Foundation for their financial aid during the first two years of my PhD. Thank you for giving me this once-in-a-lifetime opportunity.

Last but not least, my warmest thanks to my family for being always there to hear me, guide me and support me during these years. My deep appreciation goes to my best teachers, my parents!

Konstantinos Michos
January, 2019

Abstract

The notion of teachers as designers of learning environments has emerged with the increasing use of Information and Communication Technologies (ICT) in Education. Research in Learning Design (LD) studies how to support teachers in making pedagogically-sound decisions in the design of learning interventions which make effective use of resources and technologies. In this context, the shift from individual to collective teacher practices via communities around LD is challenging. Additionally, training teachers as reflective practitioners who inquiry into their students´ learning based on student-generated data in technology-integrating learning activities is demanding. This PhD thesis deals with how to support the collective and inquiry process of teachers as designers in technological environments with the use of data analytics. A Design-Based Research (DBR) methodology was followed to develop and evaluate solutions for teachers. Regarding the collective process, we conceptualized teacher communities around LD based on the Cultural Historical Activity Theory (CHAT) and developed a community awareness dashboard (inILDE) in an online learning design platform. Regarding the inquiry process, we analyzed current teacher inquiry practices and designed a Teacher Inquiry tool for Learning dEsigns (TILE). We conducted embedded multiple case studies within Teacher Professional Development (TPD) programs which included four educational communities; two High Schools, a pre-service teacher community and a Massive Open Online Course (MOOC) for learning design. Results show that the community awareness dashboard enabled understanding of collective teacher participation and increased social interactions in the online learning design platform. Teacher involvement in technology-supported inquiry cycles with student data led to in-depth discussions about the design and implementation of learning tasks and showed evidence of pedagogical knowledge building. Based on the above, we propose an integrated collective inquiry framework (Collective Inquiry with Data Analytics-CIDA) to support teachers as designers in technological environments with data analytics. The CIDA framework aims to guide researchers, teachers and system developers in the development of tools and TPD programs for teachers as designers.

Resumen

La noción de maestros como diseñadores de entornos de aprendizaje ha surgido con el uso creciente de las Tecnologías de la Información y las Comunicaciones (TIC) en la Educación. La investigación en Diseño para el Aprendizaje (LD) estudia cómo ayudar a los maestros a tomar buenas decisiones pedagógicas en el diseño de intervenciones de aprendizaje que hagan un uso eficiente de recursos y tecnologías. En este contexto, el cambio de prácticas docentes individuales a colectivas a través de comunidades de LD es un reto. Otro reto es capacitar a los profesores como profesionales reflexivos que indagan sobre el aprendizaje de sus estudiantes basándose en datos generados por los estudiantes en actividades de aprendizaje que integran el uso de tecnología. Esta tesis doctoral trata sobre cómo apoyar el proceso colectivo y de investigación de profesores como diseñadores en entornos tecnológicos con el uso de analíticas de datos. La tesis sigue una metodología de investigación basada en el diseño (DBR) para formular y evaluar las soluciones propuestas. Con respecto al proceso colectivo, conceptualizamos las comunidades de profesores en relación a LD según la Teoría de la Actividad Histórica-Cultural (CHAT) y desarrollamos un panel de información de la actividad de la comunidad (inILDE) en una plataforma de diseño de aprendizaje en línea. Con respecto al apoyo al proceso de investigación, analizamos las prácticas de investigación actuales de los profesores y diseñamos una herramienta dedicada a que los profesores investiguen sobre sus diseños de aprendizaje (TILE). Llevamos a cabo un estudio de caso múltiple, donde los casos se integraban en programas de desarrollo profesional docente (TPD). Estos casos incluyen cuatro comunidades educativas: dos institutos, una comunidad de profesores en formación y un curso masivo abierto en línea (MOOC) sobre el diseño para el aprendizaje. Los resultados muestran que el panel de información de la comunidad permitió comprender la participación colectiva de los profesores y aumentar las interacciones sociales en la plataforma de diseño de aprendizaje en línea. La participación de los profesores en los ciclos de investigación con apoyo de tecnología y respaldados con datos de los alumnos condujo a discusiones profundas sobre el diseño y la implementación de tareas de aprendizaje y mostró evidencias de construcción de conocimiento pedagógico. Construyendo sobre estos resultados, proponemos un marco de investigación colectiva integrado (Collective Inquiry with Data Analytics, CIDA) para

apoyar a los profesores como diseñadores en entornos tecnológicos con análisis de datos. El marco de CIDA tiene como objetivo guiar a los investigadores, profesores y desarrolladores de sistemas en el desarrollo de herramientas y programas de TPD para profesores como diseñadores.

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CHAPTER 1

INTRODUCTION

This chapter presents the research context of this dissertation, the global aim, derived partial objectives and the overall research methodology during the dissertation. The chapter also introduces the main evaluation studies and a summary of the results obtained. This dissertation is framed in the context teachers as designers of learning environments and studies how data analytics can support teacher collective and inquiry practice. Particularly, this work conceptualizes teacher communities for learning design and proposes a community awareness dashboard to support their collective processes, and a reflective tool to support their inquiry processes enhanced with learning analytics. A Design-Based Research methodology was followed to tackle the objectives of this thesis and propose technological solutions. Finally, this chapter includes the main limitation of the thesis work, the main conclusions and implications for future work. The chapter concludes with an explanation of the structure of the thesis.

1.1 Introduction

The current discussion on teaching and learning with the use of Information and Communication Technologies suggests educational reforms and the alignment of ongoing pedagogies with the changes, advantages and effective adoption of new technologies (Conole, 2013; Laurillard, 2012). Research in Technology Enhanced Learning (TEL) illustrates how technology can be designed and used for teaching and learning based on evidence-based approaches (Luckin, 2018).

In the TEL landscape, a growing body of research studies the role teachers play as designers of TEL (Kali, McKenney, & Sagy, 2015; Persico, Pozzi, & Goodyear, 2018). One argument is that teachers design work is changing in parallel with technological and cultural

advancements (Kali, McKenney, & Sagy, 2015). Additionally, this presupposes that teachers should be able to design the "best possible" opportunities for their students to learn based on pedagogically sound methods which make effective use of resources and technologies (Conole, 2013; Asensio-Pérez et al., 2017). According to Laurillard (2012), this consolidates teaching as a design science, similar to other design professions like architects and engineers. In these design professions, knowledge is represented and communicated. Accordingly, "teachers acting as designers" could represent and share their teaching ideas and experiences to collectively build knowledge for TEL. Such changes in teacher culture, which has been often described as isolationist, include the development of professional learning communities which encourages sharing, reflection, and deprivatization of teacher practice (Dana & Yendol-Hoppey, 2014).

Over a decade of research in the field of Learning Design (LD), has produced technology tools and methods towards facilitating teachers as designers. There are different definitions of LD or as some others prefer "design for learning". One of the definitions is "a methodology for teachers/designers to make more pedagogically informed decisions in the design of learning activities and interventions which make effective use of resources and technologies" (Conole, 2013, p.7). LD is both a *process* and *a product* (Agostinho, 2009). LD as a process is the design, planning, and organization of learning activities for a course or part of a course (Agostinho, 2009). LD as a product is a formalized and sharable description of a sequence of learning tasks, resources, and supports for learners which document pedagogical intent of a unit of study (Lockyer, Agostinho, & Bennett, 2016). Similarly, Koper (2006, p.14) defines LD as "the description of the teaching-learning processes that take place in a unit of learning (e.g. course, a lesson, or any other designed learning event)."

The involvement of teachers as designers of TEL provides a situated context for teacher learning and Teacher Professional Development (TPD) about pedagogy, content, and technology (Kali, McKenney, & Sagy, 2015; Koehler & Mishra, 2005; Recker & Sumner, 2018). For instance, teachers learn by designing (Kolodner, 2003) and by reflecting on their own and others´ practice (Dana & Yendol-Hoppey, 2014). Kirschner (2015) highlights the new skills,

techniques, tools, and knowledge which are used to inform teachers design work in the twenty-first century. However, a set of five competencies for teachers as reflective professionals are important in their lifelong learning. According to Kirschner (2015), these competencies are the following: gathering of information for learners; analysis of information and diagnosis for pedagogical actions; designing an effective and/or efficient course of instructions; implementing/teaching this course of instructions; evaluating if the intended design was achieved.

Training teachers as reflective practitioners such as "designers for learning", has a long tradition in teacher education and TPD (Dewey, 1933; Schön, 1987; Moon, 1999; Mor, Ferguson, & Wasson, 2015). Teacher reflection on their practice makes their tacit knowledge about teaching and learning explicit which can be further shared, discussed, re-used and analysed. Reflection requires an inquiry stance towards teaching and student learning, which is defined with the term *teacher inquiry;* a set of research practices by which teachers examine their practice and its effect in students´ learning with data to enhance their professional knowledge and practice (Clarke, & Erickson, 2003; Avramides et al., 2015; Hansen & Wasson, 2016; Luckin et al., 2017). Teacher reflection is frequently happening in an unplanned way and may account for teacher beliefs and ideas rather than everyday evidence (Dana & Yendol-Hoppey, 2014). Through inquiry, teachers utilize evidence-based approaches to conduct their own local research about practical problems which arise in their classrooms towards improving their students´ learning.

Data-driven approaches in teaching and learning have always been a challenge in Education and currently, with the increasing use of ICT are studied in the field of Learning Analytics (LA). LA is defined as "the measurement, collection, analysis, and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs" (Ferguson, 2012). In the context of LD, although learning design representations provide a result of the decision-making process of the teacher/designer, few information is available for previous particularizations of a learning design, the learners' preferences of the delivery mode and reflection about the teachers' run-time experience (Percico & Pozzi, 2015; Lockyer, Heathcote, & Dawson, 2013; Hernández-Leo et al., 2018; Mangaroska, & Giannakos, 2018;

Hernández-Leo et al., 2017). Moreover, teachers' customization of instructional materials often relies on teachers' previous experiences with students, beliefs on teaching and learning and practical or time constraints (Matuk et al., 2015). Thus, the utilization of learning analytics in alignment with learning design (Rodriquez-Triana et al., 2015; McKenney & Mor, 2015; Rienties & Toetenel, 2016) can inform further teacher inquiry based on the evidence collected from students (Alhadad & Thomson, 2017; Percico & Pozzi, 2015; Mor, Ferguson & Wasson, 2015). The implementation of learning designs in Virtual Learning Environments (VLEs) for students enables the collection of multiple types of data (including fine-grained data about student interactions and student-content interactions). However, teachers need additional help to connect learning design (their pedagogical intent) with learning analytics (analytics derived from the implementation of their learning designs) due to technological and pedagogical constraints (Rodriquez-Triana et al., 2015), lack of culture and data literacy to take pedagogical decisions based on learning analytics (Schmitz et al., 2017) and lack of metacognitive awareness about their learning designs (Michos, Manathunga, & Hernández Leo, 2016). Thus, facilitating teachers to connect learning design with learning analytics and inform teacher inquiry practice is a challenge.

Research in Learning Design and teacher inquiry emphasize in the sharing of teacher practices and the social process of knowledge construction between teachers. Social and collective arrangements for Teacher Professional Development (TPD) have been investigated in the context of teacher communities (Vangrieken et al., 2017; Lantz-Andersson, Lundin, & Selwyn, 2018). Two well-known theoretical frameworks for teacher communities are teacher professional learning communities (PLCs) (Vescio, Ross, & Adams, 2008) and communities of practice (CoPs) (Wegner, 1998). These types of communities normally use technologies such as social networking sites and portable devices which enable collective contributions, sharing of teacher artifacts, resources and knowledge exchange. These collective practices for teachers have shown impact in teacher and student learning when they are situated in teachers´ everyday practices (Moolenaar, Sleegers & Daly, 2012; Vescio, Ross, & Adams, 2008). In the field of LD, Mor, Ferguson, & Wasson (2015) stress the need to move from individual to collective practices where multiple inquiries about learning designs are aggregated.

Conole (2010) highlights “openness” in teaching and learning with “open design” and “open evaluation”. “Open design” addresses the need to move beyond open educational resources and focus on the explicit representation and sharing of the whole design process for teachers. “Open evaluation” refers to the use of data collected from students to collectively improve the teaching practice. Such participatory cultures can be supported in groups of educators in the same educational institution, but also with collaborations between different institutions (Binkhorst et al., 2015; Hofman & Dijkstra, 2010).

Various technologies for supporting learning design in teacher communities have been developed. For instance, Learning Designer is a tool for creating and sharing learning designs with the aim to develop “pedagogical-knowledge building” communities for teachers (Laurillard et al., 2018). Cloudworks is a social networking site for sharing learning-teaching ideas and designs (Conole & Culver, 2010). The Learning Activity Management System (LAMS) is a platform for the authoring, running and monitoring of learning designs, and integrates forums for educational communities (Dalziel, 2008). The Integrated Learning Design Environment (ILDE) is a community-oriented platform to support the whole cycle of the learning design process from the conceptualization to the implementation and sharing of learning designs (Hernández Leo et al., 2018).

Common in these online environments, as other types of online teacher communities, are organizational, geographical and professional boundaries that teachers need to overcome (Prenger, Poortman, & Handelzalts, 2017). Moreover, other factors that influence teacher professional development in online teacher communities are peripheral participation, the evolution of participation, moderation of the community and interactions between experienced members with newcomers (Macià & García, 2016). Socio-technical challenges can also influence effective technology use by community members. Sociability and usability are important factors referring to networked technologies for online communities of teachers (Jones & Preece, 2006). Sociability refers to the social interactions between community members with computing technology while usability is concerned with how users interact with the technology (Preece, 2001). Additionally, (social) awareness is a

main challenge studied in the context of Computer Supported Cooperative Work (CSCW). Awareness is "an understanding of the activities of others, which provides a context for your own activity" (Dourish & Belotti, 1992). Awareness of community members about the information and knowledge available in the community environment, the ability of online communities to maintain knowledge and user interests, and motivation of community members include factors for community members´ participation, involvement, and success for collaboration (Soller, 2007).

Such professional and informal learning contexts (e.g., teacher communities) have been also explored in LA research. This subfield of LA refers to workplace learning and teacher learning (Ruiz-Calleja et al., 2017; Vuorikari, & Scimeca, 2013). In this context, Social Learning Analytics (Buckingham-Shum & Ferguson 2012) or Community Learning Analytics (Klamma, 2013) can be used to facilitate organizational learning, community regulation, networking, and identification of useful resources. For instance, de Laat & Schreurs (2013) used Social Network Analysis (SNA) to provide awareness in professional teacher networks and developed an awareness tool for identifying knowledge and expertise. Data analytics can be embedded in work-related tasks to provide useful information to community members. Vasileva and Sun (2007) developed community visualizations for an online community platform devoted to sharing student resources. They concluded that visual representations of members´ contributions increased user participation.

In the LD field, limited research shows how community awareness data and community (learning) analytics can be used to facilitate the role of teachers when they engage with learning design (Hernández-Leo et al., 2018). Moreover, limited studies have analysed participation behavior in online teacher communities involved with learning design (Recker, Yuan, & Ye, 2014). Teachers´ tasks related to learning design include the preparation of classroom activities, identification of student needs, (re)design of existing curricula, repurposing of learning tasks designed by other teachers. Additionally, evidence-based learning design improvements (e.g., through teacher inquiry) include part of teacher design processes (Gerard, Spitulnik, & Linn, 2010; Khlaif, Gok, & Kouraïchi, 2019).

Considering the above topics, the goal of this thesis is *to study and support the collective and inquiry process of teachers as designers in technological environments with data analytics.* The research context is framed in the connection between Learning Design (LD) with Learning Analytics (LA) by teachers and the need to support community awareness in technological environments for teachers as designers.

The next sections of this chapter are structured as follows. Section 1.2 explains the main research question and objectives of the thesis, section 1.3 explains the research methodology followed in the thesis and section 1.4 presents the main contributions. Section 1.5 describes the limitations of the work while section 1.6 presents the conclusions of the thesis. Section 1.7 describes topics about future work and section 1.8 the organization of the thesis structure.

1.2 Dissertation goals

Based on the above context and research challenges the main research question of this thesis is "*How to support the collective and inquiry process of teachers as designers in technological environments with community and learning analytics?"* Figure 1 presents the research context of the thesis, the main research questions, specific research objectives, main contributions and evaluation studies of the dissertation. As Figure 1 illustrates, there are three main research objectives derived from the research question as follows:

[OBJ_1] To conceptually and technologically support the collective process of teachers as designers with community analytics.

Although teacher design work is often considered as an individual task of the teacher, less is known on the social and collective dimension of teachers´ design practices (Voogt et al., 2015). The socio-cultural system (e.g., educational institution, school, university, classroom, professional workshops) forms part of the decision-making process when teachers design for learning and inquiry into their students´ learning (Agostinho, Lockyer, & Bennett, 2018;

Butler & Schnellert, 2012). Learning design technology platforms can be used to facilitate such collective processes for teachers as designers as they can enable the representation and sharing of learning design artifacts. However, supporting awareness and knowledge discovery in such collective learning design platforms is critical due to socio-technical challenges and lack of teacher engagement and interactions. There is limited research on how social and community analytics can be used in the context of learning design to provide awareness in a community of teachers.

[OBJ_2] To facilitate the teacher inquiry practice by connecting learning design with learning analytics in TEL.

Although substantial research has been done in the representation and documentation of learning designs, less is known on the implementation of learning designs by teachers and the documentation of the whole learning design process (Hernández-Leo et al., 2018; Mor, Ferguson, & Wasson, 2015). Learning analytics can provide information to teachers for a real-time adaptation of learning designs during their enactment with students. However, learning analytics can also inform future learning (re)design as part of teachers´ reflective practice (Sergis et al., in press). Research on facilitating the teacher inquiry practice by connecting learning design with learning analytics in TEL is still in its infancy (Percico & Pozzi, 2015; Alhadad et al., 2018).

[OBJ_3] To propose a framework for collective inquiry in communities of teachers as designers.

Different collective inquiry frameworks which involve technologies for knowledge building have been proposed in the context of teacher communities, teacher learning, and workplace learning (Kimmerle, Cress, & Held, 2010; Ley et al., 2014; Popp & Goldman, 2016). However, in the context of LD, there are no existing frameworks which show how knowledge building can be facilitated in online professional communities of teachers as designers (Laurillard et al., 2018). The integration of new technologies in teaching such as learning analytics tools requires a collective inquiry by teacher communities to collectively build pedagogical design capacity (Recker & Sumner, 2018).

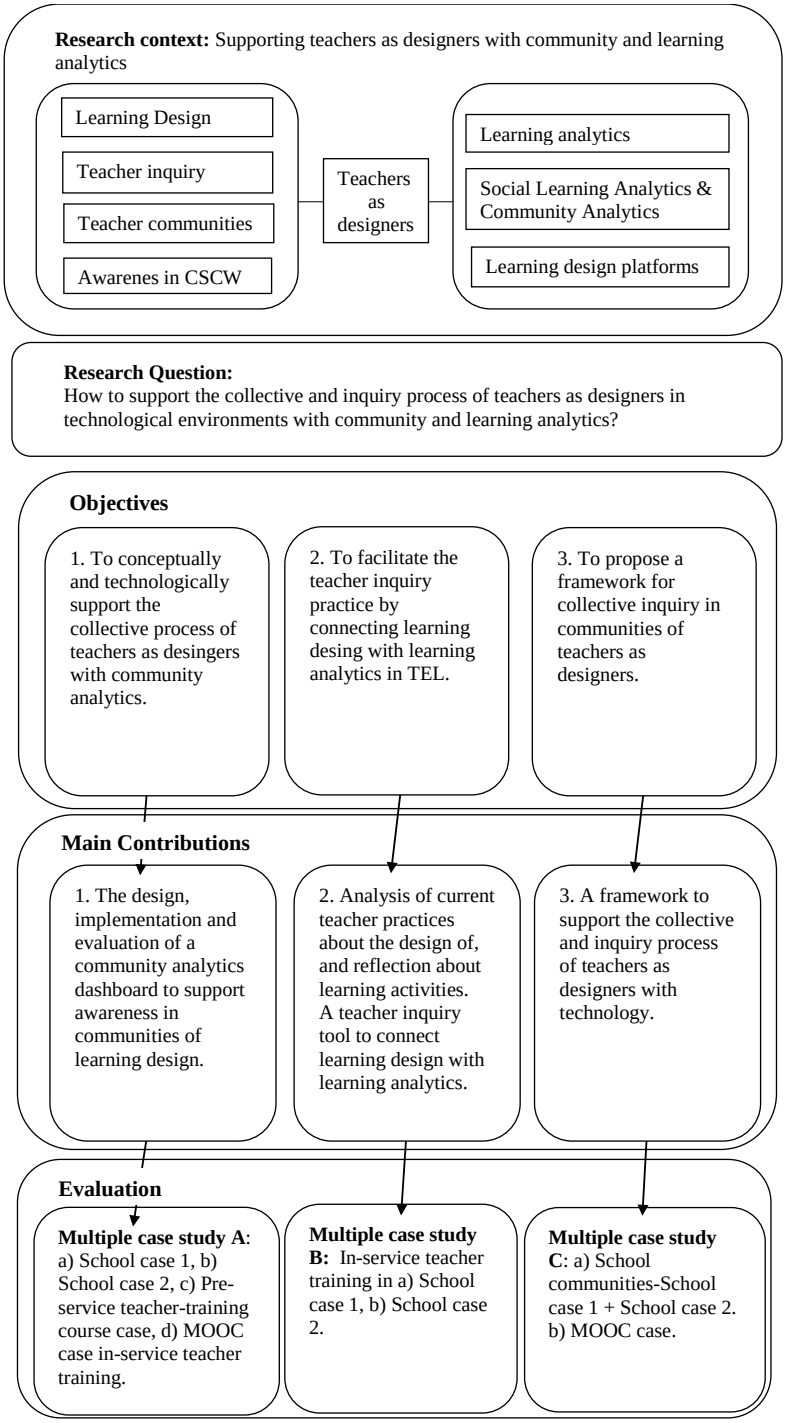

Figure 1. Schema of the research context, global research questions, specific research objectives, contributions and evaluation studies of the dissertation.

1.3 Research methodology

The research context of this dissertation focuses on supporting teachers as designers; a relatively new concept which requires further empirical investigation of teacher practices to integrate appropriate supports (Kali, McKenney, & Sagy, 2015). The partial objectives of this dissertation explain the need to understand and support teachers as designers in technological environments with data analytics as reflective practitioners. Thus, considering the research context and partial objectives of the dissertation, the examination of teachers´ practices in naturalistic contexts (Barab, & Squire, 2004) was one element to define the research methodology. Systematic engineering of these contexts allows evidence-based improvements rather than simply observation. Such methodology is referred to design experimentation or Design-Based Research (Amiel & Rieves, 2008). This methodology is increasingly used in the field of Education including ICT for a better connection between research and practice. For instance, McKenney & Pareja Roblin (2018) explain how DBR and teacher inquiry can facilitate research-practice partnerships. Moreover, Laurillard et al. (2018) & Hernández-Leo et al. (2018) explain the development of learning design platforms based on DBR which involved collaboration between researchers and teachers in iterative design cycles. DBR has been also used in the context of TPD in online teacher communities to determine effective ICT integration both for teachers and researchers (MacDonald, 2008; Dede et al., 2009).

Wang & Hannafin (2005) define DBR as a systematic but flexible methodology aimed at improving educational practices through iterative analysis, design, development, and implementation, based on collaboration between researchers and practitioners in real-world settings and leads to contextually-sensitive design principles and theories (p.6). DBR differs compared to controlled experimentation and objectivity, reliability and validity are determined with systematic analysis and triangulation of multiple sources and kinds of data. Typically design artifacts and design principles are the results of the systematic analysis in DBR. According to Amiel & Rieves (2008), good principles in DBR are the following:

1. There should be a good connection between the design of learning environments and the development of theories.

2. The research is conducted through continuous cycles of design, enactment, analysis, and redesign.
3. Research on designs must lead to sharable theories that help to communicate implications to researchers and other educational practitioners
4. Research should be conducted in authentic settings.
5. The methodology should include documentations and connections between processes of enactment to outcomes that generate knowledge directly applied in educational practice.

We applied the DBR methodology in the context of TPD for teachers as designers. Thus, instead of focusing on student learning we followed the DBR methodology to investigate teacher design practices with data analytics to enhance their professional development. Based on multiple proposals of DBR models, we applied the model by Amiel & Rieves (2008) which is based on 1) Analysis of practical problems, 2) Development of solutions, 3) Iterative cycles of testing and refinement, and d) Reflection to produce design principles and enhance solution implementations (see Figure 2).

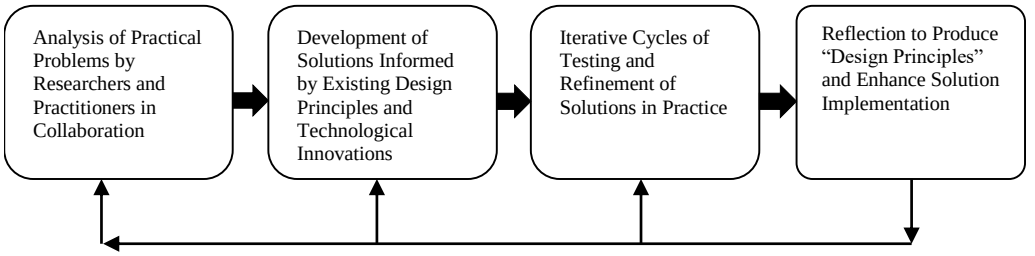

Figure 2. Design-Based Research Methodology (Amiel & Reeves, 2008)

In the context of this thesis, an existing technological environment for learning design (ILDE) (Hernández Leo et al., 2018) was used for studying and supporting teachers as designers. ILDE is a community-oriented platform for learning design, in which members can create, co-create and share designs spanning from the conceptualization of learning designs to their implementation in VLEs (e.g. Moodle, educational apps). ILDE provides both an individual space for the creation and management of learning designs with multiple tools (see Figure 3) and a social space for sharing, re-using, commenting and exploring community members´ activity (see Figure 4).

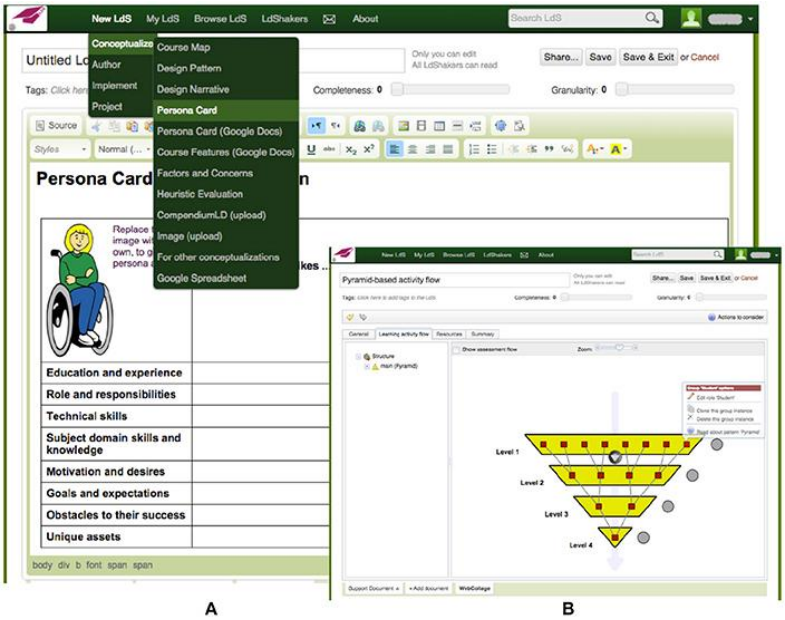

Figure 3. ILDE screenshot showing the individual space and learning design tools: A) Personal Card (Conceptualization tool) and B) WebCollage (Authoring tool) (Hernández Leo et al., 2018, p.10).

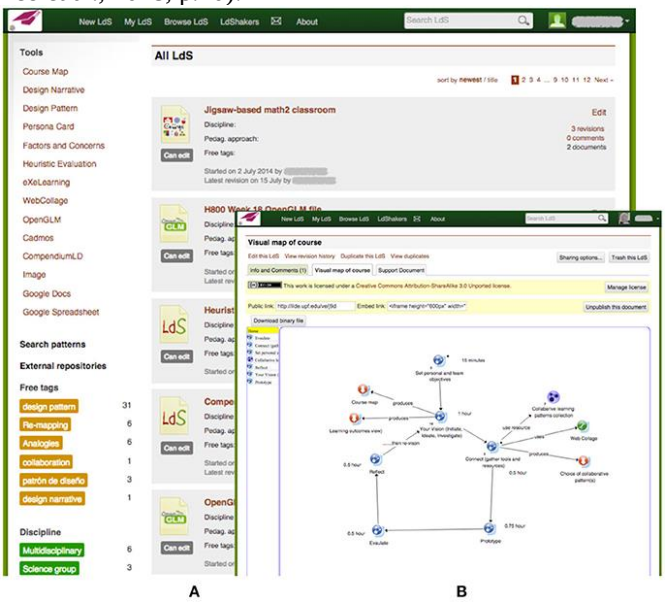

Figure 4. ILDE screenshot showing the social space: A) Browsing learning design by tags and tools and B) Viewing learning designs of others (Hernández Leo et al., 2018, p.10).

There were several reasons to choose this learning design environment instead of others during this doctoral thesis. ILDE was

developed in the GTI-learning and later TIDE research group (our research group) as an outcome of the METIS[1] European project. Additionally, ILDE enables the design and implementation of learning designs which is not the case in other learning design platforms (e.g., Learning Designer). It was feasible to analyze the implementation of learning designs with the tools provided by ILDE and we had access to the whole ILDE technological infrastructure (this was not feasible for instance with LAMS which also supports the implementation of learning designs). Moreover, this thesis proposes technological artifacts and tools as part of the DBR methodology and it was more feasible to implement and evaluate them in ILDE during the 3 ½ years of the thesis development. Lastly, this thesis proposes data analytics support in teacher communities and through ILDE we could access existing communities and data from previous projects or facilitate new teacher communities with the use of ILDE.

In the following paragraphs, I explain each step of the DBR model proposed by Amiel & Reeves (2008) and how it was applied in the context of this thesis. As Figure 5 illustrates, we conducted 3 cycles of the DBR model according to the 3 main thesis objectives. The objectives were iteratively defined after the competition of each cycle. During Cycle 1 and 2, in the analysis phase, we conducted preliminary studies in collaboration with teachers, and educational practitioners to understand the challenges and needs addressed in the literature and by practitioners. This informed the formulation of initial research questions which were iteratively revised through the whole DBR process (See Table 1 for the main research questions addressed in this thesis). Regarding the collaboration with practitioners, we analysed the current inquiry and collective process of teachers about the design of, and reflection about learning designs in real-settings. Research about "teachers as designers" (Kali, McKenney, & Sagy, 2015) stresses the need to understand how teachers engage with design and reflection in authentic settings so that the development of teacher supports and tools are meaningful in their practice.

[1] http://websites.cardet.org/metis

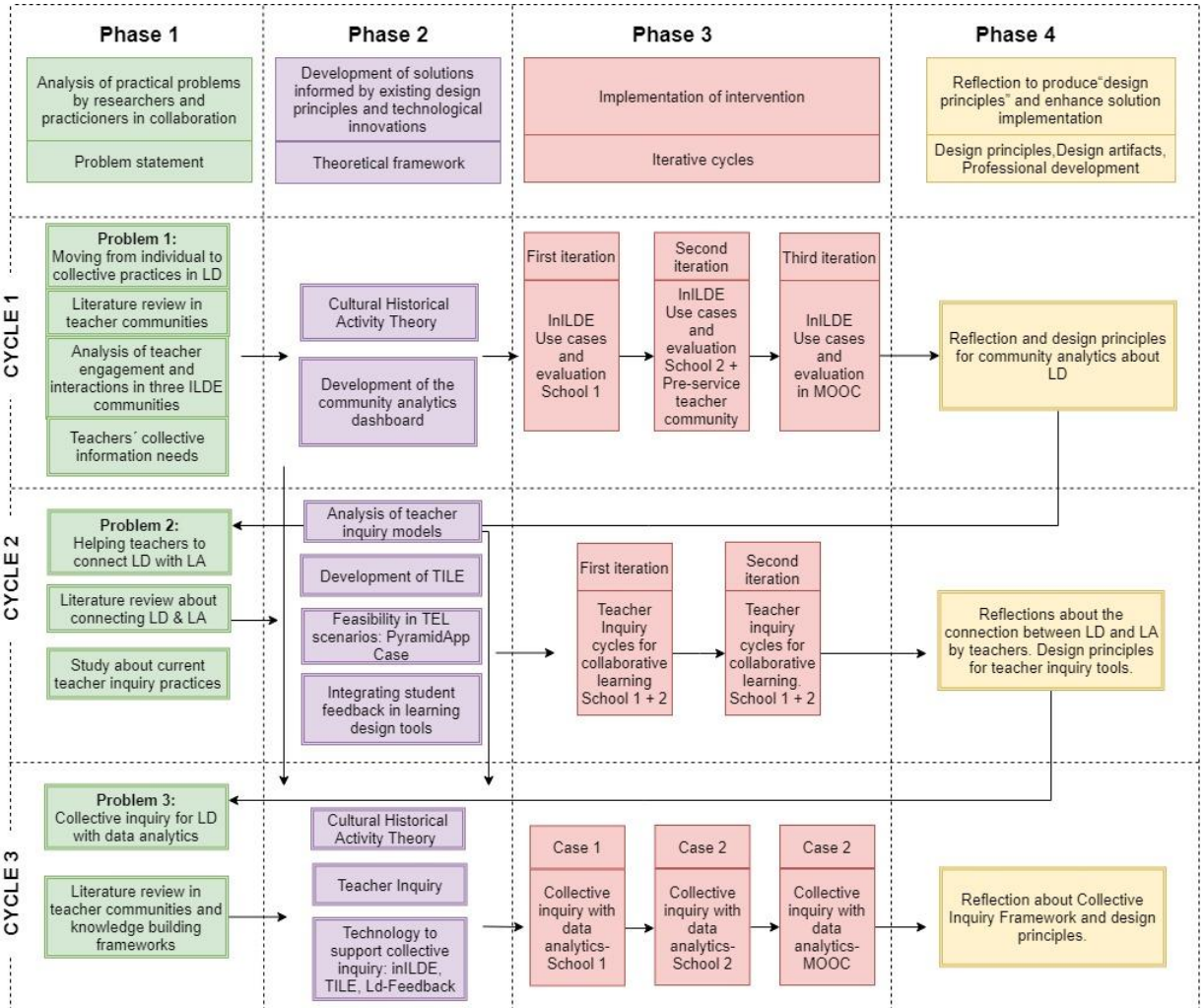

Figure 5. DBR methodology followed during the thesis

Table 1. Main research questions in the context of this dissertation

Main Research Question
How to support the collective and inquiry process of teachers as designers in technological environments with data analytics?
Specific Research Questions
[RQ1]: How can community awareness data support the learning design process of teachers? (related to [OBJ_1] in section 1.2). [RQ1a]: What data and visualizations do teachers find useful? [RQ1b]: How can community awareness data be made useful for the community and the individuals involved in learning design tasks?
[RQ2]: To what extent does teacher-led inquiry help teachers to connect their learning designs with learning analytics in teacher communities? (related to [OBJ_2] in section 1.2). [RQ2a]: What is the current teacher-led inquiry practice in different teacher communities? [RQ2b]: How can technology support teacher-led inquiry for data-informed reflections?
[RQ3]: Does and how a collective inquiry framework helps to study and support participatory teacher design practice with data analytics? (related to [OBJ_3] in section 1.2). [RQ3a]: How do teachers engage with data-intensive collective inquiry processes? [RQ3b]: How do teachers perceive data-intensive collective inquiry processes?

As part of the overall DBR process, several research-practitioner partnerships took place during the years of this dissertation in a regional project about teacher communities (CoT). In this project, a TPD program was implemented with teachers in two High School communities and included training in learning design and learning analytics tools. Moreover, ILDE was used in other educational contexts such as a master course for pre-service teacher training and a MOOC for learning design. Table 2 describes the different educational communities and participants during the DBR cycles.

Table 2 Main participants and educational communities involved during the dissertation.

Educational community	**Description**	**Participants (Teachers)**	**TPD program**
School 1	Spanish High school with cooperative management.	*N*=21	CoT project in Catalonia
School 2	Spanish High school with traditional top-down management.	*N*=12	CoT project in Catalonia
Pre-service teacher community	Pre-service secondary education biology teachers involved in a master's degree.	*N*=27	Master's degree in UPF
Teacher community in MOOC	Teachers across different educational levels involved in a MOOC for learning design.	*N*=100	MOOC deployed in Canvas platform: Innovative Collaborative Learning with ICT

Cycle 1:

Regarding the first problem ([OBJ_1]) about collective approaches and community awareness in learning design, we conducted a literature review in teacher communities and especially those that use networked technologies. We also performed an initial analysis in three educational communities regarding the levels of teachers´ engagement and interactions with ILDE. Our analysis proposes that the visibility of teachers´ activity in a community platform can provide useful information about the function of the community and the identification of learning designs for re-use. However, in the context of learning design, there is no previous research regarding types of information which are relevant for teachers as designers. During the analysis phase, we also evaluated teachers´ perceptions about the available community information in ILDE and which additional collective information could be potentially used to inform their learning designs.

In the design phase, we conducted an additional literature review in teacher communities which utilize networked technologies such as Twitter, Facebook, Moodle. Common challenges identified were limited participation, interactions, and contributions by teachers. The literature review also showed that common frameworks for teacher communities such as PLCs and CoPs did not consider the case in which teachers exchange learning designs or instructional resources.

Based on our first analysis in teacher communities who used ILDE, we emphasized on teachers´ online interactions which are not only text-based (e.g., with comments) but also interactions mediated by the sharing of learning design artifacts. Conole & Culver (2010) analyzed user interactions in CloudWorks and refer to these artifacts as "social objects" which can be used as interaction metaphor in communities interested in learning design. Relevant frameworks about artifacts-based interactions have been also used in the context of CSCW and Computer Supported Collaborative Learning (CSCL). For instance, distributed cognition (Solomon, 1993) and Cultural Historical Activity Theory (CHAT) (Engestrom, 2000) seek to explain how mediating artifacts allow communication between people.

Considering the above, we used the CHAT framework to conceptualize communities of teachers as designers (Conole, 2009). Based on this and related research in CSCW and educational communities, we designed a community awareness dashboard (inILDE), which provides information about the activity of teachers in ILDE. The community awareness dashboard aimed at showing information about the interactions with objects-learning designs, the subjects-members, and the mediating artifacts-learning design tools so that members of a learning design community can better understand emerging roles and patterns of behavior (rules) in their community. The dashboard was implemented in ILDE but the design rationale aims to inform the development of dashboards in teacher community platforms. During the implementation of the intervention, we also used the CHAT framework to evaluate and interpret usefulness of information regarding the objects-learning designs, the members-teachers, and the mediating artifacts-tools because previous studies have shown its application as an analysis framework for teachers group work (Voogt et al., 2015).

We conducted three iterations of testing and refinement in four different educational communities (School community 1, School community 2, Pre-service teacher community, MOOC for learning design). In the first cycle, we evaluated dashboard prototypes with real-data sets collected from School community 1. The prototype was developed in Tableau[2], which is a data visualization tool for data discovery and dashboard creation. In the second cycle, we implemented a first prototype of the community dashboard in the Graphical User Interface (GUI) of ILDE. The dashboard was revised based on the feedback gained in the first cycle. For instance, bar charts about teacher participation were redesigned because teachers revealed that comparisons about teachers´ participation can create undesired competitive modes in the community. In the second iteration, teachers in School community 2 and pre-service teachers in a master course evaluated the usefulness of the community analytics dashboard. Lastly, we conducted a 3rd iteration and a final evaluation of the dashboard during a MOOC for learning design. In this case, the participants used the ILDE environment for one week without the dashboard and five weeks with the dashboard. We evaluated differences in participants interactions and levels of engagement with/without the dashboard. Moreover, after the MOOC, participants fulfilled a questionnaire with open and closed questions about the user experience with the dashboard.

After the three iterations, we compared all the feedback derived from the four different educational communities considering both qualitative and quantitative data. Then, we formulated a set of design principles for community awareness support in the context of learning design communities and refined the community analytics dashboard (see main contribution in Section 1.4)

Cycle 2:
One outcome of the first cycle was that teachers needed additional information regarding the implementation of their learning designs. Teachers´ collective information needs referred to teacher experiences derived from the implementation of learning designs, student related information and student feedback.

[2] https://www.tableau.com

This informed the formulation of the second thesis objective regarding teacher inquiry and the connection between LD and LA. Teacher inquiry is both an individual and collective process in which teachers engage in evidence-based approaches to solve instructional problems that lead to improved student learning (Hansen & Wasson, 2016). In the analysis phase, we conducted studies in collaboration with teachers about their current inquiry practice in two High school communities (see RQ2a, Table 1). The analysis focused on three elements similar to previous research in teacher inquiry in school settings (Butler & Schnellert, 2012). These elements were the following: a) the current design practice of teachers, b) the current formative evaluation practice with/without the use of student data and, c) the current teacher collaborations about learning design. The analysis was performed in the context of a TPD program for teachers. We followed a mixed method approach and triangulated quantitative and qualitative data. The primary data sources were a questionnaire about the current practice of teachers, teacher documentation artifacts in ILDE and discussion groups transcripts during the TPD workshops. Summary results of this analysis are presented in section 1.4.

The above initial studies informed the focus on facilitating teacher inquiry processes for connecting LD with LA in TEL scenarios. During the design phase of the DBR methodology, a literature review was conducted about Teacher Inquiry (TI) models (Clarke, & Erickson, 2003; Avramides et al., 2015; Hansen & Wasson, 2016; Luckin et al., 2017) with focus on TEL. Studies in teacher inquiry revealed that teachers need additional support to collect data in TEL scenarios and it was difficult to follow the complete teacher inquiry cycle from the initial design until the reflection about implemented learning activities (Avramides et al., 2015).

Considering different TI models, we developed an initial prototype of a Teacher Inquiry tool for Learning dEsigns (TILE). The tool structures the inquiry process in four inquiry steps:

- Step 1: Problem formulation and Questions.
- Step 2: Intervention and evaluation design
- Step 3: Reporting of collected data and analysis
- Step 4: Reflection and proposed instructional changes

To further understand how the connection between LD and LA can be contextualized in some cases and analyse the feasibility in TEL scenarios, we focused on the case of CSCL activities. The reason is that the design and implementation of CSCL activities is a non-trivial, challenging task for teachers (Hernández-Leo et al., 2006) and an interesting case to inquiry into student learning with student-generated data. In CSCL, the structuring of meaningful learning tasks and student interactions creates the conditions for active learning in groups. Building on previous work conducted in the TIDE research group, we used the PyramidApp tool which is integrated into ILDE and allows the design and implementation of collaborative learning activities based on the Pyramid flow pattern (Manathunga & Hernández-Leo, 2018). With the PyramidApp tool, we were able to evaluate both the design and implementation of collaborative learning activities and our proposed TI model. We used activity logs collected from PyramidApp to identify learning analytics that can be presented to teachers after the implementation of their learning designs. The proposed learning analytics visualizations aimed at showing information relevant to the pedagogical intent of a learning design, the pedagogical method/structure, and the practicalities to implement a learning scenario.

During the TPD program in School 1 and 2, the TILE tool was initially designed as an Excel-based prototype and was implemented in ILDE. In the first iteration, $N=6$ teachers used TILE and PyramidApp tool to design, implement and document a complete inquiry cycle of a collaborative learning activity. After the implementation of their learning designs, teachers were provided with an analytics report about the engagement of students during the PyramidApp activity. Moreover, teachers were able to observe student discussions with a monitoring function of PyramidApp and some teachers collected student feedback about the implemented activity with Google forms questionnaires. After the classroom implementations, teachers were involved in joint discussions about the inquiry cycles and their data-informed reflections in a workshop.

In the first iteration, we evaluated the use of TILE and the teacher experience for a technology-supported teacher inquiry cycle. We used mixed method approach and triangulated different sources of qualitative data: a) Teacher open responses´ for the use of TILE, b)

teacher comments in ILDE about complete inquiry cycles with student data, c) Teacher artifacts in TILE.

A second iteration was conducted to evaluate the use of TILE in the two different school communities. *N*=8 teachers implemented and reflected on collaborative learning activities with student data. *N*=4 teachers revised their designs based on the previous iteration. During this iteration, TILE was redesigned as a web-based interactive tool considering design requirements derived from the 1st iteration. Teachers followed the same workflow as in the previous iteration. After the second iteration, we conducted 7 semi-structured interviews with the teachers who completed the inquiry cycles. We also triangulated and cross-referenced other qualitative data to warrant our interpretations. The additional data sources were: a) a questionnaire with open responses for the use of TILE, b) teacher comments in ILDE about complete inquiry cycles with student data, c) teacher artifacts in TILE. In the reflection phase of the overall DBR methodology, we formulated design principles to enhance the TI model and the implementation of teacher inquiry tools (see main contributions in Section 1.3).

Cycle 3:
In the final cycle, we reflected on results derived from the two previous cycles with the aim to construct a framework for collective inquiry on learning designs with data analytics. The framework aims at facilitating knowledge building in professional communities for learning design. We conducted a literature review about collective inquiry frameworks for knowledge building in the context of workplace learning and teacher learning. The literature review and Cycles 1 and 2, informed the design of the Collective Inquiry with Data Analytics (CIDA) framework. The framework was described in three case studies (two school communities and a MOOC community). Thus, we did not perform additional iterative cycles but we analyzed data derived from Cycle 1 & Cycle 2. A cross-case analysis was used to interpret the results from the three community cases. After this cycle, we derived a set of design principles to enhance the implementation of the CIDA framework in practice (see main contributions in Section 1.4.)

During the DBR methodology, we followed mixed method research (Creswell, 2003) due to the explorative nature of the

research questions and that the investigation was conducted in authentic contexts. Mixed method research can be defined as "the class of research where the research mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or languages into a single study" (Johnson & Onwuegbuzie, 2004, p17). In our cases, we triangulated and cross-referenced quantitative and qualitative data to warrant our interpretations during the three DBR cycles. Moreover, we relied on ethnographic methods such as content analysis of teachers´ responses and comments to deepen the analysis of teachers´ practices and perceptions. Mixed methods provide benefits such as a detailed and descriptive view of the situation (e.g., teacher inquiry in digital environments) and data interpretation with divergent views. Table 3 explains the main data sources and data gathering techniques which were used during this dissertation. In particular, as explained in the previous paragraphs, in Cycle 1 (OBJ_1) we utilized quantitative data such as activity logs obtained in ILDE. This allowed an understanding of teachers´ engagement and interactions in ILDE, the development of the community awareness dashboard (inILDE) and later the evaluation of the dashboard. Moreover, we used quantitative data obtained by questionnaires such as the User Metric for User Experience (UMUX) questionnaire (Finstad, 2010). Quantitative data were analyzed in IBM SPSS 22.0 with descriptive and inferential statistics. We also performed a content analysis of teachers´ responses and comments about the iterative design of the community dashboard. Teacher comments were analysed with thematic analysis driven by our research questions. In Cycle 2 (OBJ_2), we employed a more qualitative approach because we analysed the current teacher inquiry practices and later the subsequent teacher practice supported with technologies. Examples of data sources were teacher artifacts created in ILDE or with the TILE tool, focus groups and interviews´ transcripts, comments in ILDE during group reflections. In Cycle 3 (OBJ_3), we used qualitative and quantitative data collected during Cycle 1 and 2 such as activity logs, questionnaires, and interviews to validate the proposed collective inquiry framework. We also used a coding scheme grounded on the Technological Pedagogical Content Knowledge (TPACK) framework (Koehler & Mishra, 2005) with the aim to understand types of knowledge generated when teachers comment learning designs and teacher inquiry documentations created by others.

Table 3. Main data sources and data gathering techniques

Technique	Description	Purpose
Activity logs (Teachers)	Users actions in the ILDE environment (event timestamps about comments, creation of learning designs, learning designs views and edits, dashboard views).	Evaluating teacher participation and interactions in ILDE during all the cycles. Designing prototype of inILDE dashboard
Questionnaires[3] (Teachers)	Questionnaires were designed based on the different RQs during the DBR cycles. Questionnaires included closed questions with Likert scale (1-strongly disagree-7 strongly agree, e.g. User Metric for User Experience – UMUX) and open questions.	Evaluating the usefulness of inILDE dashboard. Evaluating the usefulness of TILE and teacher inquiry cycle with learning analytics.
Teacher artifacts (Teachers)	Teacher artifacts produced by different ILDE tools. Teacher artifacts produced by the TILE tool.	Analysis of current teacher practices about learning design. Analysis of teacher inquiry cycles.
Focus groups transcripts (Teachers)	Transcripts of voice recordings during focus groups with teachers conducted in TPD workshops.	Analysis of current teacher practices about learning design. Analysis of teacher inquiry cycles.
Interviews[4] (Teachers)	Transcripts of semi-structured, face-to-face 40 minutes interviews with school teachers.	Analysis of technology-supported teacher inquiry cycles with the collection of student data.
Comments (Teachers)	Teacher comments provided in ILDE were analysed with thematic analysis and in some cases based on existing frameworks (e.g. TPACK).	Analysis of teachers´ group reflections about the interpretation of learning analytics and teacher inquiry cycles. Analysis of teacher comments about learning designs.

[3] A sample of questionnaires is presented in Appendix B
[4] A sample of interview questions is presented in Appendix B

1.4 Main contributions

In this section are presented the main contribution of this dissertation and the main evaluation studies.

1.4.1 Contributions

As depicted in Figure 1 the main contributions of this thesis are related to its three main objectives and are the following:

- **The design, implementation, and evaluation of a community analytics dashboard to support awareness in communities of learning design.**

Research in learning design has considered tools and methodologies which can facilitate teachers to act as learning designers. One of the main pillars of learning design research is the sharing of teacher documentations or "learning designs". However, existing research about the development of communities around learning design is scarce and little is known on what elements needs to be considered. Moreover, networked technologies are frequently used in teacher communities, but they are challenging due to socio-technical factors and peripheral teacher participation. Awareness about other members´ activity in communities that utilize networked technologies can decrease the level of these challenges.

This thesis contribution conceptualizes teachers as designers in communities based on the CHAT framework. Through this framework, emphasis is given on mediating artifacts such as tools used for learning design. A community awareness dashboard was designed to visualize teacher interactions with objects-learning designs, subjects-members and learning design tools-mediating artifacts. The dashboard was iteratively evaluated in four educational communities (two school communities, pre-service teacher community and a MOOC for teachers). Results reveal that the dashboard provided a better understanding of the community activity in terms of members' roles, contribution behavior and identification of learning designs. Teachers who used the dashboard interacted more with other teachers through comments and profile views

compared to teachers who did not use the dashboard. Teachers reflected about the content of different learning designs created in the community. We derive five design principles for supporting awareness in learning design communities based on the iterative refinement of the dashboard with the teachers. The design principles are the following:

a) *Community context*: Teachers´ pre-existing relations, preferences and motivation influence the types of community data which are valuable to share.

b) *Practice-related insights*: Support for community awareness needs to consider practical teacher constraints such as available time and workload. The application of learning designs in practice (e.g. in classrooms) and the sharing of teachers´ experiences about their students inform and add more value to the overall community information.

c) *Visualizations and representations* of community awareness data need to consider the data literacy levels of teachers. Direct access to learning design artifacts allows connection between graphical representations and qualitative content.

d) *Structured vs. Unstructured tasks*: The utilization of community awareness data by teachers needs to consider the types of tasks that teachers perform. Structured tasks refer to guidance by facilitators or learning design tools. Unstructured tasks refer to the self-organized exploration and creation of learning designs by teachers.

c) *Community interests*: The interests of the learning design community should be considered in the presentation of community information visualized because they allow a higher degree of teacher interactions. The studies showed that main interests were about methodologies, tools and teacher experiences.

A detailed study about the design and implementation of the dashboard for supporting awareness in learning design communities is provided in Chapter 2.

- **Analysis of current teacher practices about the design of, and reflection about learning designs. A teacher inquiry tool to connect learning design with learning analytics in TEL.**

The second contribution refers to the analysis of current teacher inquiry practice in High Schools. Moreover, this contribution shows how a tool for evidence-based learning designs was implemented to facilitate teacher inquiry. Results reveal that the documentation of teachers´ designs was restricted to resources rather than to learning tasks. Moreover, teachers' formative evaluations of learning tasks relied on informal discussions with students or on the use of feedback questionnaires. Teachers´ collaborations on the design of learning tasks were limited and between same-subject teachers.

The TILE tool was used by 14 teachers in two iterations of design and implementation of CSCL activities. Qualitative data triangulation showed that the TILE tool facilitated awareness of inquiry steps like teaching problem formulation and reflection after the implementation of the activities. TILE enabled the sharing of teacher inquiry cycles documentations and teacher discussions focused on time management of CSCL activities and awareness of student misunderstandings about the learning task.

Some design principles for teacher inquiry tools were formulated based on the iterative cycles:

a) *Time constraints*: the development of teacher inquiry tools needs to consider the available time and teacher workload.

b) *Ease to collect different type of data*: the process to collect data should be feasible and do not interrupt the learning tasks performed by students. Qualitative student feedback was perceived relevant by teachers to inform (re)design as a supplement of learning analytics visualizations.

c) *User guidance for data collection tools*: Teachers need detailed guidance to use data collection tools during the enactment of learning tasks.

d) *Data interpretation*: Teachers need examples of data interpretations about learning design improvements.

e) *Sharing of teacher inquiries*: The sharing of teacher inquiries adds more value to the contributions and interests of teacher communities.

The detailed studies about the analysis of teacher inquiry practices and the implementation of the TILE tool are provided in Chapter 3.

- **A framework to support the collective and inquiry process of teachers as designers with technology.**

Based on the two previous contributions, a framework (CIDA) for collective inquiry for teachers as designers was conceptualized and described in three case studies. The framework proposes three interconnected components to support collective inquiry in technological environments for teachers with data analytics. The three components are:

- *The inquiry process*: Such a process needs to integrate the teacher inquiry cycle (e.g. the one proposed behind TILE). This allows the connection between learning design, learning analytics and pedagogical knowledge building.

- *The collective process*: The individual teacher inquiry can be shared and re-used within a community of teachers. In this collective process, the CHAT framework shows how the sharing of teacher inquiries and teachers´ experiences is mediated by learning design tools.

- *Technological support*: Designs for technologies to support collective teacher inquiry with data analytics are proposed. Reference implementations for these designs have been integrated into ILDE, namely, the community awareness dashboard inILDE, the TILE tool, and the Ld-Feedback tool.

A cross-case analysis in a MOOC for learning design and two school communities shows that collective teacher participation decreases through the time and this relates with time constraints, familiarity with working asynchronously and lack of community moderation (Lantz-Andersson, Lundin & Selwyn, 2018). Collective

reflections through online teacher comments showed evidence of activated pedagogical knowledge. The collective process was positively received by teachers because it allows sharing of problems, learning from others´ experiences and emerging learning design ideas. Teachers engagement in the inquiry processes showed added value in cultivating teacher reflective practice and co-regulating teaching problems and solutions. Teachers showed different levels of engagement in the teacher inquiry cycle, which also relates to their contributions to collective reflections in their community. Levels of engagement differed in terms of details provided by teachers in each inquiry step. Teachers' preferences differed in terms of tools used to collect student data.

Some design principles for the implementation of the CIDA framework in TPD are proposed:

- TPD needs to consider teacher training in reflective learning design with learning analytics. Collective reflections can be oriented by TPD facilitators towards cultivating integrated technological, pedagogical and content knowledge for teachers.
- Community awareness and collective platforms with aggregated teacher data can facilitate asynchronous teacher work.
- The implementation and sharing of teacher inquiry cycles add more value to the community information and contributions.
- Teacher roles can be distinguished from co-designers who provide peer-feedback and contribute to the collective process to enactors who complete the whole inquiry process.
- Tools for teacher inquiry should produce artifacts that can be shared and further refined by the community of teachers.

The detailed elaboration of the framework and the three case studies are provided in Chapter 4.

1.4.2 Main evaluation studies

This dissertation consists of pilot and evaluation studies conducted during the three DBR cycles. In each cycle, we used multiple case

study analysis to cross-check results across different educational communities.

- In cycle 1, we initially analysed teachers´ collective behavior about their engagement levels and social interactions in three ILDE installations as examples of learning design communities (see Chapter 2.2 for this analysis). Activity logs were extracted with SQL queries from the ILDE database. We conducted correlation analysis in SPSS IBM 22.0 and Social Network Analysis in Gephi Software[5]. Results proposed that passive participation (exploration of content) was related to active participation (content creation) and visibility of popular content and active contributors could influence teachers' social interactions. We additionally analysed teachers´ collective information needs in ILDE by means of an open-ended questionnaire in School 1 and School 2 (See table 2). After this analysis, we designed prototypes of the inILDE community awareness dashboard and evaluated its perceived usefulness for specific use cases (see Appendix A). The prototypes were evaluated in School 1, School 2 and the pre-service teacher community (see table 2). After this, we redesigned the dashboard and implemented it into the ILDE GUI. In the final evaluation, participants in a MOOC for learning design used the ILDE without the dashboard for one week and with the dashboard for five weeks. Moreover, during the MOOC, they engaged in discussions tasks with and without the use of the dashboard. After the completion of the MOOC, participants were asked to respond to a questionnaire with closed questions about perceived user experience (UMUX questionnaire) and open questions about the use of the dashboard to facilitate learning design tasks. A detailed report about cycle 1 is provided in Chapter 2.

- In cycle 2, the main evaluation studies were conducted in School 1 and School 2. In this case, we evaluated teachers´ current practices regarding a) learning design, b) formative evaluation and c) teacher collaboration. We used teachers´ documentation in ILDE, a closed questionnaire and focus groups during the workshops. After this, we designed TILE and involved participants in two inquiry cycles of design,

[5] https://gephi.org/

implementation, and reflection with technologies. The inquiry cycles were about collaborative learning activities in the classroom with the PyramidApp tool. Learning analytics reports regarding student engagement in PyramidApp were provided to teachers after classroom implementations. Teachers were involved in joint discussions about the inquiry cycles and the student-generated data. In the first iteration, *N*=6 teachers in both Schools completed an inquiry cycle and used TILE. In the second, iteration *N*=8 teachers completed the inquiry cycles. We used different qualitative data to evaluate teachers´ experiences about a) learning design, b) formative evaluation and c) teacher collaboration after using the proposed technologies. The qualitative data were: teacher generated artifacts with TILE, teacher comments in ILDE, interview transcripts. The detailed analysis and results are presented in Chapter 3.

- In cycle 3, we conducted a multiple case study analysis to evaluate the proposed CIDA framework for collective teacher inquiry. The three cases were the MOOC for learning design and two school communities. We analysed how teachers experienced collective inquiry with data analytics and how teachers perceived collective inquiry with data analytics (see Table 1, RQ3). We collected and triangulated quantitative and qualitative data for answering the research questions. The data sources were activity logs, online comments, teacher artifacts and questionnaires with open and closed questions. A cross-case analysis between the MOOC and the school communities was used to interpret the results. Last, we proposed implications for the application of the CIDA framework to TPD programs. The detailed study about the CIDA framework is described in Chapter 4.

1.4.3 Publications

This dissertation is organized and presented as a compendium of research articles published or submitted for review as given below:

[Pub1] - Michos, K., & Hernández-Leo, D. (2018). Supporting awareness in communities of learning design practice. *Computers in Human Behavior*, 85(August 2018), 255-270.

[Pub2] - Michos, K., & Hernández-Leo, D. (2016). Understanding collective behavior of learning design communities. In *European Conference on Technology Enhanced Learning* (pp. 614-617). Springer, Cham (LNCS).

[Pub3] - 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.

[Pub4] - Michos, K., Manathunga, K., Hernández-Leo, D. (2016). Connecting pattern-based learning designs with analytics: The case of the PyramidApp. In *the Workshop on Connecting Learning Analytics and Learning Design (CLAD 2016) at The Eleventh European Conference on Technology Enhanced Learning (EC-TEL 2016)*, Lyon, France, September 13-16.

[Pub5] - Michos, K., Fernández, A., Hernández-Leo, D., & Calvo, R. (2017). Ld-Feedback App: Connecting Learning Designs with Students' and Teachers' Perceived Experiences. In *European Conference on Technology Enhanced Learning* (pp. 509-512). Springer, Cham (LNCS).

[Pub6] - Michos, K., & Hernández-Leo, D. Studying and supporting teachers as designers in data-intensive inquiry communities: a framework, technology and case studies (*Submitted to Journal*).

1.4.4 Projects

The largest part of the works carried out during this thesis contribute to the research results of the following project:

- CoT (Communities of Teaching as a data-informed design science and contextualized practice). Date: 2016 – 2019. Funding entity: RecerCaixa, Catalonia. Participant entity:

Universitat Pompeu Fabra. Principal Investigator: Davinia Hernández-Leo.

In addition, this thesis contributes to the following projects:

- RESET (REformulating Scalable Educational ecosysTems). Date: 2015 – 2017. Funding entity: Spanish Ministry of Science and Innovation (TIN2014-53199-C3-3-R). Participant entities: http://reset.gast.it.uc3m.es/ 23 UC3M, UVA, UPF. Principal Investigators (UPF): Josep Blat and Davinia Hernández-Leo.

- MDM (Maria De Maeztu DTIC Strategic Research Program) – Educational Data Science (EDS). Date: 2016 – 2019. Funding entity: Spanish Ministry of Science and Innovation (MDM-2015-0502). Participant entity: Universitat Pompeu Fabra. Principal Investigator of EDS sub project: Davinia Hernández-Leo.

1.5 Limitations

During this dissertation, we followed the DBR methodology to study and support with ICT solutions the process of teachers as designers with data analytics. We performed multiple cycles of iterative refinement and evaluations with practitioners in real cases. We report the results of the whole DBR methodology and the evaluation of the solutions so that other researchers can re-use design principles and other elements in the context of teachers as designers of TEL activities. However, we encountered several challenges and limitations because of the real settings in which the research was conducted with practitioners and their students. The main limitations of this dissertation are the following:

- **Methodological issues**

During the different phases of the DBR methodology, we conducted evaluations about the proposed solutions with teachers. One limitation refers to identifying measurable changes in teacher practices by employing more quantitative techniques (e.g., inferential statistics). Although we used this in the evaluation of the community

dashboard, we did not use inferential statistics in the evaluation of the teacher inquiry cycles and the TILE tool. In general, during the whole thesis, we analysed qualitative data sources which are also challenging due to the coding performed by different researchers. For instance, in some cases, it was not feasible to involve several researchers in the coding of qualitative data. Moreover, during the teacher inquiry cycles, it would have been desirable to measure student learning outcomes and types of learning design improvements that lead to improved student learning. Although we describe teachers' practices with the TILE tool we did not measure student outcomes. Yet, our qualitative investigation of teacher inquiry practices in real settings allowed a deeper understanding of the needs and difficulties encountered by teachers. The qualitative results obtained can inform further research in this topic.

- **User interface design**.

Though functional, the final designs of the proposed solutions are prototypes that need to be further developed. The prototypical user interface implementation of the different tools (inILDE, TILE) could have influenced teachers´ perception about the usefulness of the tools.

- **Use of ILDE**

As we explained in section 1.3 we used ILDE because it enabled the implementation of the proposed solutions and the analysis of teacher's behaviors and creations as designers in technological environments. However, the specific functionalities of ILDE and its authoring tools influence the types of data analytics that can be collected and visualized. Moreover, the use of ILDE could have influenced the overall participation behavior of teachers both in the collective and inquiry processes.

- **Ethics and privacy**

In this dissertation, we encountered the challenge of data privacy and ethical implications of data sharing. During the CoT project, we collected all the required content forms by participants which explain how the CoT project minimizes data sharing risks (the CoT project procedures had ethical approval by the relevant UPF committee). However, studies about teachers´ and students´ perceptions about the implications and willingness of sharing data are beyond the

objectives of this thesis. Ethics in LA and educational technology research constitute a very important aspect for researchers and practitioners (Slade & Prinsloo, 2013; Pardo & Siemens, 2014). The TIDE research group is tackling this research line with related studies in the context of the same CoT project in which the main case studies of this thesis have been framed.

1.6 Conclusions

As mentioned in section 1.2, the global aim of this dissertation was to "*to study and support the collective and inquiry process of teachers as designers in technological environments with data analytics".* This global aim was divided into partial objectives regarding teachers´ collective process, inquiry process and the integrated collective inquiry process to support teachers as designers. The main conclusions about the three objectives are the following:

[OBJ_1] To conceptually and technologically support the collective process of teachers as designers with community analytics.

Research in LD stresses the sharing of teacher practices with formal representations so that teachers build on each other work. Although collective arrangements for TPD have been investigated in the context of teacher communities (Vangrieken et al., 2017), research in communities about learning design is still scarce (Laurillard et al. (2018). In this PhD thesis, we conceptualize teacher communities about learning design using CHAT. This framework shows how teachers build on each other contributions with mediating artifacts (e.g., learning design tools, learning scenarios designed by others). CHAT also describes the distribution of labour (e.g., the different members´ roles) and constraints or rules (e.g., teachers´ timetable) in the context of a teacher community (e.g., a school).

Networked technologies for teacher communities enable the sharing of learning design resources, exchange of teaching experiences, and teacher knowledge. However, awareness of other members activity in such technologies is critical for the knowledge sharing behavior within the community (Soller, 2007; de Laat &

Schreurs, 2013; Klamma, 2013). We used such a technological environment for learning design communities (ILDE) and developed a community awareness dashboard based on CHAT called inILDE. The dashboard visualized the activity of teachers in ILDE, such as their interactions with learning designs, other members and learning design tools, with the aim to support community awareness in a learning design community. The dashboard was iteratively designed and evaluated in four educational communities.

A preliminary study, conducted before the development of the community awareness dashboard, shows positive beliefs of teachers towards sharing learning designs and building on each other contributions. The results of the study also indicate that teachers´ collective information needs about learning design include experiences gained during the implementation of learning designs, student feedback and popular or subject-related teacher artifacts created in a teacher community. Teachers´ available time was crucial for the presence or absence of social interactions and reflections on community members´ contributions (Prenger, Poortman & Handelzalts, 2017; Jones & Dexter, 2014). The community awareness dashboard enabled a better understanding of teachers´ collective participation in the online learning design platform which may help reducing time constraints. Teachers gained an understanding about the social dynamics and sharing possibility within their community after consulting the dashboard. Blending the community dashboard with learning designs tasks showed evidence of teacher reflections on the collective activity about learning design, e.g., variations of different learning design patterns, reading others´ feedback comments, and identifying active contributors. The active community contributors used more frequently the dashboard and as a result, interacted more with other members (through comments and profile views). After the dashboard evaluation in real-settings, we proposed design principles for supporting awareness in communities involved with learning design (see details in Chapter 2).

This study can inform research in TPD programs about communities for learning design. The use of CHAT to conceptualize teacher communities for learning design can be extended in other community cases to analyse collective teacher participation and their social interactions in online or face to face settings. Moreover, the design, development, and implementation of the inILDE community

dashboard can inform research about networked technologies for teacher communities and research in the context of Social Learning Analytics and Community Learning Analytics (Buckingham-Shum & Ferguson 2012; Klamma, 2013; de Laat, & Schreurs, 2013). In particular, our design principles can be considered in the design of data visualization and community awareness tools (e.g. dashboards) for teacher communities. The visualizations can be presented to community members with the aim to ease their synchronous or asynchronous social interactions and support members´ regulation about their own or community contribution behavior.

[OBJ_2] To facilitate the teacher inquiry practice by connecting learning design with learning analytics in TEL.

In the previous study, teachers´ collective information needs referred to the exchange of teaching experiences and the collection of student-generated data during the implementation of learning designs. Considering that, we focused on teacher inquiry practice which is both an individual and collective process (Hansen, & Wasson, 2016). The aim was to study and support teacher inquiry in authentic settings and derive implications on how to help teachers connect LD with LA in TEL activities (Alhadad & Thomson, 2017; Percico & Pozzi, 2015; Mor, Ferguson & Wasson, 2015).

We initially conducted an explorative analysis of current teacher inquiry practices in two High Schools and then developed a supporting teacher inquiry tool (TILE). The tool was used during a TPD program wherein high school teachers implemented two cycles of technology-supported collaborative learning activities and jointly reflected on student-generated data.

Results showed that teachers´ current inquiry practice in the two school cases was essentially informal and invisible (e.g., discussions with students, discussions with other teachers). Teachers mainly documented recourses rather than tasks designed for learning and used diverse technologies and materials for their reflective documentations. The utilization of TILE enabled more formal, visible, and sharable practices and teachers documented their inquiries together with student-generated data (learning analytics). This also enabled in-depth discussions about the implementation of learning tasks and elaboration on student data. Teachers reflections

essentially referred to the time management of classroom TEL activities and the identification of students´ misunderstandings about the learning tasks.

The study about teacher inquiry practices in authentic settings such as schools can facilitate better adoption of learning analytics tools by teachers and their role as designers of learning environments. In this context, factors which influence the role of teachers include internal constraints (e.g., motivations, beliefs about teaching and learning), external constraints (e.g., school curriculum, educational institution policies) and practical constraints (e.g. size of the class, time) (Boschman, McKenney, & Voogt, 2015) and can also be considered for the adoption of learning analytics tools for teacher inquiry (Alhadad & Thomson, 2017). Our proposal for structured scaffolds in the teacher inquiry process can guide teachers on how to embed the evaluation of technology-integrating activities in their everyday teaching practice. Our study about the implementation of TILE in real-setting shows potential in individual reflections by teachers and joint reflections by teacher communities about data-informed learning design. During joint reflections, teachers essentially activated pedagogical knowledge about teaching and learning strategies.

[OBJ_3] To propose a framework for collective inquiry in communities of teachers as designers.

Based on the two previous studies, we conceptualized a framework to integrate the collective and inquiry process when teachers engage with learning design. The CIDA framework aims to facilitate teacher collective inquiry in technological environments with data analytics. It includes three elements namely the *inquiry process, the collective process,* and *technological support.* The inquiry process proposes the teacher inquiry cycle to facilitate the creation of data-informed learning designs. The *collective process* proposes social interactions in a teacher community through mediating artifacts such as teacher inquiry documentations about the implementation of learning designs. Designs of implemented technologies show how *technological support* can be integrated with the collective and inquiry processes of teachers when they act as designers or enactors of TEL activities.

The implementation of the framework in three teacher community cases suggests that online collective participation decreases through the time and this relates with organizational, geographical and professional boundaries that teachers need to overcome (Prenger, Poortman & Handelzalts, 2017; LantzAndersson, Lundin & Selwyn, 2018) in online teacher communities. Community awareness support in an online learning design platform enabled understanding of the collective teacher participation which can resolve problems of asynchronous communication. Teachers perceived positively their involvement in collective inquiry with student and teacher data because it facilitated the sharing of problems and solutions, learning new ideas and created spaces for collective reflections. These elements include common characteristics of professional teacher communities (Popp & Goldman, 2016). Towards cultivating teacher reflective practice, we showed how data collected from teachers in an online learning design platform and data collected from students in TEL scenarios can inform teacher collective inquiry.

This framework can be used in the context of teachers as designers of learning environments (Laurillard, 2013; Goodyear, 2015; Kali, McKenney, & Sagy, 2015; Persico, Pozzi, & Goodyear, 2018) and the implementation of TPD programs with technologies. Moreover, the framework is relevant to research about teacher professional learning in web-based communities (Tseng & Kuo, 2014; Hong et al., 2019; Prestridge, 2019) and research on (collaborative) teacher inquiry with technology (Butler, & Schnellert, 2012; Mor, Ferguson, & Wasson, 2015). The framework can also provide design guidance to practitioners such as researchers, teachers, and system developers by considering the three interconnected components: the *inquiry process*, *collective process* and *technological support*.

1.7 Future work

During the years of this thesis, we conducted research in collaboration with teachers. We also developed technological solutions for facilitating teachers as designers with data analytics. However, as we explain in section 1.5 several limitations and challenges encountered during the dissertation. The thesis contributions and identified challenges lead to the definition of future work lines that we think are worthy for further research:

- **Methodological issues**

The evaluation of the inILDE dashboard and the TILE tool could be enriched with empirical investigations from the formulation of a hypothesis to measurable variables. For instance, in our final evaluation of inILDE we identified that teachers who used the dashboard observed more other teachers´ contributions and provided more feedback with comments in others´ designs. Further studies in additional communities in which we implemented the dashboard could be conducted to shed more light in differences on individual and community participation behavior after consulting a community dashboard. Regarding TILE, additional studies with teachers can be conducted in consecutive cycles of design and enactment with students. In these cycles, a pre-posttest analysis of student learning outcomes can show if data-informed (re)design with TILE improved student learning outcomes. Moreover, since TILE is designed with the aim to share teacher inquiry cycles, more teachers could be involved in (re)designing an already implemented TEL activity.

- **User interface design**.

Regarding the user interface design of the proposed solutions, we have identified elements for improvement:

inILDE dashboard

- Improving colors of visualizations to show differences in data classes (e.g. re-used designs, designs created from scratch). Use colors that make the visualizations more appealing.
- Improve text aligned with the visualizations. In some cases, we use text that is difficult to interpret.
- Improve radial tidy tree visualization which shows the re-used designs in the community. This visualization is challenging due to scalability issues. Thus, when many contributions are visualized it is more difficult to click on them. Alternative tree visualization or metaphors for community contributions could be explored.
- Improve the calendar feature of the dashboard so that users can easily navigate through different time periods and explore community contributions.
- Embed a forum where users can discuss the learning designs identified with the dashboard.
- Embed a user guide in the dashboard interface.

TILE tool

- Improve the second step of the TILE tool so that users can easily align their problem and monitoring questions with the provided TEL tools.
- Improve the third step of the TILE tool so that visualizations are embedded in TILE and teachers can write about their interpretations.
- Embed a user guide in the tool interface.
- Integrate TILE with more authoring tools in ILDE.

- **Extension to other community and authoring platforms**

A very interesting endeavor would be to implement the design of inILDE and TILE in other community platforms for teachers. A similar community awareness dashboard can provide useful information about the interactions of members with resources, usage analytics about authoring tools and engagement analytics about community members. This will rely on the types of data collected in these platforms but the overall design of inILDE can be followed. Moreover, TILE can be used in other types of authoring communities which use TEL tools. This will allow the exchange of teacher inquiry cycles for a better understanding and evaluation of TEL tools in real cases.

- **Interplay with other educational data analytics**

In these research work, we proposed community awareness support based on teachers´ actions performed in ILDE. Moreover, we presented learning analytics visualizations regarding students´ actions in PyramidApp. As we explained in section 1.5, data collection and visualizations were based upon the available features in ILDE. Future work can analyse and quantify the content of teachers´ designs. Such analysis can include design analytics like different types and taxonomies for learning tasks and their alignment with learning analytics (fine-grained data about student interactions in TEL). Moreover, aggregated design analytics can be presented to community members for reflection and awareness which inform learning design (Hernández-Leo et al., 2018; Albó & Hernández-Leo, 2018).

- **Ethics and privacy**

Further empirical studies can be conducted with a focus on privacy issues in community data analytics. Although different types of educational data can be relevant for teachers´ participatory design, there are many challenges which need further investigation. For instance, social theories and a cost-benefit analysis about the sharing of educational data and designs for students and teachers can be considered in these studies.

- **Data literacy for teachers**

Based on the contributions derived from the investigation of teacher inquiry cycles, we have identified elements that are directly related to research about data literacy for teachers (Hansen, & Wasson, 2015). For instance, our proposed design principles for teacher inquiry tools explain the need for teacher scaffolds in the interpretation of student data with respect to learning design improvements and teaching or learning strategies.

- **Affective factors in communities about teachers as designers**

Another line of research refers to the investigation of affective factors in teacher communities related to learning design. For instance, some of these factors include emotional community support, feeling of ownership when designing technology-integrated activities, social comparison between community members.

1.8 Structure of the dissertation

This section describes the structure of the next chapters in this thesis document. Each Chapter is devoted to one of the three partial objectives described in section 1.2 and includes published articles and articles submitted for review. Before the presentation of the articles, a synopsis of the chapter explains the content of the articles. A graphical representation shows the connection of the chapter with the overall DBR methodology and thesis contributions following the structure proposed in (Muñoz, 2015; Manathunga, 2017).

- Chapter 2 describes the study and support for the collective process of teachers as designers in technological environments and includes the 1st cycle of the overall DBR

methodology. The Chapter contents are from the [Pub1] and [Pub2] mentioned in section 1.4.3.

- Chapter 3 describes the study and support for the inquiry process of teachers as designers in technological environments and includes the 2nd cycle of the DBR methodology. The Chapter contents are from the [Pub3], [Pub4] mentioned in section 1.4.3.

- Chapter 4 describes the proposed collective inquiry framework and multiple case study analysis regarding the 3rd cycle of the DBR methodology. The Chapter contents are from [Pub6] mentioned in section 1.4.3

- Appendix A presents the technological solutions proposed in this dissertation. The solutions are a community awareness dashboard for learning design communities-inILDE and a reflective tool for teacher inquiry (TILE). Moreover, Appendix A presents a student feedback tool for learning designs (LdFeedback) to facilitate the integration of students´ experiences in learning (re)design [Pub5].

- Appendix B presents instruments used during the evaluation studies of the thesis.

- Appendix C presents additional studies regarding the connection between LD and LA conducted in the context of Higher Education. The studies present teachers´ perceptions about LA to inform redesign, evaluation of learning analytics visualizations, and other information sources in the context of MOOCs.

CHAPTER 2

STUDYING AND SUPPORTING THE COLLECTIVE PROCESS OF TEACHERS AS DESIGNERS

Chapter 2 is dedicated to the first objective of this dissertation and presents the 1st cycle of the overall DBR methodology followed during this thesis work. In this cycle, we address the problem on how to study and support the collective process of teachers as designers with data analytics. The identified challenges are the transition from individual to collective practices in leaning design and awareness support in teacher communities involved with learning design. Section 2.1 presents a literature review in teacher communities which utilize networked technologies and the conceptualization of teacher communities for learning design based on CHAT. Moreover, it presents the design, implementation, and evaluation of a community awareness dashboard (inILDE), and design principles for community awareness support. Section 2.2, presents a preliminary study which informed the design of the community dashboard. In this study, we conducted an analysis in three educational communities who used ILDE to understand the collective participation and interactions between teachers in real cases. Description of the 1st DBR cycle and the main contributions derived from this cycle are presented in Figure 6. The content of this chapter is based on a JCR-peer reviewed journal article (Section 2.1) and a peer-reviewed conference paper (Section 2.2).

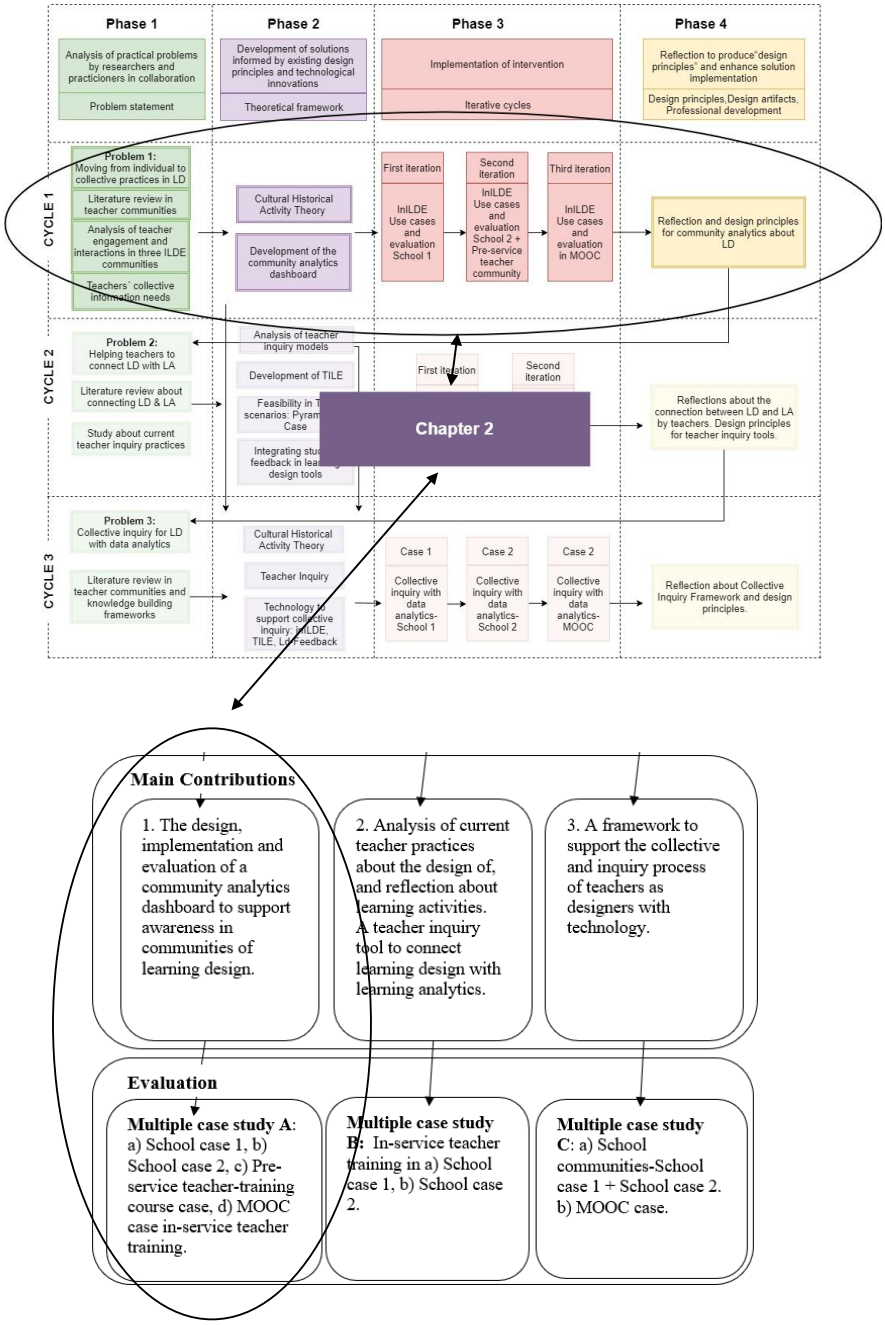

Figure 6. DBR cycle and main contribution presented in Chapter 2

2.1 Supporting awareness in communities of learning design practice

The content of this Section was published in the following JCR peer-reviewed journal article:

Michos, K., & Hernández-Leo, D. (2018). Supporting awareness in communities of learning design practice. *Computers in Human Behavior*, 85 (Aug. 2018), 255-270. https://doi.org/10.1016/j.chb.2018.04.008

Computers in Human Behavior 85 (2018) 255–270

Contents lists available at ScienceDirect

Computers in Human Behavior

journal homepage: www.elsevier.com/locate/comphumbeh

Supporting awareness in communities of learning design practice

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ARTICLE INFO

Article history:
Received 17 January 2018
Received in revised form
30 March 2018
Accepted 3 April 2018
Available online 4 April 2018

Keywords:
Learning design
Activity theory
Communities of practice
Awareness
Community analytics
Dashboards

ABSTRACT

The field of learning design has extensively studied the use of technology for the authoring of learning activities. However, the social dimension of the learning design process is still underexplored. In this paper, we investigate communities of teachers who used a social learning design platform (ILDE). We seek to understand how community awareness facilitates the learning design activity of teachers in different educational contexts. Following a design-based research methodology, we developed a community awareness dashboard (inILDE) based on the Cultural Historical Activity Theory (CHAT) framework. The dashboard displays the activity of teachers in ILDE, such as their interactions with learning designs, other members, and with supporting learning design tools. Evaluations of the inILDE dashboard were carried out in four educational communities – two secondary schools, a master programme for pre-service teachers, and in a Massive Open Online Course (MOOC) for teachers. The dashboard was perceived to be useful in summarizing the activity of the community and in identifying content and members' roles. Further, the use of the dashboard increased participants' interactions such as profile views and teachers showed a willingness to build on the contributions of others. As conclusions of the study, we propose five design principles for supporting awareness in learning design communities, namely community context, practice-related insights, visualizations and representations, tasks and community interests.

1. Introduction

The field of Learning Design (LD) or 'design for learning' studies how educators prepare and revise a set of learning activities toward achieving particular educational objectives in pedagogically-informed manners (Dalziel et al., 2016; Mor, Craft, & Hernández-Leo, 2013; Beetham & Sharpe, 2013). LD research studies how technological tools support teachers in thinking about both the design and implementation of their learning activities (Bennett, Agostinho, & Lockyer, 2015; Hernández Leo, Agostinho, Beardsley, Bennet, Lockyer, 2017; Celik & Magoulas, 2016).

The creation of explicit representations in the learning design process is supported by mediating artifacts such as patterns, models, and case studies (Conole, 2008). These representations aim to train teachers/designers (Papanikolaou, Makri, & Roussos, 2017) to thoroughly consider the tasks carried out by them and students during a learning session and facilitate the sharing of good practices within educational communities (Mor et al., 2013). Although the design of learning units is often considered to be an individual task of the teacher, the sociocultural dimension of the learning design process, namely how teachers work and interact in small groups or within larger educational communities to better inform their design tasks is still underexplored (Asensio-Pérez et al., 2017; Bennett et al., 2015; Michos & Hernández-Leo, 2016; Voogt et al., 2015).

Different community environments enable teachers to design, share and re-use learning activities using learning design and authoring tools. LD community environments include the LAMS community (Dalziel, 2008), the Learning Designer (Laurillard et al., 2013), LdShake (Hernández-Leo, Moreno, Chacón, Blat, 2014), and ILDE (Hernández-Leo, Asensio-Pérez, Derntl, Prieto, Chacón, 2014). Related educational platforms provide more specialized offerings such as WISE (Slotta & Linn, 2009) which integrates authoring tools for inquiry learning and the Instructional Architect (Recker, Yuan, & Ye, 2014) which integrates problem-based learning tools. Moreover, EDS (Martinez-Maldonado et al., 2017), a collocated environment, enables teachers to design in group learning scenarios with digital and non-digital devices. However, these environments lack the provision of mutual awareness between community members to

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https://doi.org/10.1016/j.chb.2018.04.008
0747-5632/

benefit from the sharing of learning designs and the community dynamics (Dalziel, 2013).

In this paper, we focus on the social perspective of learning design that is supported by web-based platforms. The main addressed problem is to support awareness in distributed community environments for learning design by identifying appropriate analytical units. Research was conducted in authentic settings including secondary schools and professional development programs for teachers to understand the application of community awareness in different contexts. The educational communities involved in the research used an online community platform for learning design named Integrated Learning Design Environment (ILDE) (Hernández-Leo, Asensio-Pérez et al., 2014).

In the following sections, we present literature review. Section 1.1 introduces models, technologies, and barriers in web-based educational communities. Section 1.2 presents further interrelated community frameworks aiming to explain social dynamics in communities of learning design. Finally, Sections 1.3–1.4 articulate the application of community awareness in learning design.

1.1. Models and technology support in web-based educational communities

Social environments are frequently used in educational settings for the management of educational resources and the creation of informal communities or networks of teachers. Two community models applicable to teachers are the Communities of Practice (CoPs) (Wenger, 1998) and Professional Learning Communities (PLCs) (Vescio, Ross, & Adams, 2008). CoPs are broadly defined as “groups of people who share an interest in a domain of human endeavour and engage in a process of collective learning that creates bonds between them” (Wegner, 1998, p.1), while PLCs aim to support the development of educational practitioners by providing opportunities for teachers to change their practices as a result of their students' learning (Vescio et al., 2008).

Technological support for web-based educational communities aims to respond to the individual and collective needs of teachers and help them create learning processes in an atmosphere of openness (Lieberman & Mace, 2010). Examples of such environments include wikis like EduOntoWiki, an environment for real-life narratives of educators built on ontologies (Petrucco, 2011); online discussion groups such as the Mosaic Email Group (Brown & Munger, 2010); generic social networks like Twitter (Davis and Varma, 2008); web-based platforms like Cloudworks (Conole & Culver, 2010) which enable the sharing of teaching ideas and teaching experiences; and learning management systems like Moodle (El-Hani & Greca, 2013). Macià and García (2016) summarize studies in networks of teachers and identify certain challenges both for individuals and for the performance of the whole community. The barriers included peripheral participation, evolution of participation, the moderation of the community and professional development through the interaction between experienced users and newcomers. Moreover, teachers' time constraints and limited amounts of social support (Prenger, Poortman, & Handelzalts, 2017) are factors which influence knowledge sharing and professional development in web-based teacher communities. The above barriers are often discussed in the context of distributed environments as problems of awareness and knowledge discovery (Soller, 2007) which is the focus of this paper. The following section illustrates additional frameworks aiming to explain the social dimension of learning design communities.

1.2. Linking sociocultural frameworks with web-based learning design communities

Design communities include social structures that facilitate groups of people to share knowledge and resources for collaborative design (Fischer & Ostwald, 2005). Usually, interactions around boundary objects like design templates and reflective journals are used to trigger knowledge and communication within their members (Fischer & Ostwald, 2005). In addition to CoPs and PLCs, Communities of Inquiry (Garrison & Arbaugh, 2007) and Communities of Interest (CoIs) (Fischer, 2001, pp. 1–13) were applied to online design communities and communities of teachers. However, although all the above frameworks facilitate the understanding of the community as a whole and how members build common ground and their own identities, the identification of analytical units for connecting the individuals to the community activity system have been thoroughly addressed in models such as distributed cognition (Solomon, 1993) and Cultural-Historical Activity Theory (CHAT) (Engestrom, 2000).

On the one hand, distributed cognition concerns with how cognitive activity is distributed across external cognitive artifacts, groups of people and how this happens across time and space (Belkadi, Bonjour, Camargo, Troussier, & Eynard, 2013). For instance, Carr, Johnson, & Bush (2017) apply distributed cognition as a framework to understand the use of technological tools and their peers as an extension of students' cognitive capacity. The framework helped to identify areas of improvement in learning outcomes and assessment of students. Distributed cognition and CHAT were both applied in social environments. However, some studies used the CHAT framework to describe the process of educators to design learning activities within a group or community. CHAT grounded on the Activity Theory is a sociocultural framework with increased attention in educational research and development (Gedera & Williams, 2015). Particularly, Conole (2008), Conole, McAndrew, and Dimitriadis (2010) and Voogt et al. (2015) explain how CHAT is relevant in learning design and communities or groups of designers (see Fig. 1). The designer constitutes the *subject* who intends to create a learning activity or a learning design for a particular audience of students (**individual level**). For achieving this, the designer uses a range of *mediating artifacts* in different representations (case studies, patterns, models) which aim to capture pedagogical practice and can be specific learning design or authoring tools (**technological level**). The *object to* design a learning activity is the *outcome* of the learning design process and describes the overall intentions of the designer. Multiple subjects-designers with different motives may interact together with the mediating artifacts and the created learning scenarios within a community system like an educational institution or group of subject-specific teachers (**community level**). The interaction between the designers and the community is mediated by rules like the constraints of timetables in an educational institution or the norms and values of its members. Finally, since the design of learning activities is a social process, the interaction between the community and the created learning designs is mediated by the specific roles of designers like head teachers and teachers or facilitators and members of professional development programs in a division of labor.

Although this framework provides a rich description on how groups of educators design learning activities by using various mediating artifacts or tools and how community members interact or re-purpose the created learning activities of others, to our knowledge there is no specific study which applies the CHAT model to analyse and visualize the social dynamics in web-based platforms for learning design.

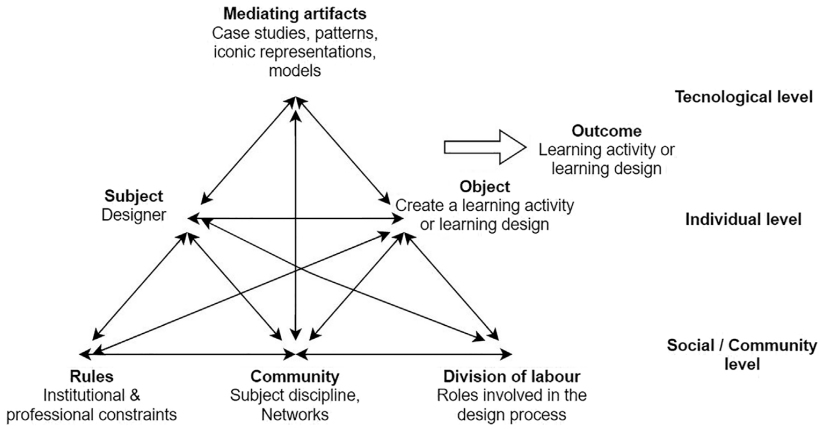

Fig. 1. CHAT framework in communities of learning design (Conole, 2008, p. 198).

1.3. Community awareness in learning design and authoring communities

Design has been applied in multiple fields such as architecture and product design (Martinez-Maldonado et al., 2017). Bearing in mind the social context of design in teacher practice, awareness plays an important role due to the design activities which are collaborative and multidisciplinary (Borges, Brézillon, Pino, & Pomerol, 2005) and the need for shared knowledge between a group of people in the design of complex situations (Belkadi et al., 2013). Awareness has been broadly defined as "an understanding of the activities of others, which provides a context for your own activity" (Dourish & Bellotti, 1992) or a "person's being or becoming aware of something" in a social context of interaction between individuals (Schmidt, 2002). In groups of teachers, multidisciplinary teams may either include teachers, educational designers, and researchers or different subject matter teachers who share a common interest and have different motives and preferences.

In addition to work teams, research on awareness has been conducted in larger communities (Koch, 2005; Saparova, Kibaru, & Bašić, 2013). For instance, in the educational context, Catteau, Vidal, and Broisin (2008) explain a system which provides awareness for a community of teachers and curriculum managers who use a learning object repository. They used two visualization techniques; 3D representations, treemap, and a notification system to inform teachers how the learning objects evolve and become imported in a learning management system. Vassileva and Sun (2007) developed community visualizations in the comtella system, an online community for sharing resources between university students, to stimulate their participation. They found that visual representations of members' contributions increased user participation. In workplace communities, interactive displays such as Community Mirrors shown in public spaces aim to show an aggregated and detailed view about the members of the community and their sharing resources (Koch, Ott, & Richter, 2014, pp. 145–161).

Ruiz-Calleja, Prieto, Ley, Rodríguez-Triana, and Dennerlein (2017) performed a literature review in Learning Analytics for workplace learning and identified publications with similar meaning like Community Learning Analytics (Klamma, 2013) or Social Learning Analytics (Buckingham Shum & Ferguson, 2012) which were applied in different disciplines such as teacher learning. The papers were classified according to three learning metaphors: *knowledge acquisition*, *participation* and *knowledge creation*. Analytics for knowledge acquisition were providing feedback with visualizations relevant to the mismatch between workplace learning goals and progress. The participation metaphor was used to show awareness of a learning network or to provide information to community managers to increase participation. Lastly, the knowledge creation metaphor referred to analytics regarding the relationships between users, the artifacts, and the actors.

1.4. Research questions

Although awareness tools and learning analytics have been used to provide support for the collaborative learning of students (Janssen & Bodemer, 2013) and teachers' orchestration of such learning (Martinez Maldonado, Kay, Yacef, & Schwendimann, 2012), little is known on how the presentation of community awareness data can facilitate groups of teachers in the design, sharing and re-use of learning activities within a social platform (Hernández-Leo et al., accepted). This problem applies both to educational platforms that use specific learning design tools as well as to environments which use a variety of authoring tools. In both cases, users can create, share and re-use the designed products within an individual and social space. In this paper, we seek to understand how the display of community awareness data can support teachers in their learning design process. Our research question and derived sub-research questions are:

RQ: How can community awareness data support the learning design process of teachers?
RQ1: What data and visualizations do teachers find useful?
RQ2: How can community awareness data be made useful for the community and the individuals involved in learning design tasks?

These research questions have been explored through the interactions of teachers with a prototype community awareness dashboard that supports the understanding and awareness of a learning design community based on the CHAT framework. The ultimate goal is to support users (teachers, learning designers) in acquiring aggregated and detailed information, based on member roles and community rules, about the emerging activity of the actors (members), the created objects (learning designs) and the tools (various learning design, authoring tools, methodologies).

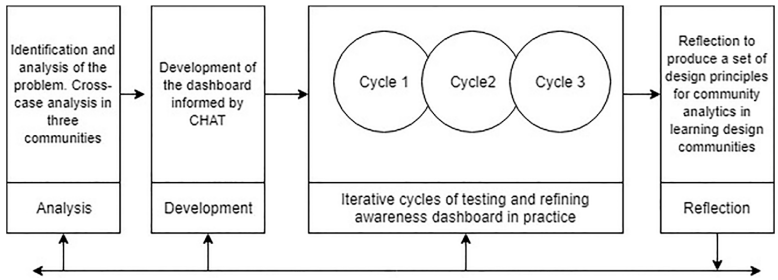

Fig. 2. Overall design-based research methodology to develop a community dashboard for web-based educational communities based on Barab and Squire (2004).

2. Methodology

2.1. Design-based research

Design-based research (DBR) provides flexibility and proposes an analysis of requirements through the collaboration between teachers and researchers in real-life settings to improve educational practices (Anderson & Shattuck, 2012; Barab & Squire, 2004; Wang & Hannafin, 2005). Our objective to develop community awareness support in the existing ILDE environment led us to follow this methodology (see Fig. 2). Researchers in DBR methodology are involved in the everyday practice of the practitioners, rather than merely acting as observers and report results of their iterative cycles.

ILDE[1] is a community environment for learning design, in which members can create, co-create and share designs spanning from the conceptualization of learning scenarios to their implementation (Hernández-Leo, Asensio-Pérez et al., 2014). The ILDE provides both an individual space for the creation and management of learning designs with multiple tools and a social space for sharing, re-using, commenting designs and exploring community members' activity.

In the first stage, we sought to elicit requirements for the development of community awareness support in the existing system. We carried out a cross-case analysis in three large groups of educators who used the ILDE (Michos & Hernández-Leo, 2016). The objective was to identify the engagement and interactivity levels of the members based on actor-artifact interactions (Ludvigsen, Stahl, Law, & Cress, 2015; Reinhardt, Moi, & Varlemann, 2009). Results of this study showed that the more divergent artifacts that the members of the community explore, the more they create artifacts (in this case learning designs with multiple tools). Moreover, social network analysis showed an influence of the users who create popular artifacts (many received views) in the overall community exploration of the content.

This initial analysis led us to explore further how awareness support in the different communities which use the ILDE facilitates members to explore the emerging creation of content, to be aware of the main actions occurred within their community and how this supports their main tasks (exploration, creation, re-use, comments). We analyzed different frameworks which can explain the social dynamics in such design communities of teachers and collected initial feedback from teachers with respect to available or requested community awareness information in the existing environment. In the second stage, we proposed a community awareness dashboard with data visualizations based on CHAT. In the third stage, we performed 3 iterative cycles. The first cycle was devoted to the evaluation of prototypical data visualizations in *Tableau*[2] with teachers. The second cycle aimed to evaluate visualizations implemented in ILDE with additional teacher communities. Finally, a pilot study was conducted with integrated real-time data visualizations in a community of teachers who participated in a Massive Open Online Course (MOOC) for learning design (see Table 1 for the three iterative cycles and the context of teachers). We designed the community dashboard using the CHAT framework to articulate the representation of participation in learning design communities. In all the stages of the DBR methodology, we documented the results to inform how a theoretical framework in learning design communities can be used to provide community awareness support in web-based communities of teachers.

2.2. Participants in cycle 1

2.2.1. School 1

Teachers ($N = 14$) in Secondary and Vocational education schools were involved in a professional development program about learning design. The participants used the ILDE in a series of face-to-face workshops from November 2016 until June 2017. The facilitators of the program prepared six face-to-face workshops which lasted 2 h and included individual and group activities in ILDE. The topics of the workshops were about collaborative learning, problem-based learning, teacher inquiry and learning analytics. Teachers were asked to complete the design of learning activities and implement them with their students, to document classroom activities and share material with their colleagues. Many teachers used authoring tools later to design their own learning activities without the instructions of the facilitators. After four months of the program, participants were presented with a prototypical community dashboard which showed data visualizations of their past activities in ILDE.

2.3. Participants in cycle 2

2.3.1. School 2 & master course for pre-service secondary teachers

Teachers in School 2 ($N = 9$) and pre-service teachers ($N = 27$) participated in this cycle. The teachers from School 2 were involved in a professional development program, similar to the program followed by teachers in School 1 including a series of four face-to-face workshops. Participants were presented in the third workshop with a community dashboard integrated into ILDE. Pre-service teachers who were registered to a master course about Biology

[1] https://ilde.upf.edu/about.

[2] https://www.tableau.com.Tableau is a data visualization tool for data discovery and dashboard creation.

Table 1
The three iterative cycles ("Development and iterative cycles" stages).

	Cycle 1	Cycle 2	Cycle 3
	Initial prototypes in Tableau	Real-time visualizations in ILDE + prototypical visualizations about tools	Real-time temporal visualizations in ILDE/Pilot study
Participants	14 teachers	9 teachers + 27 pre-service teachers	209 participants-49 active teachers/users
Community	School community	School community + Pre-service teacher community	MOOC community

teaching in secondary schools used the ILDE during a period of one year. Their main activities were the sharing of material with their colleagues and tutors, preparation and documentation of their classroom practices. In the final session, they were presented with the community dashboard integrated into ILDE.

2.4. Participants in cycle 3

2.4.1. Teachers in a MOOC for the design of collaborative learning with ICT

Teachers ($N = 209$) registered in the ILDE as part of a MOOC "Innovative collaborative learning with ICT"[3] which was deployed in the Canvas Network Platform that lasted for 6 weeks. The MOOC aimed to train teachers in the design and implementation of collaborative learning scenarios with technology. Participants carried out their design activities during the MOOC in ILDE. In the second week of the MOOC participants were presented with the community dashboard with temporal analytics (filtered by dates) and were asked to carry out some tasks e.g. commenting on others' resources and designs. In week 4 participants used different authoring tools to design their collaborative learning activities. They were also presented with some visualizations about the use of tools by the MOOC community.

2.5. Data collection instruments in the different stages of the DBR methodology

We performed a literature review in all the stages of the methodology and collected data from divergent sources following a mixed-method methodology (questionnaires, field notes, group discussion transcripts, log data from ILDE). Mixed-method enables joint analysis and triangulation of quantitative and qualitative data (Creswell & Plano Clark, 2007). Quantitative analysis with descriptive and inferential statistics was conducted using IBM SPSS 22 while log file analysis was performed with Heidi SQL and Tableau 10.2 software. Qualitative data analysis was used to deepen analysis in teachers' perception about community awareness information. The analysis was performed in the open responses of the questionnaires, group discussion transcripts and teachers' comments in the MOOC. Open coding was developed to identify the main topics of teachers' responses (Strauss & Corbin, 1998). The research was carried out in collaboration with the ILDE users in different educational communities (Table 2).

3. Results

This section reports first the results of the analysis stage (see Table 2), then follows the development and iterative cycles stages in which the community awareness dashboard was evaluated in the different educational communities.

[3] https://www.canvas.net/browse/valladolid-en/courses/innovative-collaborative-learning-en.

3.1. "Analysis" stage

Our initial analysis with datasets of different communities in ILDE (Hernández-Leo & Michos, 2018) showed that the exploration of designs and members influenced the creation of new learning activities and designs. During this stage, we gathered initial feedback from school teachers in School 1 and School 2 to better understand to what extent ILDE facilitates awareness about the main activities carried out in the platform and which types of data are more interesting for the teachers involved in their community. The feedback was gathered with a post-questionnaire with closed and open questions in Workshop 3 in each School 1 and School 2. In this stage, a requirement analysis was conducted and elements of CHAT were examined in teachers' responses.

The main topics from the teachers' responses in the open questions were that, for those of them having sufficient time to use the environment, ILDE facilitated awareness of other members' activity because it supports the sharing, review of learning designs and browsing by educational topics. They also mentioned that ILDE helps them to access learning designs from the perspective of another teaching area and provides useful information when teachers are involved in joint work. One teacher pointed out that the environment helped to access learning activities designed by others which could be a starting point for his own activity creation (see Table A.1 in the Appendix).

> "It helps because it is easy to explore and browse the designs of other members." [T1], "Yes, it helps to see the activities designed from the perspective of another area of education." [T8].

Finally, teachers proposed that additional data could be associated with designs and would be interesting for their school community. They were interested to know the impression of their students about their implemented designs and issues that worked well or not during their implementation, subject-specific designs, the most used and most visited designs (see Table A.2).

> "Yes. [I would like to know …] What are the most used designs, whether it has worked or not … to know the contents that worked better." [T18]. "Yes. [I would like to know …] those that have been most interesting for the students." [T14].

The main problem reported by teachers was that time restrictions did not allow frequent exploration and sharing of designs. Their open responses showed some first elements of the CHAT framework. Sharing of teachers' artifacts was indicated valuable to understand how other teachers design their learning situations based on different methodologies and this shows their interest in social interactions within the platform. Teachers revealed that sharing helped to build on the design learning activities of others. Their main goal was the practical application of their created designs as they specified that they want to know how students perceive the learning activities and what happened in the classroom implementation. Identifying popular content and learning designs relevant to their teaching subject was also a common response. As such, the initial motivations of the teachers referred to

Table 2
Data collections methods, participants, and purposes.

DBR Stage (see Fig. 1)	Data collection methods	Participants	Purpose
Analysis	Literature review Log file analysis Questionnaire	2 MOOC communities +1 open community (Michos & Hernández-Leo, 2016). School 1 - School 2	Explorative analysis of the use of ILDE. Participants' perceptions about community awareness information.
Development	Literature review Questionnaire	School 1 - School 2	How to support community awareness based on CHAT in alignment with ILDE features and collected data.
Iterative cycles	Questionnaire, voice discussion recordings, field notes. Log file analysis	School 1- School 2 Master Course MOOC participants	Perceived usefulness and user experience testing Real-case scenario Task behavior
Design elements	Reflection from iterative cycles		Design principles

the sharing of learning designs, students' impressions and the identification of relevant and popular topics that emerged from their community.

3.2. "Development and iterative cycles" stages

3.2.1. inILDE: a community awareness dashboard for learning design communities based on CHAT

Analysis of teachers' perception of awareness information in two schools suggested that the limited time, teacher motivation and preferences are critical aspects that affect the social perspective of the community. This analysis drove the development of a prototypical community awareness dashboard with real datasets from School 1 and School 2. Our rationale was first to develop the community dashboard based on the CHAT units of analysis as relevant to understand participation and interactions in learning design communities and second to evaluate the feasibility of the approach with the collected data in ILDE, e.g. initial behavioral data. The process which we followed was to use data from the platform and classify them as activity indicators for the members, designs, and tools.

For the metaphor of the name, we used the prefix **in** (**in**side the **I**ntegrated **L**earning **D**esign **E**nvironment-**inILDE**) and as a motive to encourage users to **in**vestigate their community (see Fig. 4). We designed three separated tabs regarding the objects-learning designs (designs tab), the subjects-members (members tab) and the mediating artifacts-tools (tools tab). A tab including both members and designs was used to display combined information. In each tab, we proposed aggregated activity awareness data about the designs, the members and the tools and detailed awareness data regarding common user actions in the environment (e.g. create, explore, comment, re-use). The aim was to align the provided information with the performed actions of the users.

The **designs tab** included aggregated data about the different attributes of the created *learning designs* (original, re-used, public, explored from different members) aiming to understand how designs were created or explored by others within the community. Detailed information included the 10 most viewed designs (requested from teachers) and the 10 most re-used designs with the titles and authors' names. This information intended to show how emerging exploration and re-use of designs indicated periodically the common interests of the community. Last, a radial tidy tree visualization showed connections between the original and the duplicated designs of all the community (see Fig. 5). The aim was to visualize how teachers build on the designs of each other.

The **members tab** included aggregated data about the different *members' characteristics* (total registered members, contributors, commenters, publishers) to support understanding of the different actions performed by the community members. Detailed awareness information was provided on top 10 contributors of the community by counting the amount of created learning designs and the top 10 commenters by counting the number of comments aiming to identify periodically the key contributors and active participants in the community.

The **tools tab** included aggregated data about the number of designs created using different tools of ILDE in the last 10 days. The visualization showed dots with different colors which represented different tools in ILDE and different sizes which represented the number of learning designs created using each tool. Figs. 3–5 show the dashboard in each of the 3 iterative cycles from initial prototypes with Tableau to the integration of the dashboard in the Graphical User Interface (GUI) of ILDE.

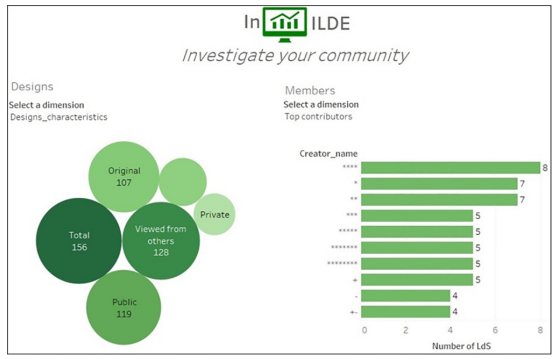

Fig. 3. Screenshot of the community awareness dashboard in Cycle 1: Prototypes in Tableau showing an overview of designs' attributes and top contributors in the community.

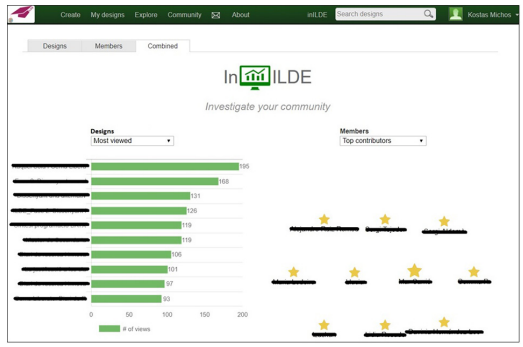

Fig. 4. Screenshot of the community awareness dashboard in Cycle 2: Implemented visualizations in the GUI of ILDE showing bar chart with most viewed designs and stars proportional to the number of contributions per member.

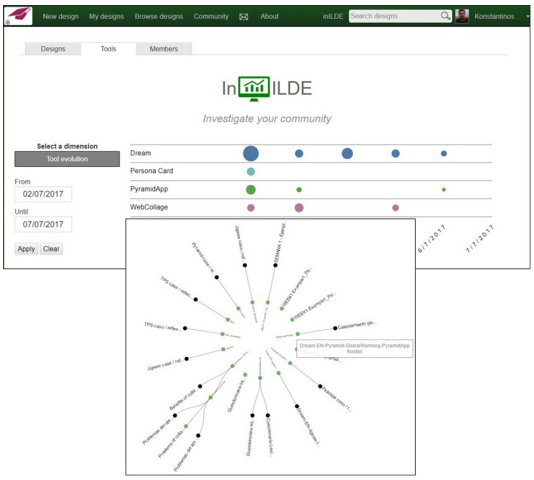

Fig. 5. Screenshot of the community awareness dashboard in Cycle 3: Integrated temporal visualization in the GUI of ILDE showing the evolution of design tools' use during the MOOC for learning design and radial tidy tree with the re-used designs and creators in the community.

3.2.2. Cycle 1: first prototypical visualizations

Teachers ($N = 14$) in School 1 evaluated the usefulness of this information for their educational community. During the 3rd workshop, we demonstrated and explained the community dashboard. Users were given time to explore and navigate through the prototypes. A post-questionnaire for evaluation was attached to the prototypes. The questionnaire included closed and open-ended questions about the usefulness of the different proposed tabs and visualizations for specific use cases like the identification of active members of the community and the most interesting designs. Participants were also asked to explain negative, positive features and recommendations for improvement. Participants reactions were documented by a researcher.

Teachers rated all the visualizations with means ranging between 3.08 and 4.33 in a Likert scale 1–5. This proposes that they appreciated the majority of the presented information in the dashboard. The most highly rated was bar charts, which showed the most viewed designs of the community ($M = 4.33$, $SD = 0.91$) following the most re-used designs ($M = 4.25$, $SD = 0.82$). The fact that this graph showed more detailed information about the title and name of the creator as opposed to the aggregated information which showed only numbers and the different categories may have influenced their opinion. However, the members tab in overall ($M = 4$, $SD = 0.61$) was perceived more useful compared to the designs tab ($M = 3.66$, $SD = 0.94$). This result suggested that teachers are especially interested in knowing the participation of community members. The lowest rating was given to a radial tidy tree representation which showed the original and duplicated designs of the community. The fact that teachers were presented with synthetic data, in this case, may have influenced the understandability of this visualization. The open-ended responses yielded better insights for teachers' opinion.

Regarding **the designs tab,** teachers' main positive responses were that it helped them to have a quick summary of what is happening in their community and it saved their time to search designs in ILDE. They also pointed out that the most used and most viewed designs may help them to find interesting designs in the community. As negative aspects, one of the teachers explained that in a heterogeneous community (in which teachers are experts in different subjects) the most used designs or the most popular designs are not necessarily as valuable as those designs relevant to their specific subject area. The ILDE supports this type of exploration with the use of tags for semantic content but this information was not visualized in the dashboard. Bar charts as visualization for the main contributors was also mentioned as a negative aspect because it introduces a comparison between teachers which was stated as unnecessary. They also recommended that the graphs should be linked with the design descriptions in ILDE. They find it even more useful if the community dashboard is used in larger communities which include different schools (see Table A.3).

> "The information to find the most used or duplicated designs is interesting, maybe it could directly appear the works or designs properly linking with them." [T32], "The positive aspect is that from this platform I can see the summary of my community in a dynamic and fast way, but as a negative point is that if my community is very heterogeneous in terms of the subjects which we represent, some tools are not useful for me." [T34]

Regarding the **members tab,** teachers explained that it facilitated understanding of the overall members' participation. Information from this tab has provided a glimpse towards influential members, who use specific learning designs tools. It also helped them to identify the roles of the different community members. Negative comments were about the inconsistency of active members and their subject expertise as some teachers wanted to find designs related to their subject. Other responses acknowledged that quantitative data sometimes are not useful and access to the specific comments or contributions would provide more interesting information. The teachers recommended that this tab can be used as social advice to follow active members of this community and facilitates interaction between active and inactive members (see Table A.3).

> "Positive: it helps us see the degree of participation of the members of the community. Negative: From here we cannot (directly) access their contributions." [T55], "They are very visual and stand out the most active members and the ones who make the most out of it. It may be useful to identify users who do not benefit from the tool and check for possible improvements." [T50]

Regarding the visualizations, we presented three prototypes of the dashboard with different graphical representations and colors. Teachers pointed out that they prefer the prototypes which showed different colors in the visualizations as it helps them to find information quickly. Bubble charts were perceived more dynamic which requires less space as opposed to tree maps.

During the demonstration of the dashboard, field notes of one individual researcher revealed that teachers showed enthusiasm when the community data were presented. One of the teachers commented: *"I am not even on the list!"*, meaning that his name did not appear in the contributors' visualization. When teachers were presented with the visualization of the most active commenters, many teachers started to laugh and look at the person who appeared as the person having written many comments. The above face-to-face reactions of the teachers has shown that visualizations included information which was not obvious in the platform.

3.2.3. Cycle 2: visualizations integrated into ILDE

In the second cycle, we incorporated the dashboard in the ILDE GUI considering the feasibility of the approach (collected data in

ILDE, estimation of new data to be collected, presentation of the data) (see Fig. 4). In this prototype, real-time visualizations about the members and designs were shown as a community dashboard in ILDE. The java script libraries d3.js[4] and chart.js[5] were used for the development while prototypical visualizations about the use of the tools were designed in Tableau. We considered all the initial feedback from teachers of School 1 to re-design our first prototypes. For instance, we redesigned members' contributions visualizations from bar charts to a visualization with growing stars as proposed by Vassileva and Sun (2007) aiming to stimulate users' participation.

Teachers in School 2 ($N = 9$) and pre-service teachers in the master course ($N = 27$) evaluated the community dashboard inILDE in Cycle 2. In the school, teachers were presented with the dashboard after a series of four workshops while in the master degree it was presented during the final session of the course. In the school, after the demonstration of the dashboard, teachers were involved in a discussion about the use of the community awareness dashboard. One of the teachers explained that such awareness tools could be used to understand which colleagues work and design together during the year and which were the main topics and most useful tools. The teacher stated that this promotes community culture in their school (see Table A.4).

Regarding the **designs tab**, the teachers of the school community indicated that the dashboard provides an overview of the activity in their community and can offer additional support for joint work within their school. The teachers claimed in this school that they prefer to access more qualitative information than statistics and would be interesting to know the level of elaboration of the different learning designs. The pre-service teachers appreciated that the dashboard provides a general idea about the designs created during their master course (see Table A.5).

> "It allows a joint vision." [T58], "It helps me to see the designs globally." [T80], "It's only a statistical tool, it does not allow access to the designs." [T58]

Regarding the **members tab**, teachers mentioned that it helped to identify productive members and potential experts in a tool but visualization which classifies teachers into categories might create inappropriate identities. The pre-service teachers explained that they could identify the most influential members within their course community but they would also like to have access to learning designs with joint authorship and the comments of the members (see Table A5).

> "A positive aspect would be that it allows identifying a colleague who is more expert in the use of a particular tool, to ask, consult or share methodologies, doubts, etc." [T73]. "You can see people who comment more on the designs ." [PT95].

Finally, regarding the **tools tabs** both pre-and in-service teachers mentioned that it is interesting to know who is using different tools, which helped them to assess tools incorporated into the platform.

> "I think it would be important to identify who has created with the different tools because in case I am interested in working in something similar, I will be able to identify the creator and if necessary contact him." [T100], "This tab is interesting to see the trend of what is being used in ILDE." [PT102].

[4] https://d3js.org/.
[5] http://www.chartjs.org/.

3.2.4. Cycle 3: pilot study in a MOOC for teachers. Blending the community dashboard with learning design tasks

In the third cycle, we redesigned the inILDE community dashboard based on the feedback gathered in Cycle 1, 2. The changes were links to specific design artifacts or members shown in the visualizations, integrated visualizations about the use of tools and filtering of data by dates (see Fig. 5). The objective of this cycle was to test the community dashboard during a longer period and to evaluate how it affects the behavior of community members (exploration, creation, re-use, comments) and user experience. 209 participants registered in the ILDE during the MOOC "Innovative collaborative learning with ICT" which lasted 6 weeks. Out of 209, 100 participants created at least one artifact in the environment (Michos & Hernández-Leo, 2018).

In this cycle, we designed an experiment to evaluate the differences in individual and community behavior and user experience with the use of the dashboard. The objective was to understand how the community awareness dashboard facilitates members to a) perform *common actions* in the environment (explore, re-use, create, comment designs) and b) perform *the epistemic tasks* proposed by the facilitators of the MOOC. For the evaluation, we used the log files generated by ILDE platform, comments of users during the tasks of the MOOC and a post-questionnaire with closed and open questions. Table 3 shows the different tasks during the MOOC and the weeks in which participants had access to the dashboard.

The design of the study was as follows:

a. 1-Week use of ILDE without the inILDE community dashboard.
b. 5 weeks use of ILDE with the dashboard.
c. Task supported by the dashboard during the second week of the MOOC (comment learning designs with and without the use of the dashboard).
d. Subjective usability of the dashboard with the Usability Metric for User Experience (UMUX) (Finstad, 2010). It is a four-item Likert scale aimed to measure the three dimensions of usability: effectiveness, efficiency, and satisfaction. Open-ended questions regarding the support for the users' tasks and the overall experience.

We initially explored the community activity during the 6 weeks of the MOOC with four common actions: the designs views, the comments, the profile views and the dashboard views. We counted the number of participants who performed those actions throughout the MOOC (see Fig. 6).

As shown in Fig. 6, a decrease of participants with designs views, comments, profiles views and dashboard views was present from Week 1 until Week 6. However, in the last days of Week 2, 3, 4 there was a peak of participants who explored designs and used the community dashboard. The deadlines of the proposed assignments may explain this behavior. 49 out of 100 active participants (created designs > 1) used the community dashboard. To understand the relationship between the dashboard views and *performed actions* by participants we conducted a correlation analysis. We included participants who used the community dashboard in the 6 weeks of the course. Spearman's correlation was used because data were not normally distributed (Table 4).

There were significant correlations between all the common actions of users (designs views, profiles views, comments, created designs, re-used designs). Regarding the community dashboard, the highest moderate positive correlations were between dashboard views and re-use of designs and dashboard views and exploration of designs. This result proposes that the users who explore the dashboard more, have re-used/explored more designs

Table 3
Main tasks in ILDE and access to the dashboard during the MOOC.

	Week 1 12/06–19/06	Week 2 19/06–26/06	Week 3 26/06–03/07	Week 4 03/07–10/07	Week 5 10/07–17/07	Week 6 17/07–24/07
Tasks	Explore and comment examples of collaborative learning. Re-use a design pattern for collaborative learning and describe your case.	Explore the social features of ILDE. Comment a case of another participant. Comment a case after using the dashboard.	Re-use and edit your own design for collaborative learning (Pyramid pattern).	Re-use and edit your own design for collaborative learning (Jigsaw pattern).	Create your own complete Learning Design (LD) project.	Evaluate two other LD projects.
Awareness dashboard	No access to the dashboard.	Provided access to the dashboard. Instructors triggered dashboard use.	Provided access to the dashboard. Free-choice to use the dashboard.	Provided access to the dashboard. Free-choice to use the dashboard.	Provided access to the dashboard. Free-choice to use the dashboard.	Provided access to the dashboard. Free-choice to use the dashboard.

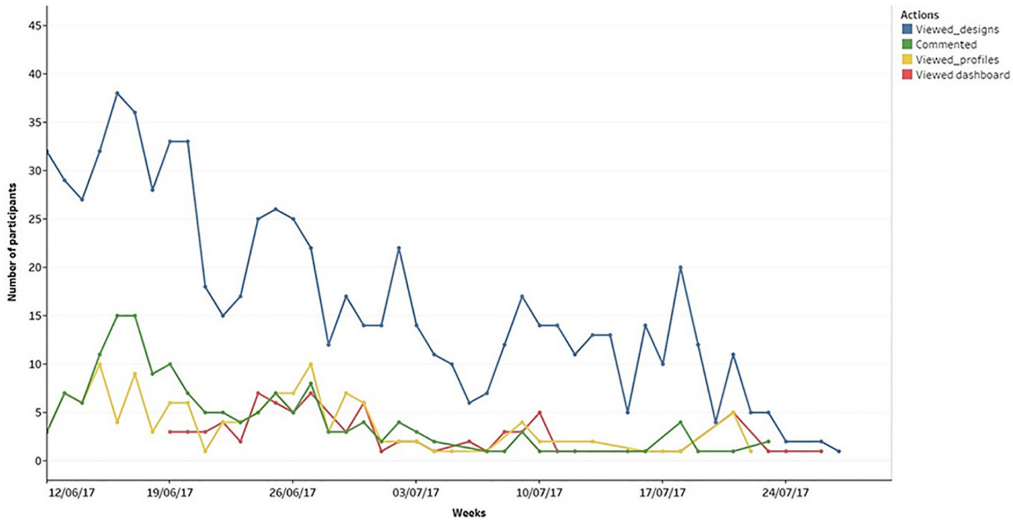

Fig. 6. Timeline of participants actions during the MOOC. Viewed_designs: Number of participants viewed a design, Commented: Number of participants commented a design. Viewed_profile: Number of participants viewed a profile. Viewed_ dashboard: Number of participants viewed the dashboard.

Table 4
Spearman's correlation matrix between dashboard views and participants' performed actions during 6 weeks of the MOOC.

	Mean(SD)	1.	2.	3.	4.	5.
1. Dashboard views	7.90(6.89)					
2. Designs views	146.10(99.99)	.528**				
3. Profiles views	10.24(10.76)	.397**	.579**			
4. Comments	3.51(4.37)	.434**	.519**	.394**		
5. Created designs	8.31(5.63)	.470**	.758**	.300**	.571**	
6. Re-used_designs	7.61(5.52)	.537**	.783**	.287*	.544**	.899**

$N = 49$, $^{**}p < .01$.

or vice versa. We conducted further analysis by each week of the MOOC to better understand the use of the community dashboard. Fig. 7 shows more frequent dashboard use during Weeks 2, 3 while in Weeks 4, 5, 6 there was a significant decrease.

Regarding the influence of the dashboard towards the participation behavior of users, we performed two types of analysis. First, we compared the actions of the participants during Week 1 (without the dashboard) and Week 2, 3 (with the dashboard). Second, we compared the actions of participants who used more the dashboard compared to participants who used it less.

In the first analysis, Wilcoxon signed rank test (non-parametric repeated measures *t*-test) was used to compare actions of participants in Week 1 (without dashboard use), Week 2 and 3 (with dashboard use). There were $N = 14$ participants who performed actions in Week 1 and used the dashboard in Week 2, while $N = 15$ participants performed actions in Week 1 and used the dashboard in Week 3. A non-parametric *t*-test was performed for both groups of participants. There was a significant difference ($Z = -3.267$, $p = .001$, $r = -0.59$) with higher profile views between Week 1 and Week 3 but no significant difference ($Z = -2.125$, $p = .034$, $r = -0.40$) between Week 1 and Week 2. These results propose that the utilization of the dashboard has increased the profile views in Week 3.

In the second analysis, we separated the participants who used the dashboard in two equal groups based on the frequency of dashboard views which resulted to $N = 24$ participants with low

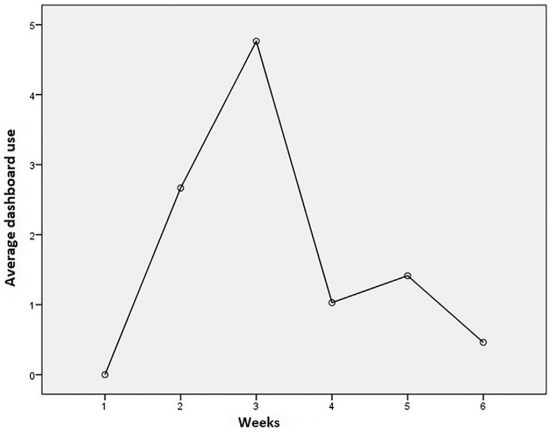

Fig. 7. Average dashboard use during the 6 weeks of the MOOC.

dashboard use and $N = 25$ participants with high dashboard use. Our hypothesis was that participants with frequent dashboard use perform more actions (re-use, creation, comments, edits, exploration of designs) compared to participants with less frequent dashboard use due to awareness support. Shapiro Wilk test showed that data were not normally distributed in both groups except the variable designs views. Thus, we performed Mann–Whitney *U* test for independent samples for all the variables and T-test for the variable designs views. Table 5 shows significantly higher profile views and comments for the participants with frequent dashboard use compared to participants with low dashboard use. However, there were no significant differences in the number of created designs, re-used designs, and edits.

A *t*-test for independent samples revealed significant difference $t(47) = -3.852$, $p = .000$, 95% CI [46.32, 147.64], $d = 1.10$ in the group with frequent dashboard use in designs views ($M = 193.60$, $SD = 101.40$) compared to the group with low dashboard use ($M = 96.93$, $SD = 71.63$). The above results propose that participants who used frequently the dashboard explored more members' profiles and designs in the social platform compared to participants who used the dashboard less. Moreover, participants who used frequently the dashboard wrote more comments.

The participants were asked to perform different *epistemic tasks* during the MOOC relevant to the design of collaborative learning with ICT. In Week 2 one of the tasks was to comment one case for collaborative learning based on patterns written by another participant and point out the relevance in their own teaching context. Then participants were asked to repeat this task after exploring the visualizations in the community dashboard. To understand differences with/without dashboard use we performed a content analysis of the messages. The unit of analysis was the sentences in each message. After reading all the messages with/without the dashboard we used an emerging coding scheme about the main topics of the sentences ($N = 69$ coded messages, $N = 118$ coded sentences) (See Table 6).

$N = 34$ participants completed this task with/without the dashboard. The messages usually included a sentence for positive feedback like “interesting” or “very nice”. This occurred equally with/without the dashboard. The main difference with the use of the dashboard was that participants commented more frequently with multiple types of sentences in their comments including positive feedback, a reference to the pattern and observations. In particular 10 participants after using the dashboard included in their comments their observations from the visualizations. For instance, they referred to the different explored designs, the different content in the variations of the same pattern and the titles of the designs (“*I chose this case from the visualizations, because its title deals with learning and technology, like mine*”). This shows that these participants reflected on others' contributions prior to commenting. Another difference with the use of the dashboard was that participants commented designs that they already included comments because they could see it in the visualization “Top commenters”. The depth of the discussion was higher with the dashboard use ($M = 2.3$, $SD = 2.01$) as opposed without the dashboard use ($M = 1.32$, $SD = 0.55$).

During Weeks 3, 4, 5, 6 participants were asked to work on examples of collaborative learning activities based on collaborative patterns e.g. pyramid, jigsaw. In week 5 participants had to create a learning design project from the conceptualization of a collaborative learning situation to its implementation in a Virtual Learning Environment. Finally, in week 6 the main task was to review and evaluate the project of another participant. Regarding the dashboard use for the different tasks, although from Week 3 to Week 6 was periodically decreased, we observed a pattern of frequent dashboard use during the first and last day of each week. Participants who used the dashboard explored more frequently the visualization about the members following by visualizations about the designs and then about the tools.

Regarding subjective usability, out of the 100 active users in ILDE, 40 responded in the final questionnaires (40%). 29 responders confirmed that they used the dashboard during the MOOC and 11 that they did not use it. Participants responded that the community dashboard was effective (row Effectiveness) and easy to use (row Overall). However, 12 participants had spent too much time to interact with the interface of the dashboard and 4 participants found the experience somewhat frustrating or frustrating (row Satisfaction) (see Table 7).

Two additional open-ended questions were used to better understand participants' experiences and how the dashboard facilitated their tasks during the MOOC. The first question was whether

Table 5
Results of Mann–Whitney U in high dashboard use vs. low dashboard use groups.

Variables	Group	N	Ranks	*U*	*Z*	*p*	*r*
profiles views	High dashboard use	25	31.26	138.50	−3.238	.001	−0.46
	Low dashboard use	24	18.27				
comments	High dashboard use	25	30.70	157.50	−2.877	.004	−0.41
	Low dashboard use	24	19.06				
created designs	High dashboard use	25	30.12	172.00	−2.570	.010	−0.36
	Low dashboard use	24	19.67				
re-used designs	High dashboard use	25	30.08	173.00	−2.547	.011	−0.36
	Low dashboard use	24	19.71				
edits	High dashboard use	25	29.60	185.00	−2.335	.020	−0.33
	Low dashboard use	24	20.21				

Table 6
Coded sentences in the MOOC task with and without the dashboard.

Code of sentence	Meaning	Example	Frequency of occurrence in the messages	
			Without the dashboard	With the dashboard
RC	Reflecting on the case in his/her own context	*"I could follow the same in my class where I teach engineering students to pair them and give small tasks and then join all the results to solve the entire problem"*	11	14
PF	Positive feedback e.g. interesting, very nice	*"Very nice practice and very detailed description."*	25	25
Pat	Referring to the pattern of collaborative learning	*"We have selected the same pattern to design the tasks of our collaborative activities."*	13	11
Pro	Making a proposal to the other participants	*"If you really want to do this activity in your class, the sub-activities should be explained clearer for the students."*	6	3
Obs	Observing other designs, comments or titles	*"I chose this case from the visualizations, because its title deals with learning and technology, like mine."*	0	10

Table 7
Results of the UMUX questionnaire measuring user experience. Likert scale from 1 (strongly disagree) to 7 (strongly agree).

	Disagree					Agree	
	1	2	3	4	5	6	7
Effectiveness. The capabilities of the inILDE community panel meet my requirements.	0	0	2	1	3	18	5
Satisfaction. Using the inILDE community panel is a frustrating experience.	4	11	3	7	1	2	1
Overall. The inILDE community panel is easy to use.	0	0	4	1	7	13	4
Efficiency. I had to spend too much time interacting with the interface of the inILDE community panel.	2	4	3	8	6	6	0

$N = 29$.

the community dashboard helped participants to be aware of their community and how it facilitated their tasks. Their comments were based on the time they spent using the dashboard. For example, some participants mentioned although they have used it for a limited period of time they were willing to understand the community through the dashboard. Other participants pointed out that it helped them to search and comment others' designs, re-use designs, get inspiration for ideas and understand the overall activity of the members during the MOOC. Moreover, they mentioned that it helped them to understand which tools were used during the course and their activities in specific time periods of the MOOC. In the second open question, participants were asked to write a positive, a negative aspect and a recommendation relevant to the development of the community dashboard. Among the positive aspects were the realization of the sharing possibility in the community, the easy-to-use interface of the dashboard, the opportunity for data-informed search and the variety of the functionalities to continue the learning process in the course. However, they have also mentioned that in some cases interpretation of information provided in the dashboard was hard, which lessen the benefits of using it. Some recommendations were to group designs based on a topic and the use of badges for the contributors. Further, they recommended user ratings for learning designs visualized in the dashboard and incorporation of the dashboard in more tasks during the training actions.

4. Discussion

In this paper, we followed a design-based research methodology to develop awareness support in web-based communities for learning design. Our proposal arises from the CHAT framework both for supporting the theoretical understanding of a community of teachers who design innovative learning activities as well as analytical support for community awareness in which units of analysis are defined and displayed as emerging participation metaphors in the community. We investigated our proposal in close collaboration with school teachers of Secondary and Vocational education, pre-service teachers in a Master course and teachers in a MOOC who all used a social platform for learning design named ILDE. Our aim was to build both theoretical understanding of how teachers perceive our proposal and second to derive a set of design principles in community awareness support for educational communities. We defined the **RQ** addressing the issue of community awareness data in such social platforms and their utilization by teachers in their learning design process. We first seek to understand **RQ1**: which community awareness data and visualizations could be useful in such communities and **RQ2**: how community awareness data can be made useful in this context. The involvement of different participants in the iterative cycles helped us to compare our results in different educational communities and contexts.

Regarding the **RQ1** initial analysis of the ILDE (before the development of the awareness dashboard) showed that teachers who used the system during a professional development program reported limited time to explore and share designs both during the workshops and after them. This statement aligns with teachers' time constraints in PLCs (Prenger et al., 2017) and informed our development of community visualizations with aggregated data. Teachers showed interest in knowing the popular content in their community, how designs are implemented and perceived by students, and willingness to build on the contributions of others. This further informs the development of visualizations as a knowledge-creation metaphor and a social process (Paavola, Lipponen, & Hakkarainen, 2004) in such design communities.

The above analysis, as well as literature review in communities of learning design, led us to develop a community awareness dashboard based on the CHAT framework which displays aggregated and detailed behavioral data regarding the members' actions, the actions performed on the designed artifacts and the actions performed with different tools. In all the cycles participants agreed that the dashboard provides a summary of the community activity and saves their time to identify content which may help reducing time constraints (Jones & Dexter, 2014). They also agreed that it shows influential members and common interest topics in the

community. Specifically, users identified the dashboard as support when they perform joint work with common goals. This reveals that such community dashboard may be used to depict evolving community's interests and members' roles to facilitate knowledge sharing (Chiu, Hsu, & Wang, 2006) and community regulation (Klamma, 2013) in specific teachers' projects. They also identified additional use cases of the dashboard as they recognized that it facilitates re-use of designs, comments on designs and understanding of the overall use of the tools during different time periods. Their statements helped us to further define the context in which community awareness data can be used for learning design.

As negative aspects, teachers repeatedly stated that the presentation of the dashboard should be linked to the actual artifact or comments. They needed to construct better understanding on what the displayed data mean. For example, they pointed out that in heterogeneous teacher communities with different subject matters, the grouping of designs should be based on topics rather than popular content. Moreover, in teacher communities, the display of comparisons related to the contributors was identified as inappropriate. During the MOOC, the visualization for the members' participation was the most used feature, which may imply the interest of participants to periodically identify most engaged members in their community within a course. In cycle 2 and 3, pre-service teachers in a Master course and the MOOC participants connected the use of the dashboard with the formal tasks proposed by the facilitators. They needed to understand better the displayed data and how this supported their tasks during the course. This shows the relevance of the epistemic tasks and how meditating tools like the community awareness dashboard can lead to meaningful outcomes as defined in the Activity Centred Analysis and Design (ACAD) framework (Goodyear & Carvalho, 2014).

Regarding **RQ2**, the pilot study in Cycle 3 showed an influence of dashboard use in exploration of members' profiles in the community, which suggests that the dashboard can provide an understanding of the social presence in the community (Garrison & Akyol, 2015). Moreover, high use of the community dashboard revealed more exploration of designs, profile views, and comments. This shows increased social interactions mediated by the community. Regarding the epistemic tasks during the MOOC, participants that used the dashboard commented on designs that received more comments as opposed to those that did not use it and thus were able to reflect more on others' contributions. Dashboard use revealed higher variability in the content of the messages and evidence of participants' reflections about others' designs. User experience was positive in general, with only few signs of frustrations regarding user interface by some of the users. Participants explained that the dashboard helped them in better search of the designs and understanding the possibility of sharing within their community.

5. Conclusions and future work

This paper focused on communities of learning design practice supported by a social platform named ILDE. The members of the different communities are teachers in schools, pre-service teachers in a Master course and participants in a MOOC for learning design. The social platform provides both individual and shared space for teachers to create, share and re-use learning designs. The first stage of the design-based research methodology illustrates beliefs of teachers towards sharing the design of learning activities, like willingness to build on other teachers' designs and the need for student feedback. Second, teachers' time constraints hindered the social interactions in the platform like the exploration of material and sharing of resources. Our proposal for community awareness based on the CHAT framework was initially perceived to be useful as an overall understanding of the community activity and realization of the sharing possibility within the community. The different units of analysis (learning designs, tools, members) were visualized with behavioral data of teachers' interaction including them in the platform. Teachers used the community dashboard during the MOOC with more interest in the visualizations about members' participation behavior in the platform linked with their own artifacts and comments. Blending the community dashboard in MOOC tasks and teachers' face-to-face discussion in workshops showed evidence of community reflection e.g. review of variations of a design pattern, reading others' comments, understanding of active contributors. Moreover, active users throughout the MOOC who used the community dashboard explored profile of other participants more frequently. In both cases in which the community dashboard was used as support for a formal course, participants needed a better understanding of how the community data relate to the proposed task from the facilitators.

The above mentioned iterative cycles and observations in the different educational communities helped us to derive in a set of design principles to support awareness in communities of learning design practice. We classify the principles as follows:

a. **Context of the community**. Different communities require different types of support according to members' pre-existing relationships, preferences, motivation, and curiosity to reveal meaning in the specific educational community. There is no “one-size-fits-all” solution.
b. **Practice-related insights and support.** The need for time efficiency, subject-related information, and alignment with institutional constraints e.g. academic program, working life should be considered. Practical application of learning designs and students' reactions to them needs to be integrated with the community awareness support.
c. **Visualizations and representations.** Members of the communities need easy-to-understand and explore data visualizations/representations with access to artifacts. The overview of interactions between members, tools, and designs can summarize the activity in learning designs communities. Visualizations need to be platform independent but at the same time aligned with the performed users' actions in the platform.
d. **Structured vs. unstructured tasks.** Structured learning designs tasks in professional development programs and formal courses which use social platforms require thoughtful integration of awareness dashboards to benefit from the community dynamics. Community reflection and discussion tasks can be enhanced with awareness dashboards. When users are engaged in unstructured tasks e.g. without facilitators' instructions, should consider and benefit from the evolution of participation and members' emerging roles.
e. **Interests of community.** The predominant interests are community information about methodologies, tools and teacher experiences. It is important to cultivate community and group work culture within an educational institution. The display of community awareness information between different institutions can create additional interactions.

Our results are strongly connected to the context in which the evaluations were conducted like school communities and course communities. Thus, it is difficult to generalize to a variety of teaching communities. Moreover, teachers used a specific social platform and thus in other platforms the different user interfaces could have different results. However, the development of the community awareness dashboard based on the CHAT framework helps us to align this research with different platforms in which the members, the tools, and the designed artifacts can be used as units

of analysis for community awareness support. Future work needs to evaluate how the individual interests of users in such social platforms relate to the community provided information. For instance, in our case, the community data can be filtered by specific subject topics to benefit different subject teachers. Another important aspect is how the emerging community information of the dashboard relate to the implementation of the learning designs. For instance, to what extent the most re-used or popular learning designs are perceived as satisfactory by the students. This perspective will need to consider also the students as part of the community or as end users of the created designed products. Future work needs to include metrics about quality and description of designs, feedback given by students and improvements in the user interface. We are planning to extend our research in the above educational communities focusing on the interplay between the proposed tasks for learning design and the use of the dashboard to better understand in which specific tasks and how the community dashboard mediates the creation of new learning designs. Last, extension of our work could be performed in other types of authoring communities to better understand how the social space impacts users' interactions and the authoring of new designs.

Acknowledgements

Special thanks to the teachers participating in the communities studied. Authors also want to thank Pablo Abenia, Patricia Santos, Juan Asensio-Pérez, Sara Villagrá-Sobrino, Judit Martínez, Ishari Amarashinghe, Marc Beardsley and Milica Vujovic. This work has been partially funded by RecerCaixa (CoT project) and the Spanish Ministry of Economy and Competitiveness under MDM-2015-0502, TIN2014−53199-C3-3-R, TIN2017-85179-C3-3-R.

Appendix

Table A.1
Teachers' responses for awareness support in the ILDE ($N = 18$).

Does ILDE help you be to be aware of the activity done by other members? If yes how?		
Coded Category	Example	Frequency
Limited time	"*I have not much time to browse other designs. I would like to see what designs have been implemented and the assessment of other teachers when they put them into practice*." [T10]	5
Explore, browse, review	"*It helps because it is easy to explore and browse the designs of other members.*" [T1]	4
One-word	"*No*" [T10], "*Yes*" [T3]	5
Sharing	"*Yes. You have access to activities shared by other members of the community that can serve as a starting point for others.*" [T5]	2
Joint tasks	"*Yes, in the case of common tasks. I suppose if we are involved in joint design tasks, it is a useful tool.*" [T6]	1
Comparison	"*I compare the work done by other colleagues regarding mine.*" [T7]	1
Another subject	"*Yes, it helps to see the activities designed from the perspective of another subject matter.*" [T8]	1

*T1,2,3 … = Teacher response number.

Table A.2
Teachers' responses about additional community data in ILDE ($N = 18$).

Would you like to have additional data regarding the use of ILDE in your community? If yes, which data will be the most interesting for you?		
Coded Category	Example	Frequency
Most used designs	"*Yes. [I would like to know …] What are the most used designs, whether it has worked or not … to know the contents that worked better.*" [T18].	2
Most visited	"*Most visited proposals.*" [T11]	1
Subject-specific	" *[I would like to know …] areas or topics and within each area by a number of queries, number of times an activity was duplicated, positive comments …* " [T13]	3
Impression by students	"*Yes. [I would like to know …] those that have been most interesting for the students.*" [T14]	2
Activities with different design tools	"*Yes, I would like to see designs related to problem-based learning, web quest, and other design tools.*" [T15]	1
Similar resources	"*Yes, [I would like to …] be informed whether other colleagues use resources similar to what I use.*" [T16]	1
Devote more time	"*Yes, I think it would be very interesting, but I would need a constant contact with the platform and not so sporadic because then I can understand what possibilities I had … etc.*" [T17]	1
Interesting without specifying	"It could be interesting." [T21]	2
No	"*No, I do not need.*" [T22]	1
Other	"*I think the platform should be used more in general.*" [T24]	4

*T1,2,3 … = Teacher response number.

Table A3
Teachers' responses in School 1 about the usefulness of the community awareness dashboard in Cycle 1 ($N = 13$).

Visualizations about designs	Visualizations about community members
"Everything seems good to me." [T30]	*"Everything seems right to me.."*[T44]
"It already seems good to me." [T31]	*"I find it ok.* " [T45]
" *The information to find the most used or duplicated designs is interesting, maybe it could directly appear the works or designs properly linking with them.*" [T32]	*"Tool not so much intuitive."* [T46]
"*The positive aspect is that from this platform I can see the summary of my community in a dynamic and fast way, but as a negative point is that if my community is very heterogeneous in terms of the subjects which we represent, some tools are not useful for me.*" [T34]	*"It is useful to recognize the most active users in the community but I do not see the utility for using the different tools since regardless of the top users it may be very different from my profile and his contributions do not interest me.*" [T48]

(*continued on next page*)

Table A3 (*continued*)

Visualizations about designs	Visualizations about community members
"It's good to get an idea of what is most used and therefore it can be more useful for not "losing" so much time searching. It is a more immediate search." [T35]	*"It's good to be able to put in common with these people who use these tools more and to be able to share."* [T49]
"… It can be useful in the case of greater use and a larger community of users (for example, from various schools and institutes), then this tab could be an improvement in the tool ."[T36]	*"They are very visual and stand out the most active members and the ones who make the most out of it. It may be useful to identify users who do not benefit from the tool and check for possible improvements."* [T50]
"*Positive: It is possible to know the "best" designs. Negative: It is not evident."* [T37]	"*It could be an aspect to improve if the comments are useful or significant*." [T51]
"*Positive: it allows to visualize the role and participation of the different members. Negative: It introduces an aspect of comparison that cannot always be good among teachers*." [T38]	*"Positive: it allows to see my level of participation and the others. Negative: I do not understand how the top commenters contribute."* [T52]
"*Positive aspect: it gives a very graphical comparison*." [T39]	"*Positive: the global vision. To be improved: to appear who are the members*." [T53]
"*Positive aspect: an overview of all the information."* [T40]	*"Positive aspect: overview of all the information*." [T54]
"It helps us to identify those most popular, most used designs … Only a certain number of people appear in the ranking, not everyone/all designs appear." [T41]	*"Positive: it helps us see the degree of participation of the members of the community. Negative: From here we cannot (directly) access their contributions."* [T55]
"I'm sorry but I would need more time to point out negative aspects." [T42]	*"It is mostly quantitative*." [T56]
"I think that, while being quite useful, the interface is not intuitive and not too attractive." [T43]	*"I think it's not clear how to sort the columns*." [T57]

*T1,2,3 … = Teacher response number.

Table A.4
Quote of discussion between facilitator and teachers during a workshop for learning design in Cycle 2.

Teacher #1: "Actually, if we had a similar tool to track our students, to see what our students are doing that would be great!". Then many teachers started to laugh.
Teacher #2: "But this is only between us? So the presented data is about our interaction with the platform."
Facilitator of the workshop: "… Yes, they are about the use of ILDE by your group of teachers."
Teacher #3: "For me, it looks very interesting to be able to evaluate during the term, what really happens during a whole course. a) Which are the teachers who are working and design together, and which are b) the main themes and most interesting tools used. I think for this purpose it is useful. This is something that we miss. However, I cannot think of how to use it, because for example here we have never done it in the educational center to supervise our work or to know what kind of person works with whom. For example, we do not have a summary or history of projects in which we worked together."
Facilitator of the workshop: "The dashboard is showing awareness data to see the evolution of the community and not as an evaluation tool between teachers."
Teacher #3: "Yes I understand what do you say. What I want to say is that I find it interesting because we do not have this community culture. We used to work on our subjects but we do not have the culture of the community to share the experiences of our work. I think it's a matter of work method. I have realized that sometimes we are using methodologies that are the same, doing the same, and we have not realized until we have shared the subject. And maybe we do not know how to take advantage of that. "

Table A.5
Responses in School 2 and Master course about the usefulness of the community awareness dashboard during Cycle 2 ($N = 36$).

Visualizations about designs		
Coded Category	Example	Frequency
Positive responses		
Global view of the designs	"*It allows a joint vision*." [T58], "*It helps me to see the designs globally*." [T80]	8
Most used, duplicated or interesting designs and tools	"*It allows knowing what are the most duplicated designs, with more implementation …* " [T60],"*I can see what are the most commonly used and most consulted documents that could be interesting to use*." [T81]	9
Understandable, intuitive	"*Very intuitive*" [T61]; *"The information is easily viewable*" [PT85]	3
Objective analysis	"*The presented data allow an objective analysis of what is happening and not a subjective perception that hardly comes close to reality. It allows me to understand better how we work in my community*." [T64]	1
Other	"*Everything is ok*." [PT75]	1
Negative responses		
No link to artifacts	"*It's only a statistical tool, it does not allow direct access to the designs*." [T58]	3
Difficult to understand duplicates tree	"*Difficult to understand information in duplicates tree*." [PT87]	7
Connection with teaching practice	"*I cannot find the real application that it could have in my teaching practice*." [T59]	1
Competitiveness	"*In the community, the quantification of the data can generate competitive movements to achieve more visualizations, … or to have more presence as a designer, etc*." [T65]	1
No indicators for the level of completeness	"*A negative aspect is that it does not show the level of completeness, nor if it has been put into practice or if the experience has been documented*." [T65]	1
Other	"*Most viewed designs would be best if the* "*others*" *have viewed them, but not if you have viewed it many times!*" [T90], *"Most of the designs included in ILDE relate to the tasks which had to be done during the course" [PS92]*	4
Visualizations about members		
Coded Category	Example	Frequency
Positive responses		
Key and active members	"*It allows knowing the most productive members, what can be a good starting point for a research.*", [T68] *"You can see people who comment more on the designs."* [PT95]	10
Community analysis	"*I can analyse the operation of the group objectively.*", [T71] "*It allows me to know how the community works.*" [PT97]	2
Finding experts	"*A positive aspect I see is the fact of identifying that member who has designed an activity that may interest you and be able to get in touch to know how it works and/or respond to possible identified problems.*" [PT100], "*A positive aspect would be that it allows identifying a partner who is more expert in the use of a particular tool to ask, consult or share methodologies, doubts, etc*" [T73].	2

Table A.5 (*continued*)

Visualizations about members		
Coded Category	Example	Frequency
Other	"*Interesting information appears,*" [PT99],"*I find useful the part of members characteristics in statistical terms.*" [T70]	5
Negative responses		
Quantities vs. qualities	"*The number of contributions can sometimes lead to deception. It is quantitative value, but not qualitative. In certain circumstances, an excess of participation can be interpreted negatively ("I no longer do it because they always speak of everything and do not always add added value").*" [T69]	5
Applicability of information	"*In some cases, it might not interest someone and that a person makes fewer comments.*" [PT100]	5
Not very representative	"*It does not describe well the tasks each one has done. I appear there and I think I have not contributed so much as to appear.*" [PT101]	1
Work in pairs	"*We worked in pairs and one did the actual comment.*" [PT101]	1
Visualizations about tools		
Coded Category	Example	Frequency
Positive responses		
Understanding use of tools	"*This tab is interesting to see the trend of what is being used in ILDE.*" [T102], "*It shows how the different tools were taught by the facilitator.*" [PT106]	6
Useful, understandable	"*It is a very understandable and simple graph.*" [T104]	4
Expert finding	"*I think it would be important to identify who has designed with the different tools because in case I am interested in working in something similar, I would like to identify the creator and if necessary contact him.*" [PT100]	1
Time of creation	"*The ability to visualize activities at the time of its creation and over time*". [T110]	1
Negative responses		
Information applicability	"*The function of the application is not very well understood*" [PT111]	5
No link to the artifact	"*Improve the connection to the link.*" [T105]	3
No devoted time	"*I have not been able to explore it much.*" [T108]	3
More for teachers than students	"*I think it is more useful for teachers than for students (as a teacher I would use it more than now as a master student).*" [PT112]	1
Inconsistency with tasks	"*It would be necessary to make a summary of the situation in which the tool in question was used.*" [PT114]	1

*T1,2,3 … = Teacher response number, PT1,2,3 … = Pre-service teacher response number.

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2.2 Understanding collective behavior of learning design communities

The content of this Section was published in the following conference paper:

Michos, K., & Hernández-Leo, D. (2016). Understanding collective behavior of learning design communities. In *European Conference on Technology Enhanced Learning* (pp.614-617). Springer, Cham (LNCS). https://doi.org/10.1007/978-3-319-45153-4_75

Understanding Collective Behavior of Learning Design Communities

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Abstract. Social computing enables collective actions and social interaction with rich exchange of information. In the context of educators' networks where they create and share learning design artifacts, little is known about their collective behavior. Learning design tooling focuses on supporting educators (learning designers) in making explicit their design ideas and encourages the development of "learning design communities". Building on social elements, this paper aims to identify the level of engagement and interactions in three communities using an Integrated Learning Design Environment (ILDE). The results show a relationship between the exploration of different artifacts and creation of content in all the three communities confirming that browsing influence the community's outcomes. Different patterns of interaction suggest specific impact of language and length of support for users.

Keywords: Learning design · Communities of educators · Collective behavior · Social network analysis

1 Introduction

The current discussion on teaching and learning with the use of Information and Communication Technologies suggests the reformulation of teaching practices and alignment of ongoing pedagogies with the changes, advantages and effective adoption of emerging technologies. In this direction, the notion of "openness" in teaching with Web 2.0 environments and the movement from individual to collective practices when teachers are designing learning scenarios constitute new paradigms of knowledge exchange. Learning Design is the field that studies the art and science of *designing* meaningful and effective scenarios *for learning* and proposes tools to support the design process by enabling their explicit representation in sharable formats [1, 2]. The artifacts reflecting the designed learning scenarios are generally called *learning designs*.

Social computing enables collective action and online social interaction with rich multimedia exchanges and evolution of aggregate knowledge [3]. Significantly, social network environments are highly based on user participation and contribution behavior to benefit from collective intelligence. Existing research has studied participation behavior in diverse types of social networks [4], including teacher's communities [5, 6]. However, in the context of educators' networks whose aim is creating the

K. Verbert et al. (Eds.): EC-TEL 2016, LNCS 9891, pp. 614–617, 2016.
DOI: 10.1007/978-3-319-45153-4_75

best possible learning designs for their particular contexts, very few studies provide results between different communities on the collective usage and contribution behavior of the users.

In this paper we focus on the online activities undertaken by three groups of educators using three separate installations of the ILDE community environment [7]. ILDE supports the development of "learning design" communities in which members are able to share and co-create multiple types of learning designs. The research question investigates and compares the usage and contribution behavior of the three learning design communities (a multilingual training community-ILDE-MOOC1, a monolingual training community-ILDE-MOOC2 and an open learning design community-ILDE-Demo). The analysis focuses on identifying common patterns and differences in four user's actions: creation, modification, exploration of learning designs and comments. Data used is extracted from log files automatically collected by ILDE. Correlation analysis examines the relationship between exploration of content and contribution behavior and social network analysis aims to identify the network structure of these communities.

2 Results

In each community we observed the number of learning designs viewed by user (passive participation) considering the users with at least one view and their overall creation, number of modified learning designs and comments (active participation). The aim was to identify the levels of engagement and analyze if exploration of different artifacts was related with explicit user's actions. In all the communities there was a positive relationship between viewing and modification and between viewing and creation of learning designs (see Table 1).

Table 1. Descriptive statistics and Spearman's correlation matrix in the three communities

	ILDE-MOOC1(n = 315)		ILDE-MOOC2(n = 359)		ILDE-Demo(n = 289)	
	M(SD)	1	M(SD)	1	M(SD)	1
1. Views	33.79(44.69)		25.81(40.37)		8.36(17.04)	
2. Edits	4.79(5.09)	.827*	3.34(4.15)	.753*	1.36(4.79)	.434*
3. LdS	5.62(5.13)	.818*	7.43(6.36)	.553*	3.15(8.03)	.426*

*p < .01, LdS (Learning design Solution, in ILDE/LdShake terminology) = Total created learning designs per user, Views = Total number of LdS viewed per user, Edits = Total number of LdS edited by user.

Although in the open-environment (ILDE-Demo) this was identified in a lower level since the other two communities were running within a MOOC training course [8], this relation was present. These results propose that users do check examples of learning designs when they create new artifacts and that learning designers in a community platform can influence each other on the way they design. To further explore the interaction patterns between different users in the communities using the ILDE environment and identify how users influence each other we followed a social network analysis approach. We constructed in each community two directed, weighted networks based on the following relationships: a views network which was representing that one user (node x)

viewed the learning design (edge) of another user (node y), a comments network which was representing that one user (node x) commented the learning design (edge) of another user (node y). Table 2 presents network statistics of the observed networks in the three different communities.

Table 2. Statistics of the different networks

	Views network			Comments network		
	MOOC1	MOOC2	Demo	MOOC1	MOOC2	Demo
Nodes	310	264	229	154	191	22
Edges	5729	1134	1050	376	481	36
Degree	101.31	29.27	16.17	2.98	3.49	2.22
Modularity	.12	.35	.35	.42	.64	.43

We can see in the views network that in the monolingual community (MOOC1) more users (nodes) compared to the multilingual community (MOOC2) browsed the designs of others (edges). In the multilingual community (MOOC2), participants concentrated in browsing mostly designs created in the language they understand best and thus created more clusters (higher modularity) while in the first MOOC all participants explored designs (only in English) created by the whole community. In contrast, in the comments network of the monolingual community (MOOC1) fewer users commented the learning designs of others. This suggests that the familiarity of users with the language can influence the commenting behavior and the frequency of messages between them. Additional differences like domain of expertise or familiarity with technology may also influence their interactions. In the open community (Demo) the network was developed through a three year period of time, and users periodically contributed with creation of learning designs and comments to them. Views network shows that fewer users, than in the others communities, explored learning designs created by others. However, despite the use of ILDE was self-organized or free use in this case, we observe an arguably relevant interest of users in browsing designs in the community. In terms of communication, the community showed a similar behavior (less clusters) as the first MOOC because the interaction occurred in English. Although comments were few, the fact that some users knew each other and had a common goal (e.g., project members designing training workshops) created a dense network and purposeful interactions.

3 Conclusion

Sharable formats of learning designs serve as representation of designers' thinking about effective learning in their contexts and as means of communication between educational practitioners. Our results suggest that visibility for popular users and designs, monitoring of users' participation and identification of high quality artifacts in such communities may add additional value in the way users explore and contribute. Scaling sharing of teaching practices in community environments enables the identification of patterns shedding light about how teachers are designing being inspired by other educators' ideas and based on diverse pedagogical approaches. In this paper we touched one aspect of

collective behavior analysis in the usage of a social online platform for learning design in three particular communities. Further studies should consider properties of the designs (learning design representations and tools used, qualitative analysis of its content) and whether created designs have been created from scratch or refine copies of reused designs available in the community.

Acknowledgments. This research is partly funded by RecerCaixa and the Spanish Ministry of Economy and Competitiveness under RESET (TIN2014-53199-C3-3-R) and the Maria de Maeztu Units of Excellence Programme (MDM-2015-0502). DHL is a Serra Hunter Fellow.

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CHAPTER 3

STUDYING AND SUPPORTING THE INQUIRY PROCESS OF TEACHERS AS DESIGNERS

Chapter 3 is dedicated to the second objective of this dissertation and presents the 2nd cycle of the overall DBR methodology followed during this thesis work. In this cycle, we address the problem on how to study and support the inquiry process of teachers as designers with data analytics. The notion of teachers as reflective practitioners has a long tradition in educational research. With the integration of ICT in teacher practices new opportunities and challenges emerge. Understanding current teacher inquiry practices in real settings (e.g. schools) is a challenge addressed in Section 3.1. Moreover, the connection between LD and LA in TEL scenarios is demanding for teachers due to pedagogical and technological constraints, lack of practices to act upon learning analytics data, and lack of guidance. A teacher inquiry tool to support teachers in connecting LD and LA is presented in this chapter. An embedded multiple case study in two High schools was employed to qualitatively investigate teacher inquiry cycles with technologies by using the TILE tool. We contextualized the connection between LD and LA in the case of CSCL activities and a particular tool (PyramidApp) which allows the authoring and implementation of collaborative learning activities. In section 3.2, we propose reflection support for teachers based on the evidence collected from students to (re)design collaborative learning activities. The data-informed reflection support aims to inform teachers´ pedagogical intentions, the pedagogical method/structure and the practical challenges encountered during the enactment of learning activities. Figure 7 presents the 2nd DBR cycle and the main contribution presented in Chapter 3. The content of this chapter is based on a JCR-peer reviewed journal article (Section 3.1) and a peer-reviewed workshop paper (Section 3.2).

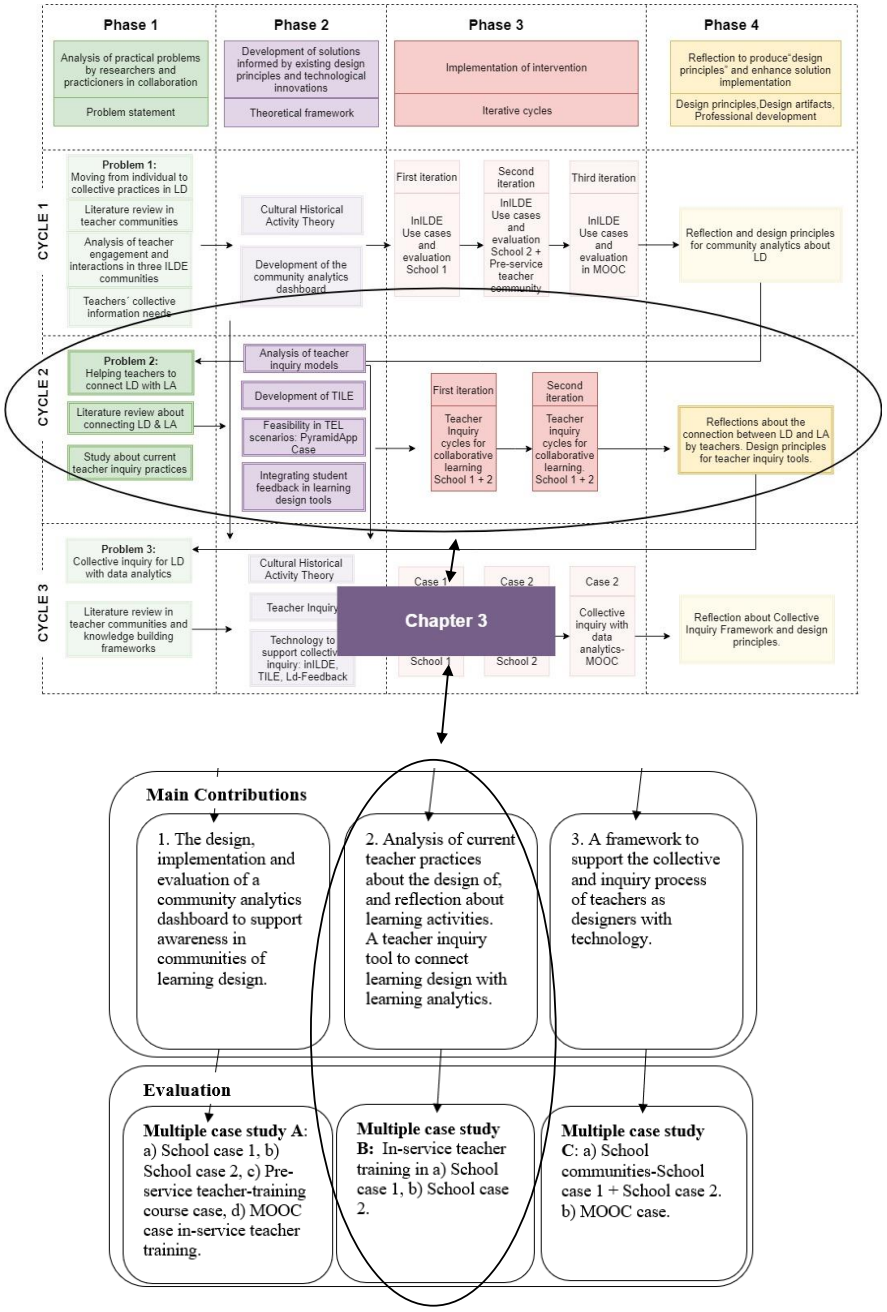

Figure 7. DBR cycle and main contribution presented in Chapter 3

3.1 Teacher-led inquiry in technology-supported school communities

The content of this Section was published in the following JCR peer-reviewed journal article:

> 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://doi.org/10.1111/bjet.12696

British Journal of Educational Technology *Vol 49 No 6 2018* 1077–1095
doi:10.1111/bjet.12696

Teacher-led inquiry in technology-supported school communities

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Abstract
Learning design is a research field which studies how to best support teachers as designers of Technology Enhanced Learning (TEL) situations. Although substantial work has been done in the articulation of the learning design process, little is known about how learning designs are experienced by students and teachers, especially in the context of schools. This paper empirically examines if a teacher inquiry model, as a tool for systematic research by teachers into their own practice, facilitates the connection between the design and data-informed reflection on TEL interventions in two school communities. High school teachers participated in a learning design professional development program supported by a web-based community platform integrating a teacher inquiry tool (TILE). A multiple case study was conducted aimed at understanding: (a) current teacher practice and (b) teacher involvement in inquiry cycles of design and classroom implementations with technologies. Multiple data sources were used over a one year period including focus groups transcripts, teacher interview protocols, digital artifacts, and questionnaires. Sharing teacher-led inquiries together with learning analytics was perceived as being useful for connecting pedagogical intentions with the evaluation of their enactment with learners, and this differed from their current practice. Teachers' reflections about their designs focused on the time management of learning activities and their familiarity with the enactment and analytics tools. Results inform how technology can support teacher-led inquiry and collective reflective practice in schools.

Introduction

The proliferation of technology in teaching and learning offers opportunities for educational innovations. This aligns with the changing needs of teachers and learners and the affordances of their learning environments. A growing body of research studies the role teachers play as designers of Technology Enhanced Learning (TEL) (Goodyear, 2015; Kali, McKenney, & Sagy, 2015). Benefits of this approach are that teachers reflect on their own work and learn by designing (Kali et al., 2015). In addition, the Learning Design (LD) field contributes with languages, practices and tools which guide teachers to effectively design and share artifacts for their students'

Practitioner notes

What is already known about this topic
- The learning design field has proposed conceptual and technological representations as support for teachers as designers of Technology Enhanced Learning (TEL) scenarios.
- Teacher data use is a valuable strategy to inform the design decisions and methods for classroom activities.
- School teachers design practice is constrained on curriculum requirements and time.

What this paper adds
- This paper proposes a technology-supported teacher-led inquiry approach, grounded in different teacher inquiry frameworks and supported by a tool (TILE).
- Analysis of current teacher practice and collaboration in High Schools about the design of, and reflection about learning activities.
- Study about how teacher-led inquiry with technology has been implemented in school classrooms enabling shareable data-informed reflections of TEL activities.

Implications for practice and/or policy
- The adoption of data-informed reflection in schools requires explicit use of dedicated time and (technology-supported) spaces that enable and guide teacher inquiry and sharing.
- Participatory and community approaches can inform the design and reflection of TEL activities within schools.
- Training for teacher-led inquiry should consider the inquiry cycle process and supporting tooling, the technology used to support TEL activities, data collection possibilities and data interpretation.

learning (Mor, Craft, & Hernández-Leo, 2013). However, although there is a need to understand how teachers engage in the design of TEL, their reflections about the implementations of their designs in their everyday practices are also essential to improve both designs and practices. Substantial work has been done in being able to express and document the artifacts involved in the learning design process but little is known about which practices, tools and representations can express the impact of learning designs once they have been enacted with students. One promising direction to document the impact of the designs is to consider the growing research in Learning Analytics (LA), which aims to capture "data about learners and their contexts to understand and optimize learning environments" (Ferguson, 2012).

Towards understanding the connection between LD and LA, researchers propose to engage teachers and educational practitioners in data-informed learning design processes (McKenney & Mor, 2015). There is evidence on how learning design impacts student behavior and satisfaction in Higher Education (Rienties & Toetenel, 2016) but few research studies focus on how teachers reflect on their own learning designs with learning analytics. Technological and pedagogical constraints usually do not allow teachers to connect their design configurations with the provided learning analytics data (Rodríguez-Triana, Martínez-Monés, Asensio-Pérez, & Dimitriadis, 2015). There is also a need to cultivate the practice of teachers acting upon learner data to improve learning design decisions, ie, data literacy and metacognitive processes (Michos, Manathunga, & Hernández Leo, 2016; Schmitz, Van Limbeek, Greller, Sloep, & Drachsler, 2017). This requires additional effort, time and support for teachers. Especially in the context of schools, barriers, such

as a lack of technological infrastructure, lack of time in the school "bureaucracy" and limited teacher training do not allow for a systematic process to emerge (Gil-Flores, Rodríguez-Santero, & Torres-Gordillo, 2017).

Teacher reflection is frequently happening in an unplanned way and may account for teacher beliefs and ideas rather than everyday evidence (Dana & Yendol-Hoppey, 2014). Teachers are rarely engaged in intentional and visible reflection processes. Such reflection has been largely explored in the teacher inquiry or practitioner inquiry context but has rarely been adopted in the TEL field. Luckin, Clark, Avramides, Hunter, and Oliver (2017) define teacher inquiry as systematic research of teachers´ own practice in context in order to improve teaching and learning. A related term, action research, is a model that guides teachers to investigate and evaluate their work based on everyday evidence (eg, with learning analytics).

Teacher reflective practice has a long tradition in teacher education and professional development. The works by Dewey (1933) and Schön (1987) introduce teacher reflective practice as a way to solve local problems by reflecting *in-action* during classroom events and *on-action* to improve future classroom interventions. Moreover, reflective practice is a strategy for teacher professional development (Moon, 1999). The engagement of teachers in a cyclic process of questioning their practice, analyzing their context, designing a new model/intervention, implementing their model and reflecting on it helps to learn how to improve their own practice (Engeström & Sannino, 2010). This has been further explored in the context of school communities in which students and teachers construct knowledge within their sociocultural system (Butler & Schnellert, 2012; Sannino, Engeström, & Lemos, 2016). However, although the strategy for teacher reflection and inquiry may assist teachers to engage in intentional reflections for the improvement of their teaching, this is not apparent in their everyday practice (Dana & Yendol-Hoppey, 2014). More empirical evidence is needed to understand how teachers reflect on everyday classroom implementations to effectively support them. Moreover, it is still underexplored how technology-supported teacher inquiry can facilitate the connection of learning design with learning analytics and the individual and collective teaching reflective practice (Alhadad & Thompson, 2017; Persico & Pozzi, 2015).

This paper proposes a technology-supported teacher-led inquiry approach that includes the use of LD and LA in two school communities and studies how it facilitates data-informed reflection on TEL interventions by teachers. First, we aim to understand how teachers design and reflect on learning activities in their schools and second how to engage them in inquiry cycles with the support of technology. Our overall research question (RQ) is**:** To what extent does teacher-led inquiry help teachers to connect their learning designs with learning analytics within their school communities? This question is addressed by the investigation of the following more specific research questions RQ1: What is the current teacher-led inquiry practice in different school communities? RQ2: How can technology support teacher-led inquiry for data-informed reflections in schools?

Teacher inquiry models and technology integration

Teacher inquiry models and technology support

Different models which guide teachers in cycles of learning design realizations have been proposed. The Teacher Inquiry into Student Learning (TISL) model (Hansen & Wasson, 2016) is both an individual and collaborative inquiry which aims to use student data generated in technology-enhanced learning activities. Dawson (2006) proposed four inquiry steps for the integration and evaluation of technology in classrooms: (1) Definition of a "wondering" question which emerges from everyday practice; (2) Development of a plan to collect data in the classroom; (3) Analysis of the collected data; d) Presentation of findings in a group of teachers. Emin-Martínez et al., 2014) reflect on different inquiry models and propose the integrated teacher-led inquiry

design of learning which shows the meaningful use of LA in LD. Last, relevant literature on teacher reflection *on- action* identifies teacher scaffolds with structured inquiry steps (Marcos, Miguel, & Tillema, 2009). These studies propose a shareable inquiry process in which teachers report their findings and build on each other's contributions.

Based on the above frameworks, digital tools were developed to support teacher inquiry. For instance, TISL planner aims to support the phases of the TISL model (Clark, Luckin, & Jewitt, 2011). Sergis et al. (in press) propose a reflective analytic tool for teachers to inform student guidance in the context of inquiry-based learning. Bearing in mind the social process of inquiry, Web 2.0 tools, such as blogs and social network sites have been proposed for sharing teachers´ inquiries to trigger reflective discussions (Luckin et al., 2017).

Teacher Inquiry tool for Learning dEsigns (TILE)

Empirical results of the above studies show that support is needed not only to guide the inquiry process but also to facilitate the collection of data during the enactment of TEL activities in alignment with their design. Teachers also had difficulties adopting and following the complete inquiry process (Avramides, Hunter, Oliver, & Luckin, 2015). To articulate the investigation of RQ2, the paper proposes a teacher inquiry process based on common steps taken from the above frameworks to be used with the support of an online tool. The steps include the explicit formulation of an LD and the consideration of LA. Compliant with this process, we have developed the TILE tool to guide teachers in the design of, and reflection about, TEL interventions. This includes four steps:

- *Step 1: Problem and Questions.* Documents the context and expresses the teaching problem and challenge to overcome in a learning design. Monitoring question(s) are formulated to drive the data collection that will help to understand the impact of the design when enacted with learners.

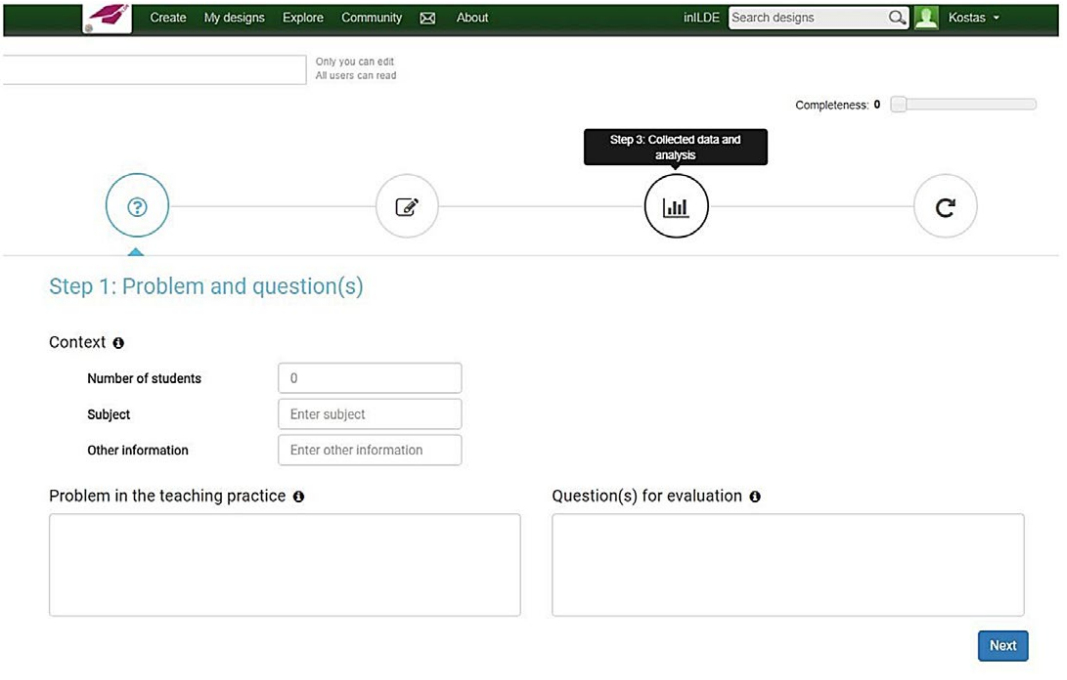

Figure 1: Teacher Inquiry tool for Learning dEsigns (TILE). Example at https://ilde2.upf.edu/dolmen/ve/dui (Michos, Hernández Leo, & Albó, 2018) [Colour figure can be viewed at wileyonlinelibrary.com]

- *Step 2: Design Intervention and Evaluation.* Describes the learning design of an intervention and the evaluation design while taking into consideration the problem and monitoring questions. In this step, TEL tools are proposed to ease and facilitate the enactment of the interventions and data collection.
- *Step 3: Data collected and analysis.* Details the reporting and interpretation of the analytics resulting from the collected data that is relevant to the enactment of the learning design. Provides space to comment on the different sources of data and add observation notes.
- *Step 4: Reflection and proposed changes.* Summarizes the experience and the collected data according to the initial problem and monitoring questions. Improvements about future realizations of the intervention are proposed based on the collected data.

TILE has been integrated into the ILDE (Integrated Learning Design Environment) community platform (Hernández-Leo et al., 2018) and teachers can share their documented inquiries together with their learning designs and collected data (Figure 1). Teachers can explore learning design artifacts generated by others related to the above four inquiry steps.

Methods

Embedded multiple case study

The research method of this study was formulated in alignment with the aim to investigate teacher inquiry practice in authentic settings, and derive implications for research and practice for technology-supported teacher reflection. To enable this, we collaborated with two High Schools which engaged in a structured Professional Development (PD) program (Figure 2) focused on designing for Collaborative Learning (CL) (Johnson & Johnson, 1994). We initially explored the current teacher inquiry practices in the two schools and later, how teachers engaged in cycles of classroom implementations (of technology-supported CL activities) with the support of the TILE tool integrated into ILDE.

We followed a multiple case study design considering the two schools-community cases. The two schools were chosen because they were located in two different locations in Catalonia with different organizational cultures (School 1 is a rural school with a cooperative organizational form, where most teachers own the school and participate in its management; and School 2 is a traditional urban school with a top-down management.) We assumed that teacher norms and practices could differ between different educational institutions and thus can enrich our analysis. Moreover, multiple case methods are appropriate when: (1) research questions mainly focus on "how" and "why"; (2) behaviors in cases cannot be manipulated and (3) the research is a contemporary phenomenon (Yin, 2003).

During the implementation phase, teachers who performed classroom implementations of their learning activities were analyzed as embedded units nested in the school-community cases (Figure 2). The teachers were chosen based on the level of involvement in classroom implementations with the aim to deepen our analysis. The two school communities involved both teachers and students during the implementation phase *(Phase 2)*.

Context

The PD program focused on the meaningful use of ICT to (1) train teachers as designers of TEL and (2) facilitate the teacher inquiry practice with the systematic, fit-for-purpose collection of student data. The program was part of a research project carried out by a university research group in collaboration with two schools. Several researchers were involved in the facilitation of the workshops. The study took place from November 2016 until February 2018. ILDE was the

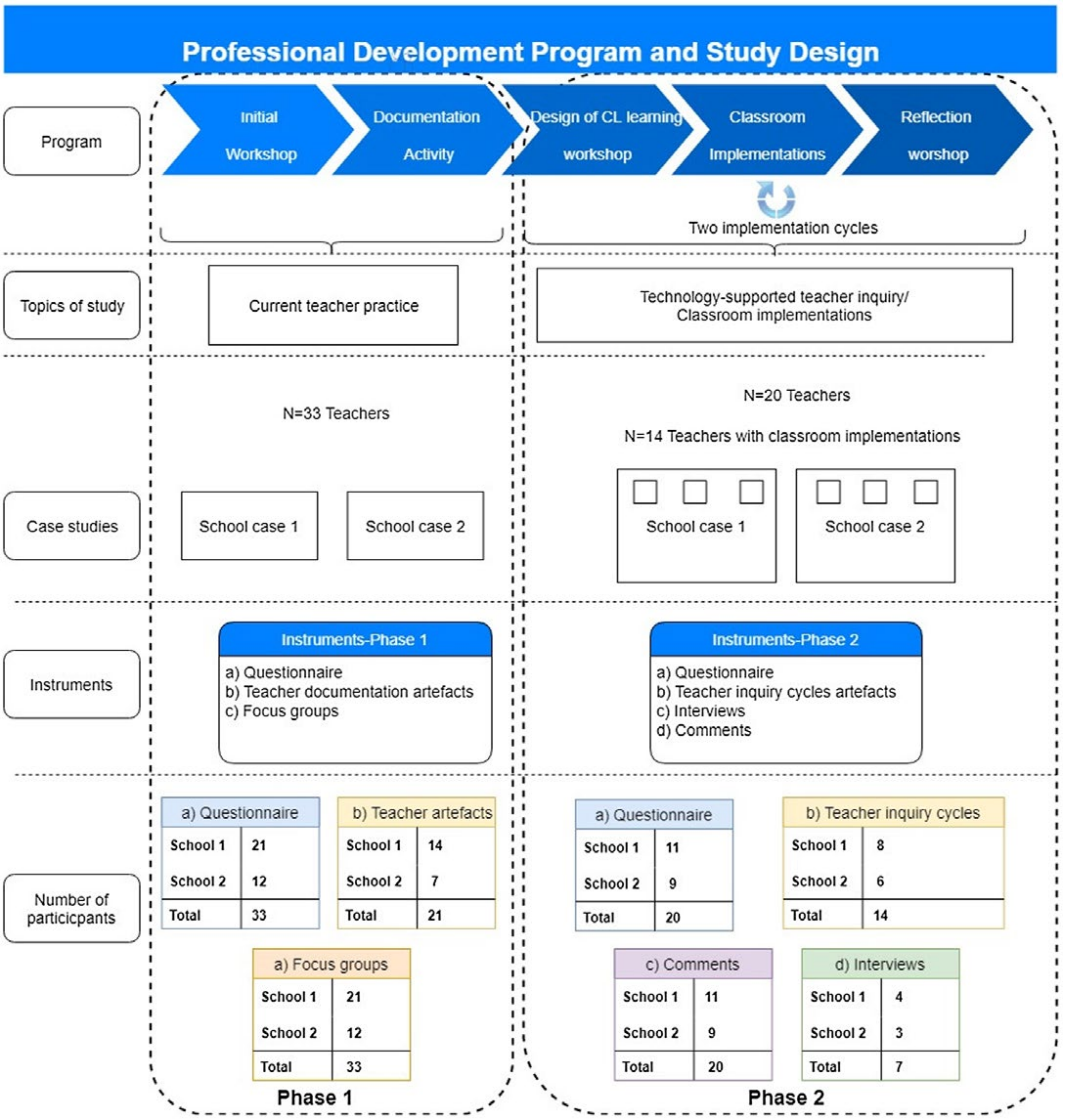

Figure 2: Professional Development Program and embedded multiple case study design in the two schools [Colour figure can be viewed at wileyonlinelibrary.com]

main design and implementation tool for the creation and sharing of designs of learning activities and teacher inquiries.

In *Phase 1*, an initial workshop aimed at introducing design for learning and relevant learning design tools to teachers. Then followed an online documentation activity in ILDE to showcase current teachers´ design and reflection practice related to learning activities implementations. In *Phase 2*, two cycles of the same workflow were followed in both schools with a design workshop, classroom implementations and a reflection workshop. The design workshop was devoted to the topic of CL as a common inquiry problem wherein teachers designed their activities and their inquiry plans. Then followed the configuration of the activities and implementations in

classrooms. Lastly, another teacher workshop was devoted to the joint reflection of the classroom implementations and the collected student data. The duration of the workshops was 2 hours and they were conducted monthly in both schools. The study included different subject matter teachers with varied teaching experience to consider and understand (if there are different needs for support in) the teacher inquiry process across varied cases.

To enable reflection about a common topic relevant to different subject matter teachers, the PD program included the notion of pedagogical patterns for CL, and covered some well-known CL patterns, such as Jigsaw and Pyramid (Hernández-Leo et al., 2006). Pedagogical patterns are design scaffolds for teachers that offer grounded ideas and structures of teaching–learning methods which potentially lead to educational benefits and can be particularized to the needs of specific learning situations (Goodyear, 2005).

In both Phases (1 and 2), teachers received training in digital tools which facilitate their inquiry cycles, and the enactment and monitoring of collaborative learning activities. Teacher training happened both during the workshops and with online activities. PyramidApp (Manathunga & Hernández-Leo, 2018) was the main authoring and enactment tool. It is a tool that facilitates the creation and instantiation of collaborative learning activities based on the Pyramid pattern. This pattern proposes a collaboration flow structure in which learners interact in increasingly larger groups along a sequence of activities (Pyramid levels). Pyramid flows foster individual participation, accountability and balanced positive interdependence. Google forms were used for the authoring and reporting of student feedback questionnaires. *Tableau* was used by researchers to visualize the learning analytics that were provided to the teachers within TILE in ILDE. Lastly, TILE (Figure 1) was used by teachers before and after the implementations to guide them through a complete cycle of design and reflection and as a documentation-sharing tool. During the first implementation cycle a table and excel-based prototypes of TILE were used and in the second implementation cycle, TILE was improved and developed as a dedicated tool.

In *Phase 1*, 33 teachers ($N = 33$) participated in the study and the PD program (see appendix Table A3*)*. $N = 20$ teachers (out of the 33) participated in *Phase* 2 and $N = 14$ teachers (out of 20) implemented their learning activities and conducted inquiry cycles with the use of the TILE tool. $N = 287$ High school students participated in the implementation of the activities in School 1 and $N = 221$ students in School 2. The first implementation cycle was between April 2017–June 2017 and the second implementation cycle between October 2017 and February 2018. Carrying out classroom implementations was voluntary and happened in these two cycles according to the school schedule. For some teachers, this was an opportunity to iterate and improve their designs.

Data collection instruments

Mixed methods, considering different sources of quantitative and qualitative data collection (Figure 2), were used due to the exploratory nature of our research questions and that the investigation is conducted in authentic contexts. Data source triangulation in the analysis was used to achieve trustworthy results.

During *Phase 1*, questionnaires with open and closed questions, focus groups transcripts, and teacher documentations in ILDE were used to examine current teacher inquiry practice. Based on our RQs and related work in a teacher inquiry study in school communities (Butler & Schnellert, 2012), three constructs were developed about: (1) learning design considering the design and documentation of learning activities by school teachers; (2) formative evaluation of learning designs considering the collection of data and the informal reflection of teachers; and (3) teacher

collaboration. An initial questionnaire (see Table A1 in appendix) aimed at analyzing the frequency of the above constructs and open questions, focus groups and teacher artifacts were used to deepen the analysis.

In *Phase 2*-implementation phase, the three constructs articulated in the current practice were examined in the subsequent emergent teacher inquiry practice as (1) technology-supported teacher inquiry (2) formative evaluation and (3) teacher collaboration. For the analysis, we used the documented artifacts from TILE, teacher comments in ILDE and a questionnaire with open questions. Lastly, 7 semi-structured, 40-minute interviews (four in School 1 and three in School 2) were conducted for the analysis of teacher involvement in the implementation cycles (Table A2). Data analysis was conducted by three researchers. The interviews and focus group discussions were transcribed. Then all the qualitative data (open questions, interviews, focus groups and teacher artifacts) were coded with inductive thematic analysis driven by our research questions and were cross-referenced to warrant interpretations. Two researchers familiarized themselves with the data and an open coding was used for identifying the main topics. A summary table with codes and samples of responses was used across the different data. Codes were iteratively discussed among the research team to reach inter-rater agreement. Finally, codes of teachers were used for the reporting of the results; for the code TS1.a, "1" denotes the analyzed school (School 1) and "a" the code of the teacher (see appendix Table A4).

Results

In this section, we report the results in each school-case and then we discuss the main findings with a cross-case analysis.

School case 1 Current teacher inquiry practice

In School 1, the analysis of qualitative data (open questions, focus groups and teacher artifacts) confirms and explains the trends identified in the quantitative results derived from the questionnaire (see Figure 3 for these results in both schools). The design of learning activities was a frequent practice but teachers mainly documented resources rather than tasks designed for learning, eg, sequences of activity descriptions with supporting tools and material (see Figure 4). Common tools used to document resources were Google drive and a Learning Management Systems (LMS) (6 out of 21 teachers). Discussions in the focus group provided insights into teachers' reasons for the design of activities and documentation of resources, like re-use for the next year, dissemination in social networks and reflections for improvements (see Focus groups, Figure 4).

Teachers' documentations in ILDE show characteristics of their designs and reflective documentations (see Figure 5 for an example of teacher artifact). 14 out of 21 teachers documented one classroom activity. The documentations included descriptions of group tasks (6) and the phases, steps and time of each activity (3). Other characteristics were the learning objectives (3), instructions for students (4) and assessment rubrics (1). Teacher reflection with observations was present only in one instance of documentation and referred to problems faced during the learning activity. This converges with quantitative results from the questionnaire about frequent informal teacher reflections. Teachers mainly prepared their activities alone and in some cases worked in pairs of the same subject (3). When happening, ways to share material were through an LMS, Google Drive and e-mail (5).

Five out of 21 teachers claimed that informal discussions after classroom activities and observation notes helped them to understand the impact of the learning activities. Seven teachers reported the use of feedback questionnaires. Lastly, only one teacher explained frequent unplanned reflections but without note taking about the implementation of learning activities.

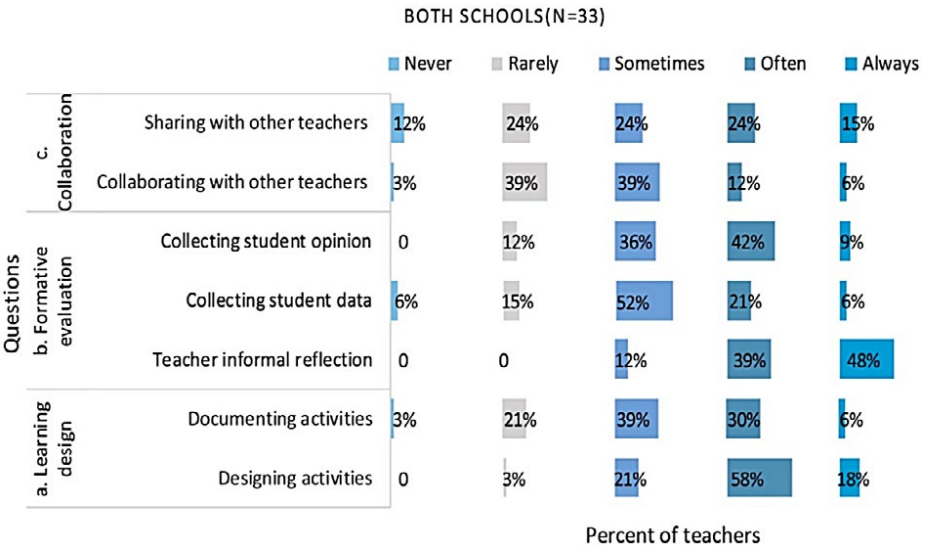

Figure 3: Teachers´ responses about frequency of design and documentation of activities, formative evaluation and teacher collaboration in the two Schools (Likert scale 1-Never, 5-Always) [Colour figure can be viewed at wileyonlinelibrary.com]

Technology-supported teacher inquiry

In School 1, 8 out of 21 volunteered to implement pyramid-based activities and documented a whole inquiry cycle with the TILE tool. Figure 6 shows an example of a teacher inquiry cycle guided by the TILE tool and content of a teacher inquiry. The teachers used their subject curriculum content and created a new activity with the PyramidApp tool. The activities lasted in each case between 20 and 30 minutes and were all carried out in the classroom. During the reflection workshops, teachers presented their results and jointly reflected as a group with comments in ILDE. The content of their documented inquiries was analyzed according to the above-mentioned four steps of the inquiry process and the available student data.

Table A4 in the appendix shows a sample of data related to teachers who implemented classroom activities and the content of their performed inquiries. Six out of eight teacher artifacts show that the initial inquiry problem and subsequent teacher reflection referred to the content of the subject and the intervention design (CL method). All teacher artifacts included a reflection about time management. Lastly, joint reflections from eight teachers focused on the evidence of student misunderstandings about the activity and the ease of collecting student data in the collaborative activity with PyramidApp.

All four interviewees agreed that the teacher inquiry process supported by the TILE tool was a valuable approach to collect objective data from classroom activities. This was confirmed further with open questionnaire responses of the 11 teachers (see Figure 7). However, interviews showed contradictions about the frequency and granularity of the performed inquiries (eg, per activity, unit, semester) and the need to devote time for documentation (see Table A7 in Appendix, TS1.c, TS1.e). Three teachers (out of the 11 completing the questionnaire) mentioned that the inquiry cycle with the TILE tool is a practical way to reflect on design elements before and after the activity. Another three teachers claimed that the tool presents a coherent set of inquiry steps and facilitates the systematic design and reflection of learning activities. Lastly, three more teachers emphasized that the documentation of their expectations before the activity and the subsequent

Current teacher inquiry pactice in School 1

	Questionnaire (Open questions)	Focus groups	Teacher artefacts
Learning design	**LMS/ Google Drive (6):** "I have used the LMS to specify the sessions and describe what activities I do, to upload all the contents related to each subject and the works that must be delivered." *TS1.a* **Resources and subject websites (4):** "Sites,weebly"*TS1.f* , "Video, photography, evaluation tables, subject websites."*TS1.g*	**Reasons to document (3):** "To have them for the next year", "To make them more visible in social networks", "For me, it is useful to design the activity because you think it, you do it and then you go back to the design and you can change things that didn't work."	• **Group tasks (6)** • **Student intruction (4)** • **Objectives (3)** • **Fases, steps, time (3)**
Formative evaluation	**Student feedback questionnaire (7):** "We carry out an evaluation about the satisfaction of the course with a survey, but not related to each activity."*TS1.m* **Oral evaluation/Notes (5):** "Sometimes I reflect on the activities at the end of each lesson. I also listen to student opinions when they talk"*TS1.e* ,"I often go and look and take notes about what they are doing" *TS1.a* **Teacher self-reflection (1):** "Whenever I do an activity I think about what could be done to improve it. Although I do not always change it due to a lack of time." *TS1.i*	**Students´ self-evalaluation:** "In the economy subject, I asked them to do a collaborative activity,[]..I wanted to know what they liked the most, what did they think about working in teams, making a self-evaluation (confidential) to see how they worked in the group, who worked more and being honest about themselves with an objective view in the evaluation."	• **Assessement rubrics (1)** • **Observation notes (1)**
Teacher collaboration	**Google drive/LMS/Emails(5):** "Google drive, virtual environment, mail..."*TS1.g* **Same subject teachers (3):** " I share activities with my colleagues when they teach a subject which I taught last year. I don't have a problem if they copy all the information."*TS1.i*	(No data related to that topic)	(No data related to that topic)

Figure 4: Main topics and samples of data referring to teachers' current inquiry practice in School 1. Topics were classified into learning design, formative evaluation and teacher collaboration based on a questionnaire, focus groups and teacher-generated artifacts [Colour figure can be viewed at wileyonlinelibrary.com]

ACTIVITY: "Letter to myself"			
COURSE LEVEL	High school	MATERIALS	• A blank sheet • A pen
SCOPE	• Reflection, evaluation • Effort culture	OBSERVATIONS	<u>February 2017 (first-year high school students):</u> The experience has been very enriching. Some students were excited when they wrote the letters. Two of the students, wanted to make an individualized tutoring after the activity to comment on the reflections that had emerged. At the beginning, there was a student who did not want to do the activity because she thought that if she did not achieve the dreams that she would write in the letter, then she would be frustrated. In these cases, it is important to explain that we all change throughout life. And in the same way that we change, our goals and dreams also change, so maybe in a moment of our lives we dream of being something that after 10 years we will not be, because we will have decided to take another path.
OBJECTIVES	• Reflect on the work that students are carrying out • Identify the obstacles they are overcoming as well as the aspects they can improve in their learning process and growth as people		
TIMING	1. The student is asked to write a letter. The student has to imagine that it is a letter from himself/herself after 15 years, and write about the dreams he/she has achieved (studies, family, etc.). 2. The students are notified that the teacher will read the letters, but they will only be made public to the rest of the students in the cases they wish. **Time**: 40 minutes		

Figure 5: Example of a teacher documentation artifact (translation, original in Catalan). Information include learning objectives, material, temporal sequence of tasks and an observation about a classroom implementation

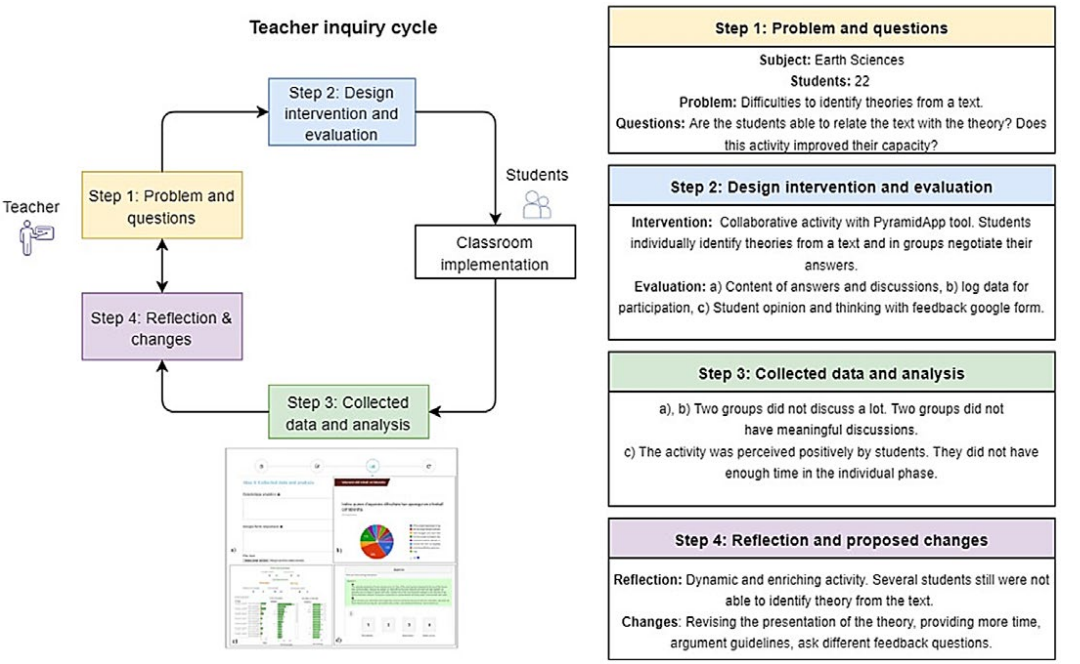

Figure 6: Example of what a teacher produced with the TILE tool. Access to the TILE tool at https://ilde2.upf.edu/dolmen/ve/dui [Colour figure can be viewed at wileyonlinelibrary.com]

reflection on the actual realization of the learning activity was useful. However, three out of four interviewees mentioned that further training is needed to master the different tools and the inquiry cycle to further facilitate adoption.

Regarding formative evaluation during the reflection phase, three teachers highlighted that all the collected data was important for reflection and this was also confirmed through their comments during their shared reflections. However, one teacher explained that information overload from data deluge can hinder their reflection. Teachers provided examples of modifications based on the data in their documented inquiry cycles and during the interviews. For example, in one case, analysis of student discussions led the teacher to provide guidelines for better argumentation in the subsequent activity (see Table A7, TS1.d).

All 11 teachers (interviews and questionnaire) said that having available shared information about teacher inquiries from their school community is useful to improve aspects in their own learning designs based on shared problems and the knowledge gained from each other. However, they acknowledged that part of the shared reflections cannot be completely re-used, because they were related to aspects specific to different domain subjects or because they could be biased towards unshared contexts and student cohorts.

School case 2

Current teacher inquiry practice

In School 2, three teachers out of 12 used photos or videos to document the experience of their students. In the focus groups, two teachers specified that they document instructions for students or document learning tasks only with limited details (see Figure 8). Two out of 12 teachers explained that note taking about the description and objectives of the learning tasks in their personal agenda

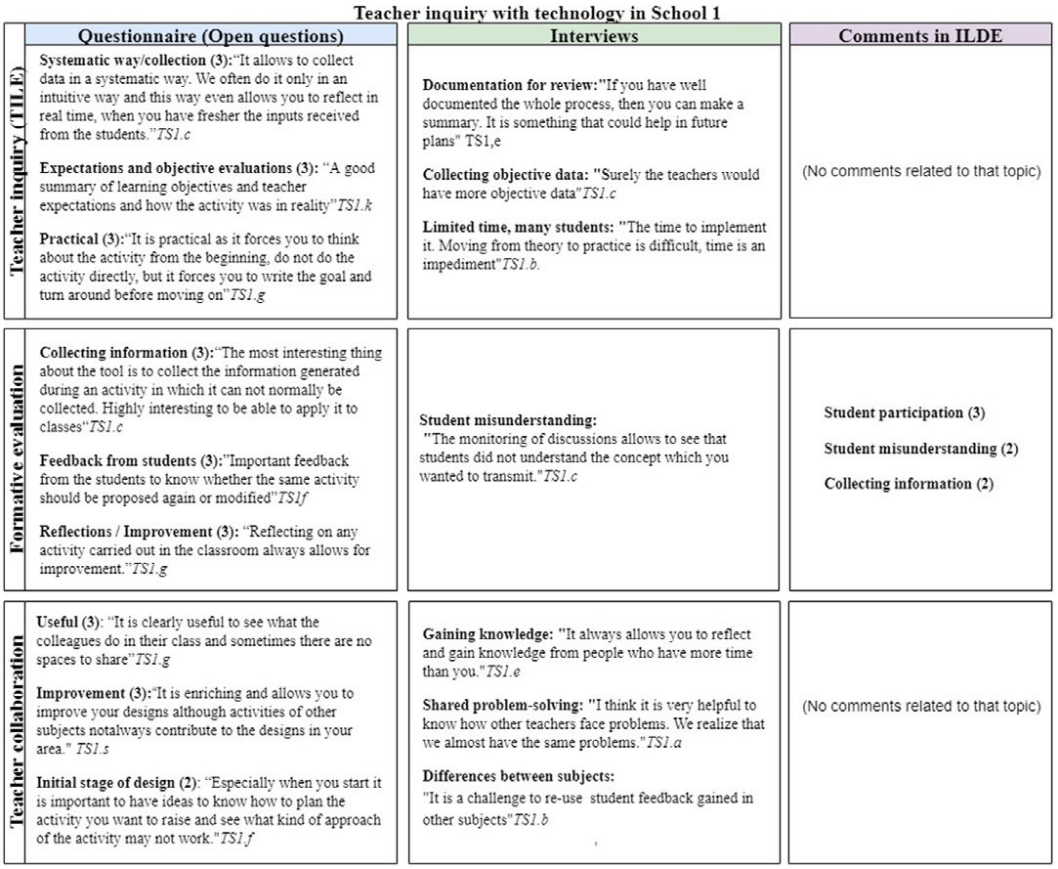

Figure 7: Main topics and samples of data referring to teachers' involvement in inquiry cycles with technology in School 1. Topics were classified into teacher inquiry, formative evaluation and teacher collaboration based on a questionnaire, teacher interviews and comments in ILDE [Colour figure can be viewed at wileyonlinelibrary.com]

or notebook is a common practice. Lastly, one teacher mentioned the use of an LMS and Google Drive. Seven out of 12 teachers provided sample documentation of a classroom lesson. Many documents included the learning objectives (3), resources (5) and description of tasks (4). One teacher included instructions for evaluation and another teacher documented observation notes.

Seven out of 12 teachers pointed out that the main practices for formative evaluations were feedback questionnaires with Google Forms and five teachers said they use informal notes during classroom activities for their own reflection. One teacher mentioned that time constraints and the high number of students did not allow for a systematic or frequent recording of evaluations for learning activities, which further informs the responses about teacher inquiry in School 2. Lastly, 3 teachers also specified that collaboration and sharing of learning activities was limited to pairs of teachers from the same subject and happened through LMS, Google Drive, e-mails and informal sharing discussions in face-to-face meetings (Figure 8, focus groups).

Technology-supported teacher inquiry

In School 2, 6 out of 12 teachers implemented and documented their inquiry cycle with the TILE tool (see a sample in Table A4). Four out of six teacher artifacts show that the initial problem and

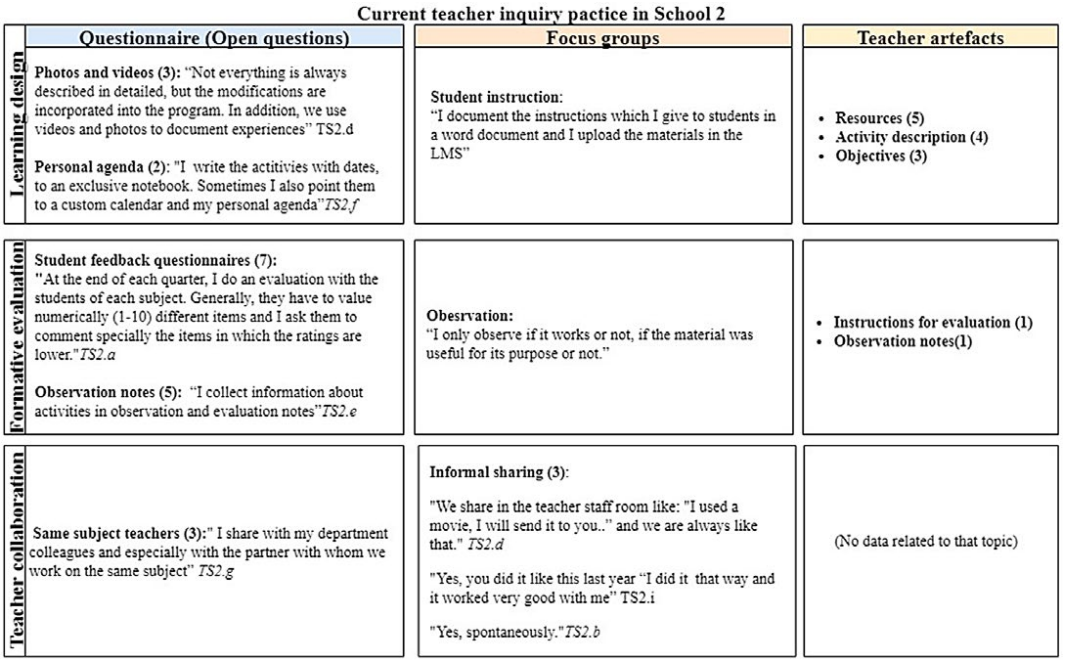

Figure 8: Main topics and samples of data referring to teachers' current inquiry practice in School 2. Topics were classified into learning design, formative evaluations and teacher collaboration based on a questionnaire, focus groups and teacher artifacts [Colour figure can be viewed at wileyonlinelibrary.com]

reflections were focused on individual and collaborative skills of students. Moreover, all teacher artifacts included reflections about time management. In one case, TS2.a designed, implemented and documented two TEL interventions applying the pyramid CL pattern. TS2.a had five years of teaching experience and her main subjects were Biology and Chemistry. The main *Problem* addressed in the inquiry cycle was the difficulty students have identifying elements of theory from a text. The teacher posed the question on how to improve this capacity with a collaborative activity using the PyramidApp tool in the class. The *Intervention* design was to identify elements of a theory in specific quotes from the text and discuss in groups until reaching a consensus at the class level. The teacher had available learning analytics of her implementation (within ILDE/TILE) that included the content of students´ discussion, their engagement levels (individually and by groups) and responses about perceived student experience about the task (see Figure A1 in Appendix and example of analytics report at https://ilde2.upf.edu/dolmen/v/dul). Teacher´s *reflections* focused especially on the time management of the intervention (providing more time in the individual phase and the group discussion phases) based on the feedback received by students through Google Forms. TS2.a proposed improvements for future enactments of the activity. According to her analysis of the content of the student discussions in the PyramidApp tool, she proposed adding prompts that trigger more on-task discussions and changing the feedback questions to include timing problems faced by students. All in all, TS2.a reflected on the activity as a dynamic and enriching way to practice how to elicit theory from texts.

Seven teachers jointly reflected on this inquiry cycle based on the collected student data. Their reflections focused on the importance of having student feedback to understand how students perceive the task. This was further mentioned in the interviews and open questionnaire (Figure 9,

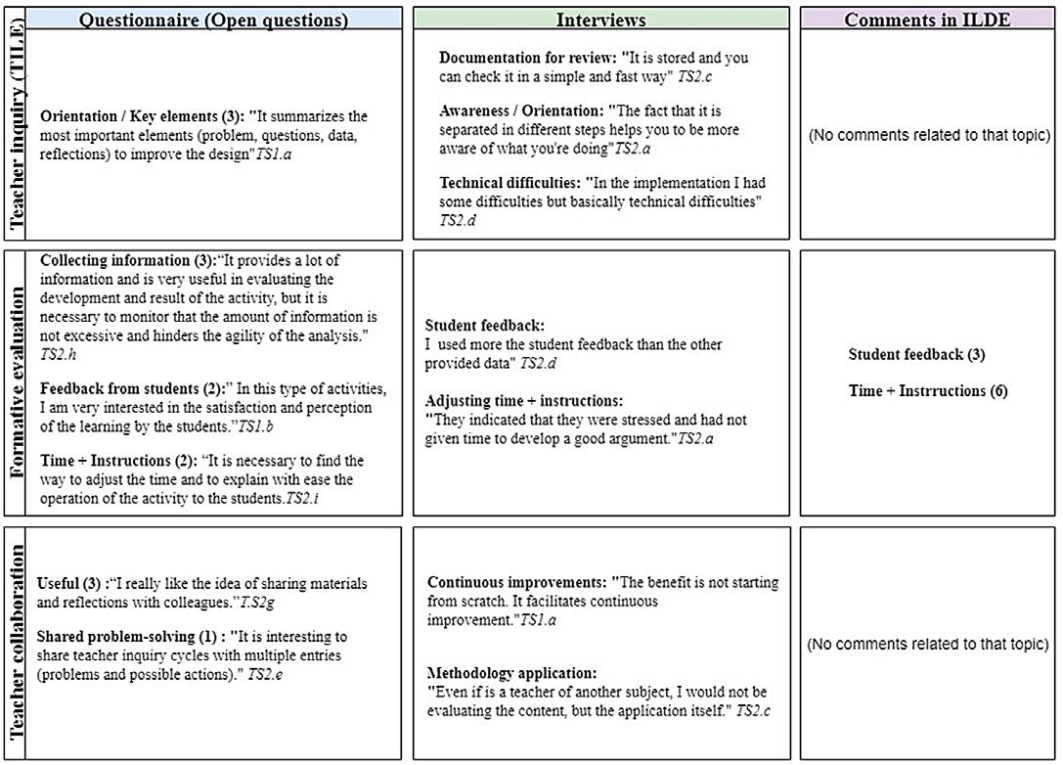

Figure 9: Main topics and samples of data referring to teachers' involvement in inquiry cycles with technology in School 2. Topics were classified into teacher inquiry, formative evaluation and teacher collaboration based on a questionnaire, teacher interviews and comments in ILDE [Colour figure can be viewed at wileyonlinelibrary.com]

Formative evaluation). Moreover, they highlighted the need to improve guidance and instructions and the monitoring of the collaborative process (see Table A6).

Regarding the teacher inquiry cycle with the TILE tool, all three interviewees agreed that it helped them visualize the different steps before and after the implementation of the learning design. Two teachers mentioned that it provided them with a complete picture of their learning design implementation and helped to focus on inquiry steps (eg, problem, reflection) which usually they perform informally (See Table A7, TS2.a). Three more teachers confirmed through the questionnaire that the inquiry cycle provides orientation for key elements in the design process. Reported obstacles to perform inquiries about the classroom activities included the difficulty and time needed to collect and analyze data. TS2.a explained that formulating questions about the monitoring of the design before the implementation helped to overcome this barrier. TS2.d explained that the amount of content in theoretical courses hinders the opportunities for innovations and they had encountered some difficulties in familiarizing themselves with the different tools. Lastly, TS2.a and TS2.c claimed that it is difficult to follow the complete inquiry cycle in everyday activities due to time constraints.

Regarding formative evaluation, three teachers highlighted with comments in ILDE the importance of student feedback after the task. Teachers´ time considerations and instructions for students were the predominant reflections on the provided data for the improvement of their designs. Teachers' interviews revealed that student data were valuable but feedback gained through

Google Forms and rubrics were easier to interpret in relation to learning design improvements. For example, student timing problems reported in their feedback led to adjustments in time duration in the subsequent activity (TS2.a).

Regarding teacher collaboration, three teachers pointed out that limited means were previously available to discuss learning design methodologies and students´ responses to them. For those teachers who did not have colleagues teaching the same subject, spaces for joint reflection were especially valuable (TS2.d). One Biology teacher specified that sharing will be more meaningful if the group of teachers implements more learning activities whose designs are carefully prepared. They all agreed (9) that sharing documented inquiries and student data helps to review teachers' questions while designing, to empathize on others' problems, to identify others´ intervention proposals, and learn about how real classroom applications have been perceived by students.

Cross-case analysis and discussion

In this paper we focused on teachers as designers of TEL interventions and considered the current practice of teachers in schools: a practice that is usually constrained by the school timetable and high amount of teaching content. We conducted an exploratory analysis of the design of teacher learning activities and how teachers reflect on these activities using student data. We analyzed both the perceptions of teachers and their produced artifacts during the activities of a PD program. Observations of the *current teacher practices* in the two schools suggest that while teachers devote time to prepare their classroom activities, their documentation is not a common practice. This is also the case in everyday formative evaluations which usually happen with informal teacher reflections and discussions with students. Documentation is limited to informal notes or quarterly student feedback questionnaires. The digitalization of resources provided opportunities for dissemination and later their re-use. This embedded day to day documentation practice was common in both Schools but differed in the materials and supporting tools (subject websites and LMS were used more often in School 1, Google Forms for student feedback were used frequently in School 2). Teacher collaborations on learning designs rarely occurred, and only between pairs of teachers from the same subjects. Essentially, teachers informally shared their ideas and experiences in school meetings. The appearance or absence of collaborations differed in the schools according to the number of same-subject teachers.

Regarding the *teacher support for data-informed reflections*, the proposed teacher inquiry process supported by the TILE tool suggests that both opportunities and challenges exist. Awareness of the different inquiry steps facilitated by the tool helped to balance the focus of teachers´ design activity before, during and after the enactment. This had previously been devoted to the design phase or the enactment phase. The content of the inquiries and teacher reflections differed between the two schools. In School 1 teachers focused on the subject content of the intervention and highlighted student misunderstandings after the activity implementation based on the available data. In School 2, teachers problematized their designs based on students´ individual and collaborative skills and reflected more on students' opinions about the learning activities. This shows that in these cases the initial design stage of the inquiry was connected with the upcoming reflection and re-design and was further informed by teacher beliefs and availability of data, as shown in their initial perceptions about their current practice and later the emerging teacher inquiry process. This shows that teacher inquiry and reflection is informed by teacher cognition, beliefs and school culture (Alhadad & Thompson, 2017). This further shows that reflection on design is a problem-solving metacognitive process (planning, reviewing and evaluating) which comprises beliefs, awareness and scaffolding inquiry (Marcos et al., 2009; Schmitz et al., 2017).

The documentation and sharing of teachers' inquiries made it feasible to receive feedback from a group of teachers and enrich reflections on the interpretation of student generated data. However, the importance of simplifying the process of collecting data related to learning design improvements was highlighted by teachers in both Schools. For example, in the case of collaborative learning guidance, instructions for on-task discussions, timing of different phases, group roles re-distribution, can be informed from student generated data. This informs research about teacher reflection-on-action which distinguishes the teacher knowledge and experience gained through practice (Hébert, 2015). A few problems with the various tools used suggests that further scaffolds are needed during the different phases of use of the teacher inquiry tool (eg, problem formulation, better awareness of the affordances of each tool with user guides, examples of student data interpretations). This further informs the development of tools for reflecting on everyday evidence with collaborative approaches for professional development (eg, between teachers or teachers–students) (Prieto, Magnuson, Dillenbourg, & Sarr, 2017).

Teacher involvement in technology-supported inquiry cycles shows that the usual informal reflection of teachers became more formal, visible and shareable. They reflected on a classroom activity realization towards a design problem and this could enrich their reflection for longer design cycles (eg, per unit). Their individual inquiry was shared within their school community and informed learning design realizations by other teachers. In school 1, more teachers, compared to School 2, reported that the different subjects, contextual issues and differences in students' cohorts hindered completely shared reflections on learning design realizations. However, in school 2 the involved teachers highlighted that the applicability of a particular CL method (such the Pyramid pattern) across different subjects and students can be a boundary object for shared multi-subject reflections.

Teachers reported individually and in groups in their inquiries various enactment problems they should consider in future learning (re)designs (eg, understanding of the activity by students, limited participation in individual activities affecting the group activities, time management). The identified problems were connected with the pedagogical intentions and elements considered in their learning design and the objectives of their inquiries. They were grounded in the collected data reflecting students´ behavior during the activities (analytics of PyramidApp use) or obtained through systematic student feedback (methodically collected just after the activity implementation rather than through an informal discussion with students). This answers our main RQ as it shows the value of linking learning design with learning analytics through teacher-led inquiry in a way that embeds design and reflection in day-to-day practice for generating and exchanging tacit teacher knowledge within their communities. However, the lack of time hindered the implementation of frequent teacher inquiries and the documentation of classroom activities. This is aligned with existing literature reporting that the role of teachers as designers is guided by issues of practicality and time (Matuk, Linn, & Eylon, 2015).

Conclusions

This paper aimed to investigate the current and emergent teacher inquiry practice supported with technology and linking learning design with learning analytics in the context of schools. The above findings contribute both to research and practice of teacher individual and collective reflection about the designs they propose for their students to learn. Barriers identified were time constraints, the need for guidance about data collection and technologically-structured scaffolds. This aligns with previous evidence in related work (Avramides et al., 2015; Butler & Schnellert, 2012).

Our findings also show that technology-supported guidance through the teacher-led inquiry steps, the explicit formulation of inquiry questions and the pedagogical intentions in a learning design, and the availability of aligned learning analytics visualizations can help overcome such barriers. An approach that appears to be especially interesting is the implementation of shared inquiries in the context of a school community, where several teachers design, implement, evaluate and re-design a selection of innovative TEL activities. Depending on the school culture and needs, common aspects for meaningful collective inquiries can be focused on elements of pedagogical methods, particularities in subject matter or in student cohorts. This approach should consider that teachers need dedicated time and may require additional training support regarding the technologies involved in the innovative TEL activity and in the meaningful collection and interpretation of student data.

This study is restricted to the specific school cases and sample of teachers. Moreover, the participation of teachers in the professional development program and the proposed professional activities restrict the generalizability of the above findings. Further research needs to consider other school contexts and diverse types of learning activities, technologies and data sources supporting reflection and learning re-design informed by learning analytics.

Statements on open data, ethics and conflict of interest

The ethics procedure was approved by the ethics committee of Universitat Pompeu Fabra Barcelona. Consent was obtained from participants. An anonymized example of an inquiry process, results from data analysis and data excerpts are available in Zenodo. The TILE tool is open source at https://github.com/TIDEUPF/TILE. There are no potential conflicts of interest in the work.

Acknowledgements

The authors would like to thank all teachers who participated in the study, as well as the researchers Judit Martínez and Marc Beardsley. This work has been partially funded by RecerCaixa (CoT project) and the Spanish Ministry of Economy and Competitiveness under MDM-2015-0502, TIN2014-53199-C3-3-R and TIN2017-85179-C3-3-R.

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Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Figure A1: Example of collected data in inquiry cycle (TILE): a) Engagement analytics during the collaborative activity; b) Content of student answers and discussions in the collaborative activity; c) Student feedback.

Table A1: Questionnaire about the current teacher inquiry practice in the two schools (N=33).

Table A2: Sample of Interview questions about the teacher inquiry process (N=7).

Table A3: Phase 1: Teachers' demographics in the two schools.

Table A4: Phase 2: Sample of classroom implementations and teacher inquiry cycles in the two schools.

Table A5: Main topics of teacher group reflections and excerpts of their comments in School 1.

Table A6: Main topics of teacher group reflections and excerpts of comments in School 2.

Table A7: Excerpts from teacher interviews in the two Schools.

3.2 Connecting pattern-based learning designs with analytics: The case of the PyramidApp

The content of this Section was presented at the International Workshop on Connecting Learning Analytics and Learning Design (CLAD 2016) collocated with the ECTEL 2016 Conference and is published in the online repository of UPF:

Michos, K., Manathunga, K., Hernández-Leo, D. (2016). Connecting pattern-based learning designs with analytics: The case of the PyramidApp. In *the Workshop on Connecting Learning Analytics and Learning Design (CLAD 2016) at The Eleventh European Conference on Technology Enhanced Learning (EC-TEL 2016)*, Lyon, France, September 13-16
https://repositori.upf.edu/handle/10230/32136

Connecting pattern-based learning designs with analytics: The case of the PyramidApp

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Abstract. This paper presents preliminary work aiming to identify learning analytics that can be presented to teachers or learning designers to support (re)use or (re)design of learning scenarios based on the pyramid (a.k.a. snowball) pattern by using the PyramidApp. A pattern-based analytics approach considers teacher´s metacognition in three levels, t*he pedagogical intent, pedagogical method/structure* of a CLFP pattern and the *practicalities* to implement a learning scenario. Learning analytics are proposed to inform these three dimensions. A case scenario where *N = 38* secondary school students in a face to face classroom used the PyramidApp was analyzed from the log files of the App. The recommended analytics for teachers are visualized in such a way that are hypothesized to foster decision making for customization of specific design elements of the pyramid pattern.

Keywords: Learning Design, learning analytics, teacher´s metacognition

1. Introduction

Current research on the design of computer mediated learning and monitoring of students´ interactions in a learning environment proposes the presentation of information to teachers with the aim to support customization of their initial plans as the learning scenario unfolds (Rodríguez-Triana et al., 2015). The adaptation of their learning scenarios can be referred to decisions made at design time (Lockyer, Heathcote, & Dawson, 2013) and possible revisions. These decisions usually are triggered by the pedagogical intentions of the teacher which can be documented in a learning design, the specific context of the students (e.g., educational level, knowledge level) and concerns on practicalities such as classroom constraints and amount of students (Mor, Craft, Hernández-Leo, 2013).

Particularly, in Computer Supported Collaborative Learning where the complexity of student's interactions increases specific focus is given on the design of effective collaborative scenarios (e.g., design of scripts) (Dillenbourg & Tchounikine, 2007; Hernández-Leo et al., 2006; Kobbe et al., 2007; Weinberger et al., 2009) and on data-driven reflections on these situation (Martínez-Monés et al., 2011; Rodríguez-Triana et al., 2015). Although the emphasis is to improve student's learning, the increasing use of technology implies the work of teachers as designers of technology enhanced learning (Kali et al., 2015, Laurillard, D. 2012). The use of evidence to reflect on and customize instructional plans and learning activities (Gerard et al., 2010) is currently being discussed. On the one hand, pedagogical patterns as scaffolds for teachers and learning designers consist of teaching-learning activity sequences which are designed to lead in a specific learning outcome and describe a pattern in terms of “context”, “educational problem” and “solution” (Goodyear, 2005). On the other hand, data-driven reflections address the need to intervene during an implemented learning scenario (regulation) or to improve future learning designs (redesign). However little research so far addresses the support of teachers on how to link pedagogical decisions and reflection with data collected from technological tools. Few practical examples regarding the design of computer supported collaborative learning activities show the connection between the learning design of the teacher and the collection of learning analytics which can help potential re-use or re-design of an implemented learning scenario.

In this paper, we aim to connect the design of a collaborative learning scenario with the collection of learning analytics data by using Collaborative Learning Flow Patterns (Hernández-Leo et al., 2006; Hernández-Leo et al., 2010) as a boundary object. We focus in a particular example of the pyramid (a.k.a. snowball) pattern and the use of an innovative tool called PyramidApp (Manathunga & Hernández-Leo, 2016). PyramidApp enables configuration and enactment of collaborative learning activities based on a pyramid pattern. The design of activities with the PyramidApp allows teachers to structure potential interactions growing from smaller to larger groups until building

consensus in a specific topic by fostering accountability and interdependence between students. Instead of focusing on events happening during the learning scenario and possible real-time interventions/regulation by teachers we address the issue of teachers reflection on past pyramid implementations and cohorts in view of redesign purposes. By providing visual analytics, the teacher might consider possible revisions and different configurations or can inform other teacher´s how to design a pyramid learning scenario.

Our research question tackled in this paper is the following:

RQ: Which learning analytics derived from the use of the PyramidApp can help designers in reflecting about re-use and re-configurations of pyramid activities in different contexts?

The paper is organized as follows: Section 2 describes the connection between learning design, teacher´s metacognition and learning analytics. Section 3 refers to pattern-based analytics in the Pyramid pattern while Section 4 their application in the PyramidApp through a case scenario. Sections 5 and 6 are devoted to the presentation of learning analytics for teacher´s reflection followed by discussion and conclusions.

2. Supporting metacognitive knowledge of learning designs with learning analytics

The field of Learning Design or "design for learning" has currently emerged as means to facilitate educational practitioners towards sharing, modification and reuse of their pedagogical plans (Persico & Pozzi, 2015). It studies the art and science of designing meaningful and effective scenarios for learning and proposes tools to support the design process by enabling their explicit representation in sharable formats (Mor, Craft & Hernández-Leo, 2013; Lockyer et al., 2009). One of the underlying principles supported by researchers in this field is the implementation of active learning approaches in the design of learning environments. In this direction, Collaborative Learning Flow Patterns (Hernández-Leo et al., 2006; Hernández-Leo et al., 2010) describe well-known collaborative techniques such as Jigsaw pattern or Pyramid pattern which can be used, revised and shared by teachers as scaffolds for the design and instantiations of collaborative learning activities. Although the design and decisions made by teachers can be documented, the teacher might not have a specific picture on what happened during the deployment of the activity with a specific technological tool. Metacognitive knowledge of teachers was introduced as support for the reflection on and adaptation of their learning scenarios and as a way to unveil hidden features during their implementations (Lin, Schwartz., & Hatano, 2005; Porayska-Pomsta, 2016). *Metacognitive knowledge* in this context can describe teacher´s beliefs towards the efficacy and facility of applications of various collaborative techniques. It consists of *declarative* (what are the available strategies and their intentions), *procedural* knowledge (knowledge of how to do the things) and *conditional* knowledge ("why" and "when" to apply each strategy) (Metallidou 2009; Schraw, 1998). Little research so far focuses on teacher's metacognition after enacting a learning scenario with students (Porayska-Pomsta, 2016). The connection of teacher's metacognition with the use of learning analytics data for reflection is being described in this paper.

Several authors proposed that the process of Learning Design, except of pedagogical grounding can also be informed by the collection of learning analytics data which show how students experienced a learning design (Lockyer et al., 2013; Melero et al., 2015; Mor, Ferguson, & Wasson, 2015; Persico & Pozzi, 2015; Rodríguez- Triana et al., 2015). Learning analytics has been defined as "the measurement, collection, analysis, and reporting of data about learners and their contexts, for purposes of understanding and optimising learning and the environments in which it occurs" (Ferguson, 2012, p. 2). It is useful to differentiate between the purpose, the target groups and the time that this data is presented. For instance, learning analytics can be used for self-regulation of students, for the regulation of the learning scenario by the teacher and may be presented during the learning process or after learning sessions (Duval, 2011; Wise, 2014). The current problem is that often teacher's needs for designing learning activities do not align with information provided by learning analytics tools. Relevant research in collaborative

learning proposes the alignment of scripting methods with monitoring support (Rodríguez-Triana et al., 2015) for improving the management of learning activities by teacher´s as the learning scenario evolves. Constraints of CLFPs were used as mediators to collect behavioral data of student's actions (e.g. edits, uploads, access to resources, attendance) and to compare it with the desired state of a learning scenario. Pattern-based analytics and feedback to the teachers concerning missing monitoring data was identified as useful to better orchestrate student's activities as the learning scenario evolved. However, little is known for the types of data that teachers might need after the implementation of the learning scenario for being able to re-use or re-design it in different contexts. Lockyer, Heathcote, & Dawson (2013) describe that during the process of designing new activities or a course, teachers often recall past experiences with students. At design time, data-informed decisions regarding past implementations may facilitate the re-design or re-use of learning activities with different students. However, there is a lack of profound understanding around which learning analytics data can be especially useful for this purpose.

In this paper, we aim to tackle this issue by providing a practical example with a specific tool. We focus on the design and deployment of collaborative learning activities based on the Pyramid pattern with the use of an innovative tool called PyramidApp.

3. From Pyramid based-designs to Pyramid-based analytics

Our approach to connect the collection of data in a specific tool with the pedagogical intentions of a learning design can be described as pattern-based analytics. This approach was already applied by Rodríguez-Triana et al. (2015) to support regulation of learning scenarios as they unfold. However, our purpose is different as we aim to support reuse and redesign of the learning scenarios once they have been implemented. To study this problem we focus on the metacognitive process of teachers concerning two aspects of the Pyramid pattern: the *pedagogical intent* (declarative) and the *pedagogical method/structure* (procedural), as well as on one aspect relevant with its particularization and the *practicalities* (conditional) to instantiate the learning scenario.

As *pedagogical intent* we refer to the rationale of this pattern (Gibbs, 1992; Hernández-Leo et al., 2010) which can be described as reach consensus in a specific topic, promote active participation from all the students. promote the feeling that each participant's opinion counts in order to succeed and positive interdependence between students, foster discussions in order to solve a problem and enhance negotiation skills.

To achieve that, teachers or learning designers will design specific activities while particularizing the Pyramid. Reflection on the pedagogical intent can refer to the desired state of students behavior which can be later compared with the final state of students behavior (Dimitrakopoulou et al., 2006; Soller et al., 2005;). Aggregated data of the overall activity can inform teachers for this reflection. Questions regarding *the pedagogical intent* can define possible data collection of the overall activity as the following: Did the students actively participate? How the discussions of the students were and what did they discuss? Data collection relevant to answer these questions could include amount of interactions, comparisons between groups, content of the discussions for their analysis or summarization.

As *pedagogical method/structure* we refer to the flow of the activities in the different phases of the pattern. The Pyramid pattern proposes a sequence of learning activities for a context in which several participants aim to solve the same complex problem or task. To achieve that, students are studying initially the problem individually or in small groups and propose a solution. Then, they formulate larger groups to compare and discuss their proposals and finally propose a new shared solution. This process is repeated until all the students conclude with a final agreed solution.

Questions regarding the *pedagogical method/structure* can be the following: How was the progress of the students from level to level? Which solutions were proposed from level to level? Data collection in this case should show light about to what extent students follow the specific phases proposed by the pattern (e.g., students actually participate in tasks proposed for each level). Data can also include students solutions (artifacts) developed per level.

As *practicalities* we refer to the specific context in which the learning scenario was instantiated. Analytics about the contexts and relevant constraints derived from it can be useful to interpret analytics answering the previous aspects and also support reuse and redesign reflection processes. Relevant aspects in this category include the scale in terms of amount of students that the activity was able to attend and the time used to carry out the activity.

Questions regarding *practicalities* can be the following: How long did the activity and each phase of the scenario last? Data may include the time of the overall activity as well as the time per each phase of the pattern.

4. Case scenario: the PyramidApp

In this section, we describe how our approach for pattern-based analytics can be applied on the Pyramid pattern with the use of an authoring and deployment tool called PyramidApp (Manathunga & Hernández-Leo, 2016). PyramidApp enables the design of scalable and flexible collaborative learning activities inspired by Pyramid flow pattern, where students may join or leave the activity without interrupting the on-going flow, accomplishing a fruitful collaborative activity. In the individual phase, participants propose their solutions for a given task (e.g., an answer or a question for the task). Starting from smaller groups, growing to larger groups in a repeated process of discussions and peer ratings, they reach a common consensus at the last level as a collective effort where they conclude with one option. Figure 1 shows a sample screen of rating and discussion in an intermediary phase of such pyramid activity designed using PyramidApp.

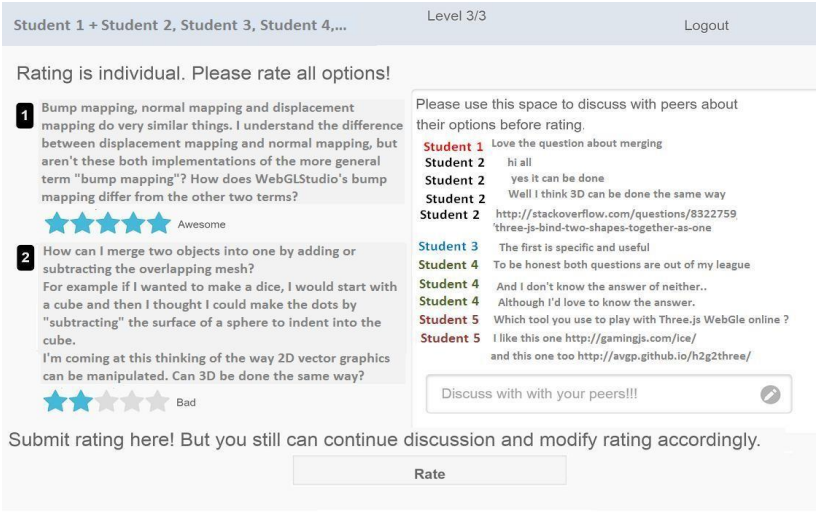

Figure 1. Rating and discussions in the PyramidApp of the student view

Although the design of the learning scenario and specific configurations can be planned in advance, students may experience the activity in different levels. Currently, teacher's configurations in the PyramidApp include design of the task, number of levels in the Pyramid, number of students per pyramid in order to facilitate multiple pyramid

creation (to promote flexible and smaller groups) and the duration of specific sub-phases of the activity (ratings, submission of the task). Diverse data elements are collected from the application such as rating values, messages per student, time duration of each event and number of participated students among others (see table 1).

Table 1. Metacognitive dimensions, teacher's configurations and types of analysis.

Dimensions	**Configurations**	**Unit of analysis**	**Data**
Pedagogical intent	Design of the task	Participation, Consensus building, Negotiations, Content	Messages, Ratings
Pedagogical method/structure	Number of levels	Overall activity, Levels of the pyramid	Messages, Ratings
	Number of pyramids	Overall activity, Levels of the pyramids	Messages, Ratings,
	Students per group in the second level	Students per level	No of students
Practicalities	Submission time	Overall duration and per level	Time

The three metacognitive dimensions which we propose for reuse and redesign reflection can be aligned with design configurations in the tool and the collection of learning analytics data relevant with these decisions. A log file analysis might provide useful information on how these decisions can be refined based on the *pedagogical intent, the pedagogical method/structure* and *the practicalities* (see table 1).

A case scenario of a total of $N = 38$ students in a secondary school was analyzed to test our pattern-based analytics approach. The students used the Pyramid App in classroom and their main task was to propose an interesting outdoor activity to their teacher. Students were encouraged to discuss the different options in groups and after negotiations and peer rating to conclude in one proposal. An individual researcher acted as the learning designer of this task and configured the learning scenario in the Pyramid App. The evaluation study was initially planned to test other aspects of the App such as scalability, flexibility and usability and thus the design of the activity as well as the epistemic task was used as testing prototypes (Manathunga & Hernández-Leo, 2016). Log file analysis in this study aimed to identify potential analytics that might be useful for teachers to reflect on the enacted scenarios based on the three metacognitive dimensions. In table 1 we define the data collection process by considering teacher's feedback for the pedagogical intent and the practicalities and propose their form according to the pedagogical method/structure.

5. Visualizations for the case scenario and discussion

Once the teacher designs the activity using PyramidApp, the tool visualizes a summary of the final learning design which is documented and saved for later retrieval. However, to reflect on questions regarding the *pedagogical intent* (participation, active discussions, consensus building) he/she may needs to know the overall levels of participation, content of the discourse and peer interactions after the activity. In our case, data for this purpose includes the messages and the peer ratings. Figure 2 shows visualizations providing feedback to the teacher on the levels of students´ participation by considering the overall learning activity and the structure of the learning design in the PyramidApp. The left graph shows the overall level of messages in the activity (green color) and messages per sub-

pyramids (red, blue color) in each level (Level 1,2,3). Graph on the right shows levels of students' participation in each sub-pyramid.

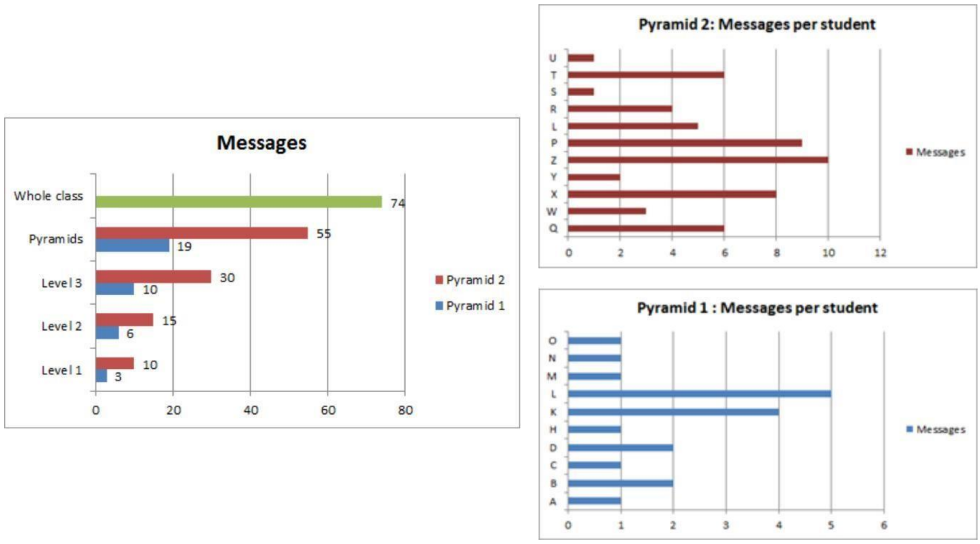

Figure 2. Levels of participation (messages) in the case scenario. Reflection on the *pedagogical intent*

Number of messages exchanged generally relates to the given epistemic task at any context. In this case scenario, the proposed epistemic task resulted with 74 messages from 38 participants implying a message frequency that can be interpreted as dissatisfying. Hence, a revised version of such pyramid activity could be driven by a different (redesigned) epistemic task requiring more active participation and peer interactions. In terms of the structure, we could see an increment of messages posting when groups grow larger. If the pyramid structure is designed to accommodate all 38 students into one pyramid, may be the number of messages can have an effect. However, sub-pyramids showed different participation levels. If revisions can be done to consider mechanisms like active and inactive participation when structuring pyramids, the pedagogical intent of implanting fruitful collaborations can be ensured.

To provide relevant information for the content of the messages as students´ messages might differ (length, content) we propose a summary of the discourse through the open source web-based application voyant-tools[1]. Teachers can paste the text of their students and perform basic text-mining functions (clouds, frequency of words) which show characteristics and different themes of the corpus. Figure 3 shows visualization of student's messages in the case scenario with the voyant tools.

[1] http://voyant-tools.org/

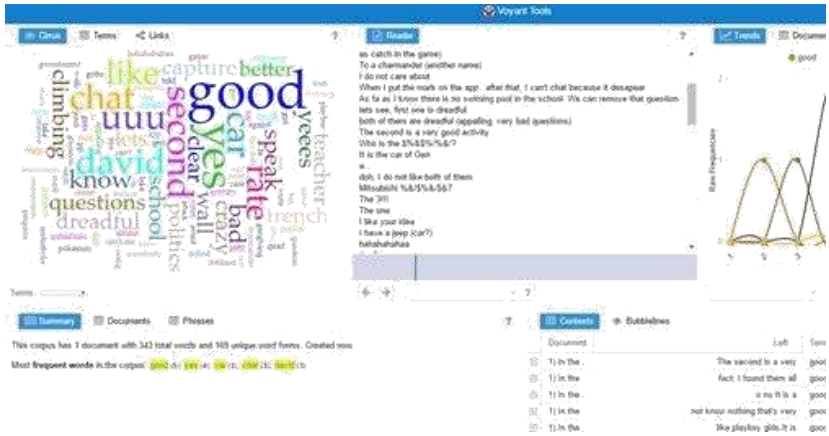

Figure 3. Summary of the discourse in the case scenario. Reflection on the *pedagogical intent*.

Summary of the discourse and topic identification may help teachers to better understand students´ engagement in the task. For instance, if the discussions were related with the learning task. Since in the case scenario, the largest part of the discourse was irrelevant future refinements may require additional scaffolds which foster more meaningful discussions.

By considering again the rationale of the Pyramid pattern and the *pedagogical intent,* the teacher might need to know how the students interacted until building consensus on that topic. In the PyramidApp, the ratings values can inform the levels of disagreement in each group regarding the different students' options. We identified this indicator as relevant to inform teachers for the learning process in the pyramid. The average level of disagreements is visualized in Figure 4 with the aim to provide feedback to the teacher on the disagreement levels based on the ratings. However, content analysis of the messages can provide additional insights for the topics of disagreement. Disagreements levels are calculated with the standard deviation of the ratings for each group. Then the mean value from all the groups is showing the disagreements of each level. Higher values show higher disagreement.

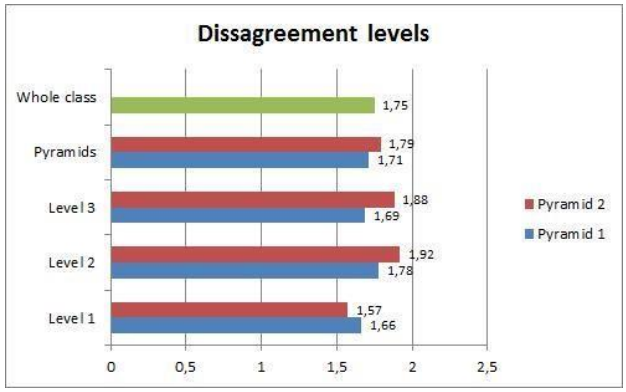

Figure 4. Disagreement levels in the case scenario. Reflection on the *pedagogical intent*

In both sub-pyramids we could identify that in the first level students disagreed less possibly because smaller groups were formed, in the second level more (larger groups) and in the final level their disagreement decreased. This can be a coincidence following the structural behaviour of a pyramid. Hence, when redesigning is considered, if the intention is to generate more debate and discussions, number of levels of the pyramid should be considered and also

the epistemic task should incorporate it. However, analysis of the content of the messages can show how students disagreed. A future revision of a pyramid activity might consider the types of debates that want to achieve and then reflect on this issue.

During the application of the *pedagogical method/structure* the teacher and the students need to follow specific steps in order to achieve the intended outcomes. Reflection on these issues may include the number of students that participate in each phase (see Figure 5).

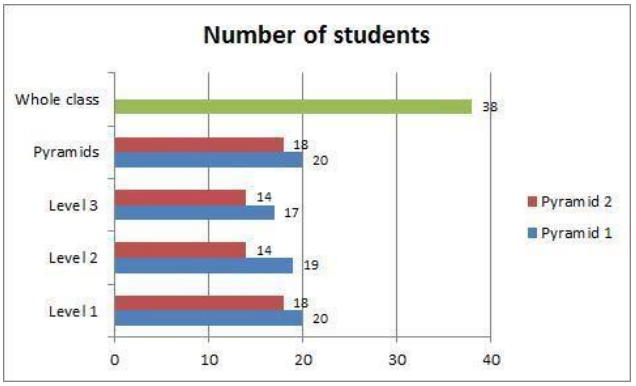

Figure 5. Number of participated students in the collaborative phases of the pyramid. Reflection on the *pedagogical method/structure.*

The number of participated students decreased from level to level in each sub-pyramid of the activity. One possible revision could be warnings and detailed instructions in order to ensure that each participant contributes to the final agreement. Last, regarding feedback about *practicalitie*s, the teacher might need to know the duration of the activity and relevance with the specific structure. Figure 6 proposes feedback to the teacher for the overall duration per level and per sub-pyramid.

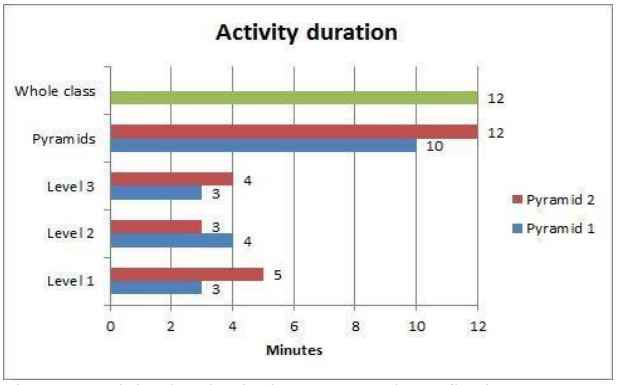

Figure 6. Activity duration in the case scenario. Reflection on *practicalities*

The overall activity lasted 12 minutes. This happened due to teacher´s configuration of the submissions timeout and the time that students used to discuss and rate. According to the available time in a classroom scenario, a teacher can re-design the activity to last more or less minutes. Feedback for the specific structure (per levels) can be interpreted according to teacher´s configurations and thus similar configurations can be used to achieve these results.

Data collected in the three dimensions can be part of the design process as they relate with teacher´s needs to design a pyramid activity. For instance the individual teacher might consider implementing another collaborative activity in the classroom. After knowing that this activity lasted 12 minutes similar time configurations would be recommended for achieving the same result. Moreover, after considering that in this task students showed low levels of engagement and the content of the messages was dissatisfying a further refinement may needs more explanations and scaffolds for the students.

6. Conclusion

In this paper we have presented preliminary work aimed to link teacher's decisions to design a learning scenario with the collection of learning analytics data in a specific tool called PyramidApp. Our approach was based on the Collaborative Learning Flow Patterns as a boundary object between the learning design of the teacher and collection of learning analytics data in different contexts. To support re-use and re-design of implemented pattern-based activities we consider teacher´s metacognition in three levels: *pedagogical intent, pedagogical method/structure* and *practicalities.* The aim was to foster teacher´s reflection towards the efficacy and application of different pyramid pattern-based activities.

PyramidApp helped to formulate the collaborative activity design considering the three dimensions of teacher's thinking; declarative, procedural and conditional. As declarative we considered the support for the pedagogical rationale of the pyramid pattern through the tool and as procedural we considered which structure or pedagogical method being followed in the tool (in the case of PyramidApp we have used consensus reaching based on rating augmented via peer discussions). As conditional we considered the practicalities to enact the learning scenario (timing) in a classroom context. We proposed learning analytics data which can inform these three dimensions and help teachers to reflect on their decisions and configurations.

The documentation of the implemented scenarios together with the proposed learning analytics may help teachers or learning designers to customize specific elements of the pyramid pattern (number of levels, pyramid structure- having multiple pyramids or not- details, additional scaffolds) according to the intended outcomes. Moreover, teachers after reflecting on practical constraints such as available time of the learning environment may save costs and time for their re-implementations of a learning scenario. All in all, this supports improvement in the teaching practice in a more systematic, effective and efficient manner. This, information can also be a starting point and analysis framework for designers who want to re-use a similar activity in a different context.

We are currently presenting the learning analytics to teachers to study the extent to which the visualizations and analysis are meaningful to support reuse and redesign thinking processes. Future work also includes exploration of how this approach can be applied to other CLFP such as the Jigsaw pattern according to its specific rationale and structure. Our method described the steps that a learning designer may follow from the explicit representation of the design, to possible questions for reflection on the design decisions and the definition of data collection for this purpose. Moreover, this process can inform the gathering of data in other enactment platforms (e.g., Moodle) supporting the implementation of CLFP-based scenarios.

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CHAPTER 4

A COLLECTIVE INQUIRY FRAMEWORK FOR TEACHERS AS DESIGNERS

Chapter 4 is dedicated to the third objective of this dissertation and presents the 3rd Cycle of the overall DBR methodology followed during this thesis work. In this cycle, we reflect on results obtained from Cycle 1 and Cycle 2 and conceptualize a collective inquiry framework (CIDA) for teachers as designers when they utilize data analytics. We conducted a literature review in collective inquiry frameworks for knowledge building with a focus on frameworks that show the meaningful use of ICT. The articulation of the CIDA framework provides conceptual and technological support and aims to inform researchers, system developers, and teachers to study and support participatory practices of teachers as designers in technological environments. To validate and enhance the implementation of the framework, we provide results from three case studies (a MOOC for learning design and two school communities). We used a mixed-method approach and triangulated qualitative and quantitative data to evaluate teachers´ perceptions and practices about collective inquiry with data analytics. A cross case-analysis between the three cases proposes that data analytics support can influence the collective online participation of teachers, their individual and collective reflections. Additionally, teachers showed evidence of pedagogical knowledge activation in individual and collective reflections. Based on the framework we developed examples of technologies to support the collective and inquiry process of teachers as designers with data analytics. These technologies are presented in Appendix A1. Figure 8 presents the 3rd DBR cycle and main contribution presented in Chapter 4. The content of this chapter is based on an article submitted in a JCR peer-reviewed journal and is currently under review.

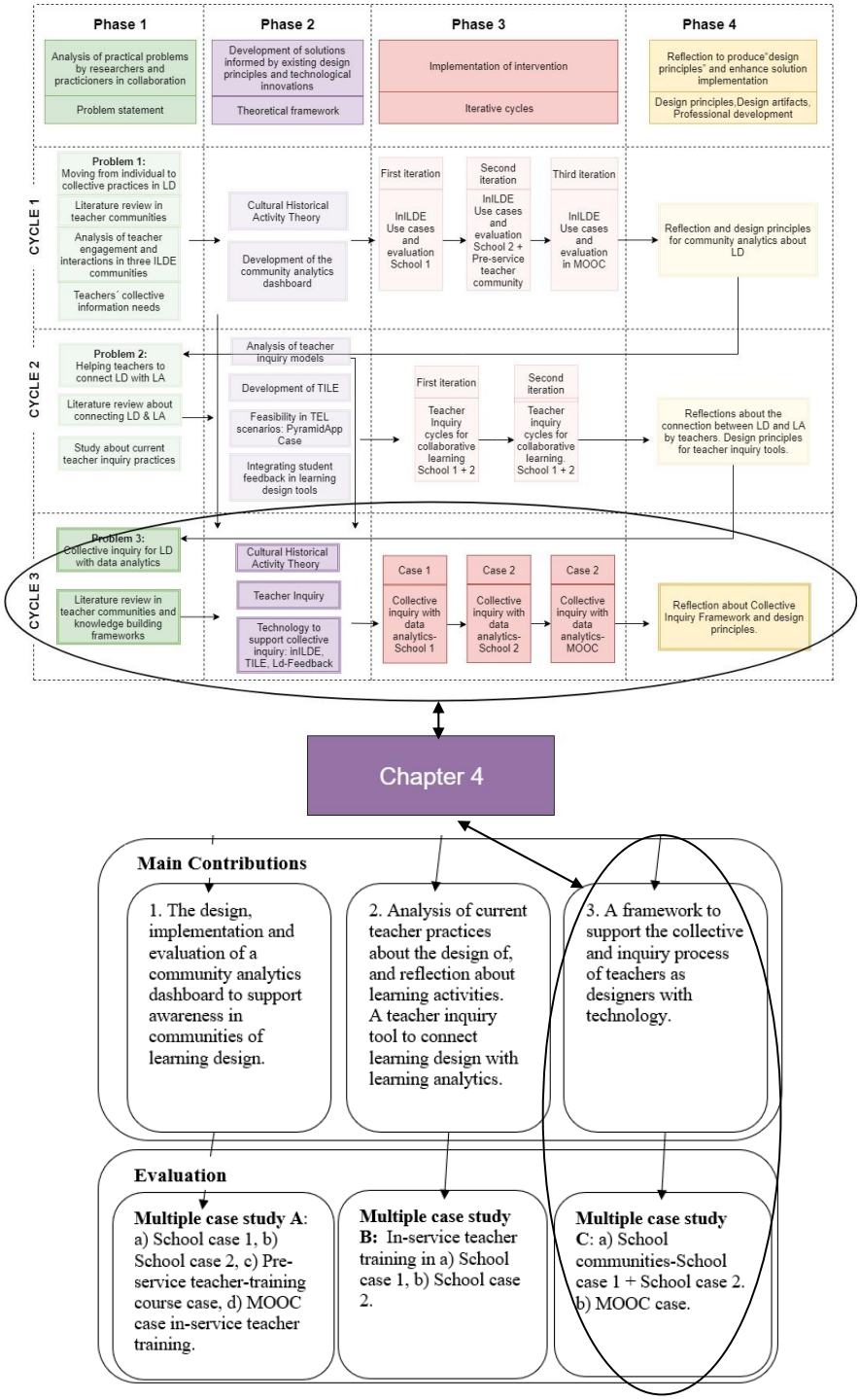

Figure 8. DBR cycle and main contribution presented in Chapter 4

4.1 Studying and supporting teachers as designers in data-intensive inquiry communities: a framework, technology, and case studies

The content of this Section was submitted to a JCR peer-reviewed journal and is under review:

> Michos, K., & Hernández-Leo, D. Studying and supporting teachers as designers in data-intensive inquiry communities: a framework, technology, and case studies (*Submitted to Journal*).

Studying and supporting teachers as designers in data-intensive inquiry communities: a framework, technology, and case studies

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Abstract. The use of new technologies such as learning analytics by teachers is challenging due to the changes they bring to teachers' practices and their pedagogical interventions. A design approach into teaching has been proposed for mapping pedagogy with technology to effectively integrate these changes. However, limited collective approaches exist in which teachers participate in professional communities to build knowledge for the design and implementation of learning scenarios with learning analytics. In this paper, we propose a framework (CIDA) for collective inquiry in such professional communities of teachers. Based on other collective inquiry frameworks for knowledge building, we propose three interconnected components: the *inquiry process,* the *collective process,* and *technological support* to facilitate and study teachers´ design practices in technological environments. We explain the framework with examples of implemented technologies and present empirical results of three cases; two High schools and a Massive Open Online Course (MOOC). Results inform further how our framework can be implemented in practice and its required supports to facilitate knowledge building for inquiry communities of teachers.

Keywords: learning communities; lifelong learning; teaching/learning strategies; distributed learning environments; improving classroom teaching

1. Introduction

Teacher involvement in designing technology-integrating activities has emerged as a challenge with the increasing use of ICT in Education. The incorporation of new technologies into teacher practices bring changes to the conceptualization and application of pedagogical interventions. A design approach into teaching has been proposed for mapping technology with pedagogy to effectively integrate these changes (Laurillard, 2013; Goodyear, 2015; Kali, McKenney, & Sagy, 2015; Persico, Pozzi, & Goodyear, 2018). When teachers act as designers of Technology Enhanced Learning (TEL), they engage in reflective, critical and epistemic practices which are beneficial for their life-long learning (Persico, Pozzi, & Goodyear, 2018). This also contributes to technology sustainability (Cober, Tan, Slotta, So, & Könings, 2015) and teachers´ feelings of ownership (Kali, McKenney, & Sagy, 2015). Typically, teachers design processes include redesign of existing activities, collaborative design (e.g., in schools, teacher education programs) and evidence-based adaptations (Kali, McKenney, & Sagy, 2015; Khlaif, Gok, & Kouraïchi, 2019). Such changes in teacher culture, which has been often described as isiolanist, include the development of professional learning communities which encourage sharing, reflection, and deprivatization of teacher practice (Dana & Yendol-Hoppey, 2014). The shifting from individual to collective teacher practices has been recently acknowledged in research for the co-construction of teaching ideas and deliberate reflection on teacher design thinking (Tseng & Kuo, 2014; Hong, Lin, Chai, Hung, & Zhang, 2019).

Teacher data use is a valuable strategy to inform the design decisions and methods for classroom activities (Mandinach, & Jimerson, 2016). Data-intensive methods can benefit teaching and learning when

collaborations are established between researchers and educational practitioners in authentic settings such as schools and universities (Krumm, Means, & Bienkowski, 2018). A growing number of research studies focus on the use of Learning Analytics (LA) for "understanding and optimizing learning and the environments in which it occurs" (Ferguson, 2012). LA can be an empowerment tool for teachers to inquiry into their students´ learning (Mor, Ferguson, & Wasson, 2015). Besides, a connection with the pedagogical design of teachers´ interventions is needed so that LA tools can inform meaningful pedagogical actions and enable teacher inquiry processes (Rienties & Toetenel, 2016; Rodríguez-Triana, Martínez-Monés, Asensio-Pérez, & Dimitriadis, 2015; Alhadad & Thomson, 2017; Percico & Pozzi, 2015).

However, there is still a lack of understanding on how teachers engage in TEL design with the use of LA. Design approaches enable the sharing of teacher ideas and bring opportunities for knowledge exchange in professional teacher communities, but they are still scarce in LA research (Wise, Vytasek, Hausknecht, & Zhao, 2016). Additionally, participatory approaches in learning design by means of learning analytics are also uncommon (Hernández-Leo, Martinez-Maldonado, Pardo, Muñoz-Cristóbal, & Rodríguez-Triana, 2018; Voogt, Laferrière, Breuleux, Itow, Hickey, & McKenney, 2015; McCoy & Shih, 2016; Cober et al., 2015; Van Gasse, Vanlommel, Vanhoof, & Van Petegem, 2017). In this paper, we look into teachers´ practices in authentic settings and argue that a design inquiry approach with the active participation of teachers is relevant for the meaningful use of learning analytics in teaching and learning. Delving into the learning design and teacher inquiry fields we pose the question on how to support collective inquiry for learning design through data analytics in which teachers and learners are the primary agents of innovative and transformative practices.

The field of learning design or "design for learning" studies how teachers prepare and revise a set of learning activities towards achieving particular educational objectives for a given context in pedagogically-informed manners (Dalziel et al., 2016; Mor, Craft, & Hernández-Leo, 2013, Beetham & Sharpe, 2013). The role of teachers as designers implies the effective use of tools and resources which create "the best possible" opportunities for their students to learn (Laurillard, 2012, Kali, McKenney, & Sagy, 2015). Although teachers design practice e.g., preparation for classroom learning activities, is often considered as an individual task of the teacher, the socio-cultural dimension of teachers work in small groups or larger educational communities is still underexplored (Asensio-Pérez et al., 2017, Agostinho, Lockyer, & Bennett, 2018, Michos & Hernández-Leo, 2018, Voogt et al., 2015).

Teachers design and inquiry practice are usually informed by their socio-cultural system and their work environment. This is situated in the context of their educational institution e.g., schools (Butler & Schnellert, 2012), universities (Agostinho, Lockyer, & Bennett, 2018) and their classrooms. Several authors propose collaborative approaches for teachers, especially in Professional Learning Communities (PLCs) (Vescio, Ross, & Adams, 2008). Mor, Ferguson, & Wasson (2015) highlight the need to move from individual to collective practices where multiple inquiries about similar learning designs are aggregated. Moreover, Conole (2010) explains the notion of "openness" in teaching and learning. "Open design" addresses the need to move beyond open educational resources and focus on the explicit representation and sharing of the whole design process. Lastly, "open evaluation" refers to the use of data collected from students to collectively improve the teaching practice. These participatory cultures can be formed within groups of teachers in the same educational institutions and through the collaboration between different institutions (Binkhorst, Handelzalts, Poortman, & van Joolingen, 2015; Hofman & Dijkstra, 2010).

Considering the current focus on design approaches to teaching, collective practices for Teacher Professional Development (TPD) and the use of LA tools, we have identified limited frameworks which can support collective teacher inquiry for building (pedagogical) knowledge for learning design. To address this, we propose a framework for connecting teachers' everyday inquiry with a community of teachers and learners when using data analytics. We show the implementation of the framework in practice and three cases studies of educational communities in authentic settings; two High schools and a professional teacher community in a Massive Open Online Course (MOOC). In all cases, the community members used an online community-oriented platform for learning design named Integrated Learning Design Environment (Hernández-Leo et al., 2018a).

The structure of the papers is as follows: Section 2 describes frameworks for collective inquiry and the use of teaching and learning analytics for teacher inquiry, Section 3 describes our proposed framework while section 4 our methodology. In Section 5, we explain the implementation of our framework and empirical results from the three case studies. Section 6 presents a cross-case analysis of the two cases and in Section 7 we conclude on how our analysis informed the articulation of the framework.

2. Knowledge building through collective inquiry for learning design

2.1 Collective inquiry supported by technologies

The engagement of teachers in goal-directed inquiry into and reflection on practice is a prominent strategy for TPD (Moon, 1999). This creates opportunities for experimentation of new teaching strategies which are situated in everyday classroom and lead to practice development. Collaborative approaches into TPD show that teacher agency can be distributed within a community of teachers to lead to educational change (Butler, Schnellert, & MacNeil, 2015). Different collective inquiry frameworks have been proposed in two similar areas; in workplace informal learning and teacher learning (Littlejohn & Hood, 2017). These frameworks show how individual and collective processes supported by technology can be used for knowledge building in a given domain.

The co-evolution model of individual and collective knowledge (Kimmerle, Cress, & Held, 2010) shows the connection of individuals to the community through knowledge artifacts when using Information and Communication Technologies (ICT) such as wikis. Individuals externalize their knowledge through knowledge artifacts like chat log files, wiki articles or weblog entries and other community members internalize them in a process of collective knowledge. In the workplace context, Littlejohn, Milligan, & Margaryan (2012) explain the interrelation of self-regulated learning and collective knowledge. They propose a model in which individuals consume, connect and contribute to collective knowledge while interacting with Web 2.0 technologies, other people and by using ICT tools to reflect and achieve their own goals. Ley et al (2014) articulate a model for informal workplace learning at scale. Their model includes the individual process to perform and reflect on a workplace task, the social support provided through social networking, the emergence, and generation of collective knowledge. This has been further proposed with the use of technologies which include community, semantic and mobile services.

In the context of teachers, several researchers study online teacher communities as Communities of Practice (CoPs) (Wegner,1998) or Professional Learning Communities (PLCs) (Vescio, Ross, & Adams, 2008). In

CoPs, collective learning processes emerge when members, e.g., teachers, work together in a joint enterprise, use shared knowledge and a shared repertoire (tools, objects, artifacts, rules). Research in PLCs acknowledges that active teachers' participation and collaborative activities have an impact in teaching practice (Berry, Johnson, Montgomery, 2005) and students´ learning (Bolam et al., 2005). Recently, many scholars study knowledge building processes (Scardamalia and Bereiter, 2003) within such professional teacher communities (Popp & Goldman, 2016). Characteristics of knowledge building applied to teacher communities include the *collaborative* community efforts, the *improvable* ideas proposed by members and the added *value* in the community such as authentic practical questions and solutions to problems. Laurillard, Kennedy, Charlton, Wild, & Dimakopoulos (2018) explain the development of a learning design tool for teachers (Learning Designer) which aims to build pedagogical-knowledge building communities where teachers can work as designers by sharing instructional products, their classroom inquiry and build on each other contributions. Such online community spaces for teachers enable the sharing of teaching knowledge and the integration of technological, pedagogical and content knowledge (TPACK) (Koehler, & Mishra, 2009).

Another well-known collective inquiry framework is that of Community of Inquiry (CoI) (Garrison, & Arbaugh, 2007) which has been often applied into student learning, pre-service, and in-service teacher learning (Yang, 2016). The framework shows the interconnection of the social, cognitive and teaching presence to study online communities. The cognitive presence describes learning as a practical inquiry which leads to knowledge construction and problem solution. The social presence shows the interaction between community members to achieve learning outcomes. The teaching presence shows the role of teachers to design and implement courses which include social and cognitive processes. Some applications of the framework include online learning with Learning Management Systems (LMS) or with Massive Open Online Learning (MOOC) platforms (Kovanović, Gašević, Joksimović, Hatala, & Adesope, 2015).

2.2. The use of teaching and learning analytics in communities of inquiry

One collective approach for TPD is the engagement of teachers in collaborative inquiry through data teams. In this model, teachers discuss and interpret together student data about their classrooms rather than working alone (Mandinach, & Jimerson, 2016; Van Gasse et al., 2017). Recent TPD programs introduce the use of Learning Analytics (LA) systems for teachers or Teaching Analytics (TA) tools with the aim to use and adopt such technologies in everyday teaching (Michos, Hernández-Leo, & Albó, 2018; Rienties, Herodotou, Olney, Schencks, & Boroowa, 2018).

LA are defined as "the measurement, collection, analysis, and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs" (Ferguson, 2012). Moreover, the subfield of TA focus on the design, development, and evaluation of visual analytics methods and tools for teachers, to understand teaching and learning (Vatrapu, Teplovs, Fujita, & Bull, 2011; Prieto, Sharma., Dillenbourg & Rodríguez-Triana, 2016). One argument is that the connection between Teaching and Learning Analytics (TLA) can provide insights and improve teacher inquiry practice (Sergis & Sampson 2017).

Teacher inquiry is a strategy for teacher professional development which includes the examination of teachers´ own and peer practices (Mor, Ferguson, & Wasson, 2015). Luckin, Clark, Avramides, Hunter, and Oliver (2017) conduct a literature review for teacher inquiry and show its connection with teacher

design research. They argue that teacher design research is a participatory design approach to "*develop teachers' expertise as adaptive innovators through long-term involvement in iterative design research and a process of guided professional development*". This approach considers teachers rather than researchers as the starting point in the design process and their involvement in a shared *community of inquiry* (Cochran-Smith, & Lytle, 2009; Bannan-Ritland, 2008; Laurillard, 2012; Kali, Eylon, McKenney, & Kidron, 2018) contributes to their own learning and professional development.

Considering recent developments on learning and teaching analytics tools and their connection with teacher inquiry, we identify limited frameworks which show how such participatory design approaches for teachers as designers can be studied and supported with technology. In the following section, we formulate our framework to address this gap.

3. Collective Inquiry with Data Analytics (CIDA): A framework for collectively supporting teachers´ design practice with data analytics.

Based on two recent studies in teacher communities (Michos & Hernández-Leo, 2018; Michos, Hernández-Leo, & Albo, 2018), we articulate the Collective Inquiry with Data Analytics (CIDA) framework (see Figure 1). Our theoretical underpinning is based on teacher professional development and teacher learning and uses the Cultural Historical Activity Theory (CHAT) (Engestrom, 2000) and Teacher Inquiry cycle to describe the meaningful use of data analytics for supporting teachers´ design work. Data analytics in this context can inform teachers when designing and implementing learning scenarios (Hernández-Leo et al., 2018b) and generate pedagogical, technological and content knowledge within teacher communities (Koehler, & Mishra, 2009). The framework is proposed as a participatory approach for studying and supporting teacher communities which utilize technology and data analytics and involve their community members as co-design participants e.g. other teachers and their students. The articulation of the framework targets: a) researchers who study teacher design practices and data use by teachers, b) educational practitioners such as teachers and, c) system developers who work with learning and teaching analytics tools for teachers.

Based on our literature review about community inquiry frameworks for knowledge building and teaching and learning analytics for teacher inquiry, we identify three interconnected components to support teachers as designers within *inquiry communities*. The three components are a) the *inquiry* process, b) the *collective* process and, c) *technologica*l support.

Inquiry process

The *inquiry process* component includes the work of teachers in goal-directed inquiry and reflection on their practice. Teacher inquiry is considered as a cyclic, self-regulating process to design and implement learning scenarios with the use of teaching and learning analytics. It shows the meaningful connection between pedagogical intentions and teachers' practical questions with the collection of learning analytics during the enactment of learning designs. In Michos, Hernández-Leo & Albó (2018) we show empirical evidence on how teacher inquiry supported by a web-based tool was implemented in practice with school teachers and enabled data-informed teacher reflections. Teachers involvement in inquiry cycles showed evidence of knowledge building regarding the design and enactment of learning activities.

Collective Process

The *collective process* component shows that the social environment shapes and guides teachers practices. Considering that teacher development and learning is informed by their socio-cultural educational system and includes the use of resources (e.g. peers, students, head teachers, professional workshops, teacher artifacts) (Agostinho, Lockyer, & Bennett, 2018; Butler & Schnellert, 2012), the framework shows how teacher individual inquiry can be connected with the community of teachers and learners through data analytics and mediating artifacts (e.g. mediated by learning design documentations and teacher inquiry documentations). For instance, in Michos & Hernández-Leo (2018) we show how we used the CHAT framework and data analytics to provide community awareness in a web-based teacher community about their peers, the use of learning design tools and teachers documentations and how data-informed community reflections can assist teachers.

Collective Inquiry with Data Analytics (CIDA) Framework

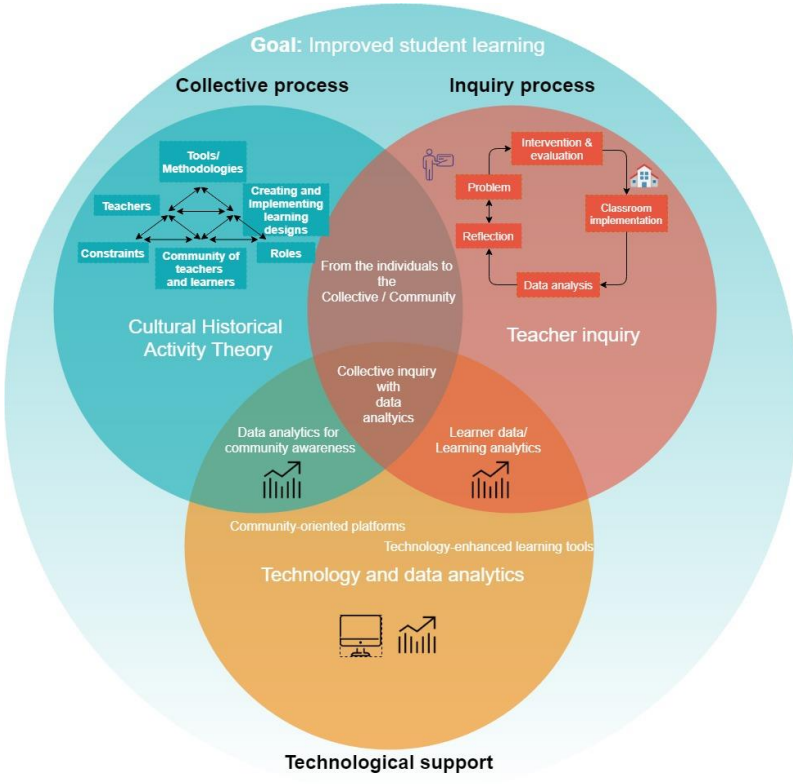

Figure 1. The CIDA framework for collectively supporting teachers´ design practice with data analytics.

Technological support

The *technological support* component includes the use of technology for collective teacher inquiry. To enable the use of data analytics, the technology used by teachers is an integral part of the framework. For

instance, community-oriented platforms which provide spaces for sharing learning designs and inquiry cycles documentations can provide technological support for community inquiry within teacher communities. In this context, community awareness with data analytics can inform and inspire teachers´ design inquiry (Michos & Hernández-Leo, 2018). Moreover, when teachers enact technology-enhanced learning scenarios, the use of learner data and learning analytics can inform further teachers´ designs and contributes to community inquiry (Michos, Hernández-Leo & Albó, 2018)

To evaluate the above framework, we formulated the following research questions:

RQ: Does and how the framework helps to *study* and *support* participatory teacher design practice enhanced with data analytics?

- **RQ1**: How do teachers engage with data-intensive collective inquiry processes?
- **RQ2:** How do teachers perceive data-intensive collective inquiry processes?

4. Methodology

This research work is part of an overall Design-Based Research (DBR) methodology (Amiel & Rieves, 2006) which aims to develop data analytics support for teachers as designers in technological environments. In Michos & Hernández-Leo (2018), we explain the suitability of this methodology to understand and support teacher practice by conducting research in authentic environments (e.g., schools). The framework was developed after completing two DBR cycles with teachers (Michos & Hernández-Leo, 2018; Michos, Hernández-Leo, Albó, 2018). In this paper, we use a case study methodology (Yin, 2009) to describe, inform and validate the articulation of our framework. We chose three representative authentic settings for teachers; two communities of High school teachers and a professional teacher community in a Massive Open Online Course (MOOC). The three analyzed teacher communities participated in a Professional Development (PD) program about learning design. The three communities differed in the pre-existing relationships of their members and the time duration of the received PD program. In schools, teachers participated in a two-year PD program and knew each other whereas, in the MOOC, the participating teachers followed the PD course for 6 weeks and had no previous relationships.

4.1 Description of the inquiry community cases

4.1.1 Communities of school teachers (two schools)

N=33 teachers participated in a two-year Professional Development (PD) program. The PD program focused on the meaningful use of ICT to a) train teachers as designers of Technology-Enhanced Learning (TEL) and b) facilitate the teacher inquiry practice with the systematic, fit-for-purpose collection of student data. The program was part of a research project carried out by a university research group in collaboration with two High Schools. The primary learning design methodology of the program was the design and implementation of Collaborative Learning (CL) (Johnson & Johnson, 1994). *N*=14 teachers out of 33 volunteered to implement their learning designs in their classrooms and completed a whole inquiry cycle with the collection and interpretation of student data.

4.1.2 Community in a Massive Open Online Course for teachers

N=209 teachers registered in the MOOC "Innovative Collaborative Learning with ICT". The MOOC aimed to train teachers in the design and implementation of CL scenarios with technology. Teachers were teaching various subjects in different educational levels (from primary education to higher education). *N*=100 teachers created at least one learning design artifact which included either a conceptualization of a collaborative learning scenario or a detailed lesson plan. In this case, teachers did not implement their learning designs because the MOOC was running between June-July 2017 and there were limited opportunities to implement them with students.

4.2 Professional development activities and data collection methods

Two schools participated in the PD program and received training in the form of 2-hour monthly workshops. The teachers were using the learning design platform ILDE (Hernández-Leo et al., 2018) to design, implement and share their inquiries. In the MOOC community, teachers were asked to perform different online activities with ILDE every week and were provided with instructions in the Canvas MOOC platform. Table 1 shows the description and duration of the PD activities in the three community cases.

Table 1. Professional development activities in the participating communities

Time period	**Communities of school teachers**	**Time period**	**Community in a MOOC for teachers**
2 times x 2 hours	*Workshop*: Initial exploration of learning design tools	*1 week*	Design of collaborative learning: theory and practices
1 month	*Online activity*: documentation of teaching-learning activity sequences	*1 week*	ICT collaborative tools for teachers and students
4 times x 2 hours	*Workshop:* Design of CL	*1 week*	Design and implementation of CL activities based on Pyramid pattern.
2 times x 2 months	*Implementations*: Classroom implementations with technology-enhanced learning tools	*1 week*	Design and implementation of CL activities based on Jigsaw pattern.
4 times x 2 hours	*Workshop*: Joint teachers´ reflections on learning analytics	*1 week*	Learning Design project and peer reflection

Throughout the PD programs, we used a mixed method approach with collection and triangulation of quantitative and qualitative data (Creswell & Plano Clark, 2007). The main data sources were the following:

- Log data (Quantitative). Teachers actions and interactions´ with the ILDE online learning design platform.
- Online comments (Qualitative). Teachers´ comments about learning design artifacts in ILDE.
- Teacher artifacts (Qualitative). Teachers´ produced artifacts with ILDE tools.

- Questionnaires (Quantitative, Qualitative). One questionnaire with open and closed questions about perceived usefulness of different ILDE tools after the completion of the MOOC. Another questionnaire about perceived usefulness of teacher inquiry cycles with student data in the schools.
- Interviews (Qualitative). 7 semi-structured interviews with the teachers who implemented learning designs in schools.

Log data were analyzed in Tableau[1] with the aim to understand teachers´ online participation and interactions. Teachers' online comments were analyzed based on a coding scheme of the TPACK framework (Koehler, & Mishra, 2009; Boschman, McKenney, & Voogt 2015). The analysis sought to understand types of technological, pedagogical, content knowledge activated during teachers´ online interactions. Two researchers familiarized with the data and coded the entire online comments as the unit of analysis. The process was iteratively done until reaching an inter-rater agreement between the coders. Teachers' interviews, open responses in questionnaires and teacher artifacts were analyzed with inductive thematic analysis driven by our research questions. An open coding scheme was used to report the results of the thematic analysis. Quantitative data from questionnaires were analyzed in IBM SPSS 22.

In Table 2 we show how the above data were used to answer our **RQs** based on our proposed framework.

Table 2. Data collection methods based on the framework and the Research Questions

CIDA framework		**Cases**	**Research questions:** Does and how the framework helps to *study* and *support* participatory teacher design practice enhanced with data analytics?	
			RQ1: How do teachers engage with data-intensive collective inquiry processes?	**RQ2:** How do teachers perceive data-intensive collective inquiry processes?
	Technological Support (see Section 5)			
Collective Process	ILDE, inILDE, TILE	School communities (two schools)	Log data, Online Comments	Interviews
	ILDE, inILDE	MOOC	Log data, Online Comments	Questionnaire (Open questions)
Inquiry Process	ILDE, inILDE, TILE	School communities (two schools)	Log data, Teacher artifacts TILE	Interviews
	ILDE, inILDE	MOOC	Log data, Teacher artifacts in ILDE	Questionnaire (Open and closed questions)

5. Implementation of the framework and Results

[1] https://www.tableau.com/

In the following sections, we describe how the framework was implemented in practice based on the three components: a) technological support b) collective process and c) inquiry process and empirical results from the two case studies.

5.1 Technological support

In this section, we describe examples of technologies co-designed with teachers contributing to the technological support component and its relation with the collective and inquiry process components of our framework.

5.1.1 Integrated Learning Design Environment (ILDE)

To enable the *inquiry* and *collective* process to emerge, community platforms for exchanging learning designs are example technologies for collective inquiry. In our case, we used ILDE, a community environment for learning design, in which members can create, co-create and share designs spanning from the conceptualization of learning scenarios to their implementation (Hernández-Leo et al., 2018). The ILDE provides both an individual space for the creation and management of learning designs with multiple tools and social space for sharing, re-using, commenting designs and exploring community members' activity. The ILDE was used in the communities of school teachers and the MOOC community.

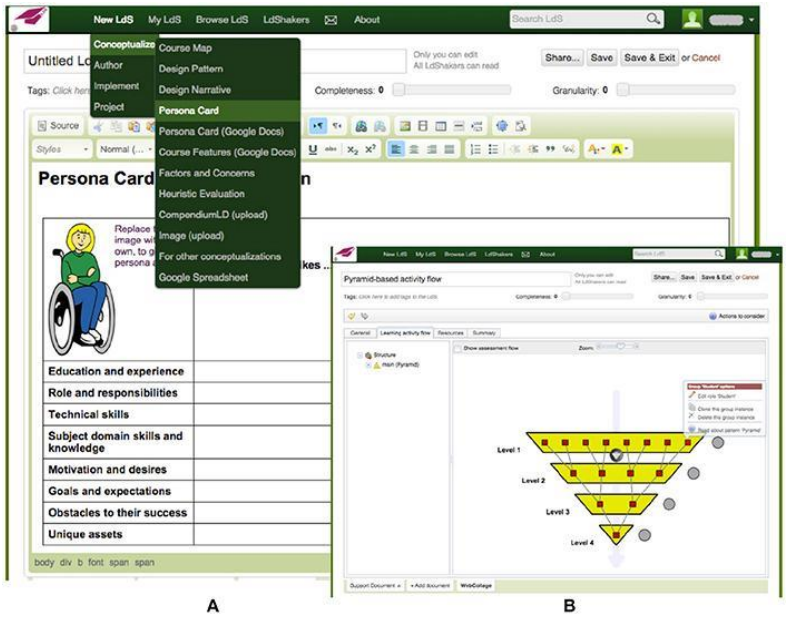

Figure 2. Integrated Learning Design Environment (ILDE) showing different learning design tools for conceptualization (A) and authoring (B) of learning designs (Hernández Leo et al., 2018, p.10).

5.1.2 Community analytics dashboard: inILDE

Towards supporting the collective process by means of data analytics, we developed a community awareness dashboard (inILDE) for online teacher communities. inILDE is a mirroring tool which displays the actions performed by teachers in the ILDE environment and aims to provide social awareness for community regulation and reflection. The tool is implemented as a dashboard and includes data visualizations regarding: a) participation analytics of community members, b) usage analytics for different learning design tools, and c) usage analytics about learning design artifacts. In Michos & Hernández-Leo (2018) we explain the design and study of the community dashboard based on the CHAT framework. The community dashboard was used in the communities of school teachers and the MOOC community.

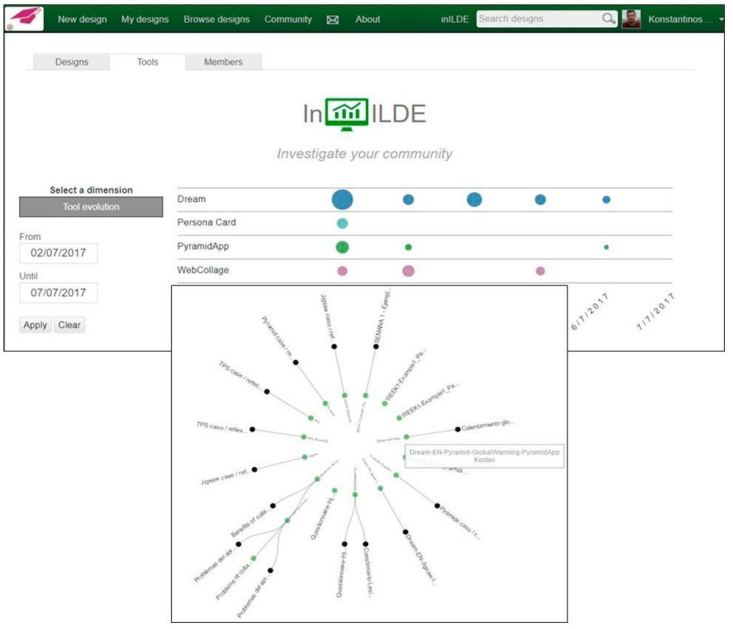

Figure 3. Community analytics dashboard (inILDE) showing usage analytics of different learning design tools (above) and radial tidy tree with reused learning design artifacts (below) within a teacher community (Michos & Hernández-Leo, 2018).

5.1.3 Teacher-led Inquiry for Learning dEsigns (TILE)

Considering the inquiry process, we developed a tool which helps and guides teachers to conduct an inquiry into classroom activities with technologies. TILE is a web-based interactive tool for teachers and educational designers which sequences the Teacher Inquiry cycle in 4 Steps: 1) the identification of problems and inquiry questions, 2) the design of the intervention with a data collection plan, 3) the analysis of the collected data after the implementation, and 4) the reflection on the implementation. The tool is embedded in learning design tools within the ILDE and aims to scaffold systematic teacher inquiry with the collection and interpretation of learning analytics. After the completion of inquiry cycles, teachers can share and comment their documented inquiries. The TILE tool was used only in the communities of school teachers (Michos, Hernández-Leo, Albó, 2018) because teachers could implement their designs with students in classrooms.

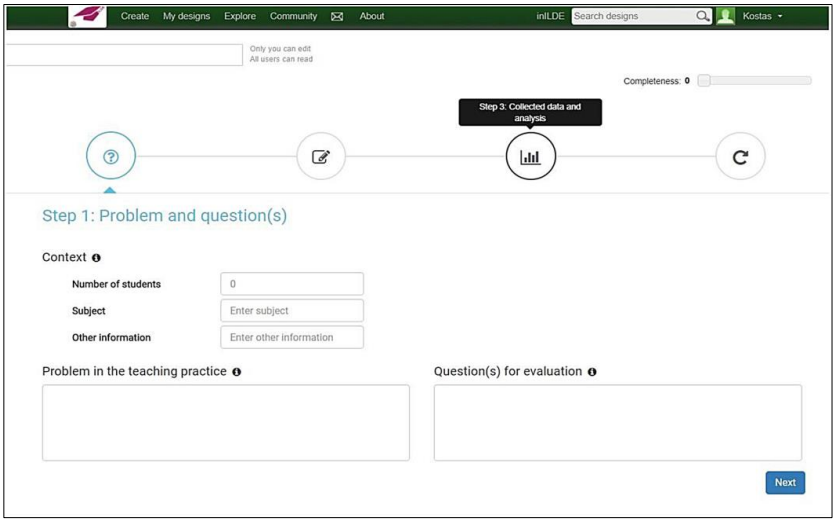

Figure 4. Teacher-led Inquiry for Learning Designs (TILE) tool integrated into ILDE showing the first step of the teacher inquiry process about problem and question formulation (Michos, Hernández-Leo, & Albó, 2018).

In the MOOC, we facilitated the teacher inquiry process with the tools provided in ILDE (conceptualization, authoring and deployment tools) and the Canvas MOOC platform. In this case, teachers created and commented artifacts which included detailed conceptualizations and descriptions of collaborative learning activities.

5.2 Results on the collective process

We present empirical results related to the *collective process* component based on **RQ1** and **RQ2** in each case study.

RQ1: How do teachers engage with data-intensive collective inquiry processes?

6.2.1 Online teacher participation: Communities of school teachers

Regarding the online participation behavior of teachers in the two schools, we analyzed their different actions performed within ILDE between November 2016-May 2018. Figures 5-6 show the different online behavior patterns of teachers in School 1 and 2. In School 1, there were more teachers, compared to School 2, that started using ILDE (Figure 4). However, about half of them continued using it by creating, editing, commenting and viewing designs and other members´ profiles throughout the time. In School 2, we observe longitudinal engagement throughout the school year with time intervals of high and low participation patterns (Figure 6). In both schools, the professional development program activities influenced their online participation behavior and in School 2 we observed active follow-up participation independently from the PD program.

The community dashboard aimed at providing awareness in the online teacher community and support the *collective* process for creating learning designs. Regarding the use of the dashboard, the red line in Figure 5-6 shows that the peak number of users who interacted with the dashboard, aligns with the peak number of users who performed other actions, e.g. created designs or profile views. The community dashboard was integrated into the community platform in May 2017 and influenced the collective behavior of teachers´ online participation.

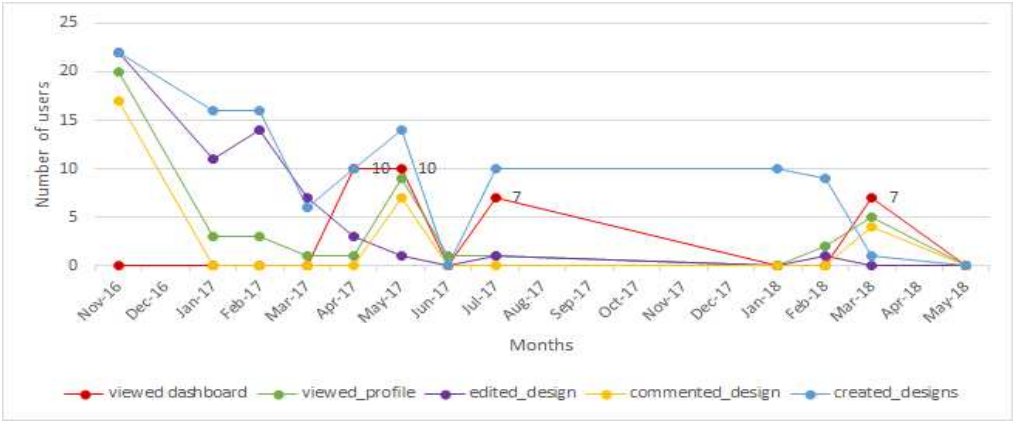

Figure 5. School 1. Members online participation represented with different actions in ILDE across months (viewed_dashboard, viewed_profile, edited_design, commented_design, created design).

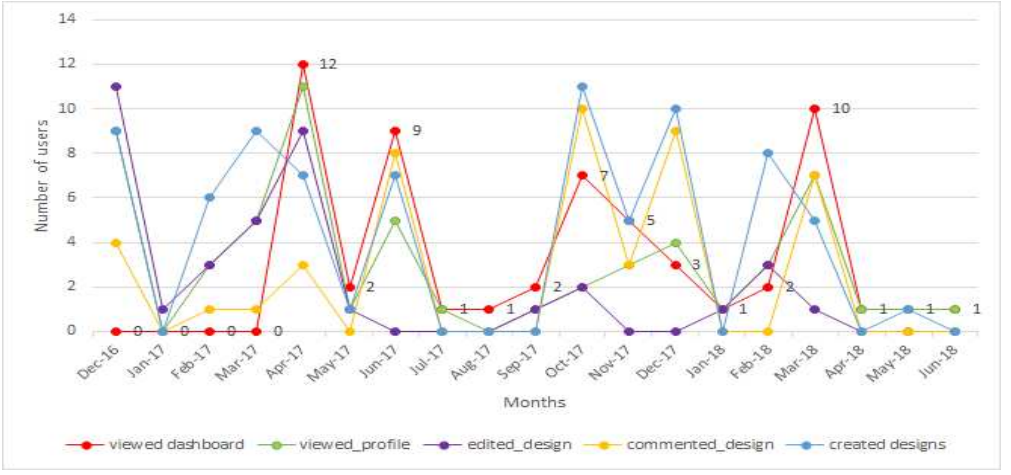

Figure 6. School 2. Members online participation represented with different actions in ILDE across months (viewed_dashboard, viewed_profile, edited_design, commented_design, created design).

5.2.2 Online teacher participation: MOOC community

In the MOOC community, we observed a similar online participation behavior as in School 1. There was a peak of users who interacted in ILDE during the last day of each week and this aligned with the deadline of the MOOC assignments. Regarding the use of the dashboard, the MOOC participants could access it after the first week of the MOOC. During the weeks 2 and 3, more participants used the dashboard because it was introduced within one assignment, and in weeks 4 and 5, dashboard use decreased (see Figure 7). However, we observed a peak number of participants who interacted with others by commenting and viewing others´ profiles and designs and this aligned with the peak number of participants who used the dashboard.

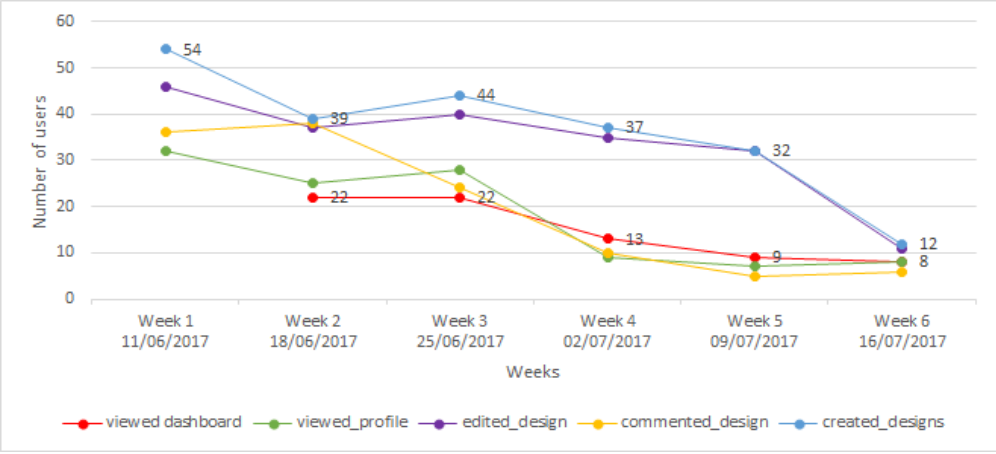

Figure 7. MOOC community. Members online participation represented with different actions in ILDE across months (viewed_dashboard, viewed_profile, edited_design, commented_design, created design).

5.2.3 Content of teachers´ collective reflections: Communities of school teachers

We performed a content analysis of teachers´ comments in two tasks for peer reflections. Teachers were provided with the learning design, a documented inquiry cycle with the TILE tool and student data of an implemented classroom activity (see Figure A.1 in the Appendix). Teachers were asked to jointly reflect with comments in ILDE. We coded their comments based on the TPACK framework with the entire comment as units of analysis (Table 3). The analysis aimed to identify what types of TPACK knowledge teachers activate while reflecting on others´ data-informed inquiry cycles.

Table 3. Analysis of group reflections based on TPACK in two data-informed reflective tasks in the schools.

Code	Meaning	Excerpt
TK	Use of computers without referencing to learning or teaching	"We have reached similar conclusions regarding the use of the tool."
PK	General teaching and learning strategies or learning activities.	"The activity seems suitable for learning. The students show satisfaction for the learning and the methodology used."
CK	Subject-matter regarding discussions.	"The discussions between the group members are in the form of chat, with incomplete and little-argued answers."

TPk	Use of computers related to teaching/learning and classroom practice.	"The activity is very good in favoring the participation of all the students in making a conclusion. However, the data shows that the number of students' responses is not equal. It may be due to connection problems, so I think it is very important to be able to keep pace with what is happening in class (if they do not respond to technical problems, connection to the internet or for lack of ideas) to be able to make an assessment, which may not show the statistics."
TCk	Use of computers to represent subject matter knowledge.	(Not present in teachers' comments)
PCk	Teaching and learning strategies related to subject matter.	"Students need more guidance in how to ask questions and answers in a debate. There is a lot of difference in how they talk about each other as they write the final answer. I think it's important because the debate is not enriched."
TPCk	Integrated use of computers related to teaching and learning strategies and content knowledge	"It is an interesting activity. It makes a comprehension work dynamic and generates debate among the students. The technology enables the collection of data that can be reviewed to improve the activity."
Other	Social appraisal comments and other feedback.	"Very good activity, very interesting reflections arise."

Out of 91 coded comments, the largest amount of knowledge activated by teachers was pedagogical (**PK**=34%) referring to teaching or learning strategy after reviewing the teacher and student data of a peer teacher. Then comments coded as **Other** referred to social appraisal such as rewarding comments and content which did not refer to one of the TPACK categories. This type of comments was the second most common (**Other**=28%). Then followed two types of integrated pedagogical and content knowledge (**PCk** =19%) and technological and pedagogical knowledge (**TPk**=11%) while separated technological (**TK**=3%) or content knowledge (**CK**=3%) was uncommon in teachers´ reflective comments (Figure 8). Thus, the predominance of pedagogical and content knowledge activation shows added value in teachers´ peer reflections with the inquiry cycles documentations and the student data.

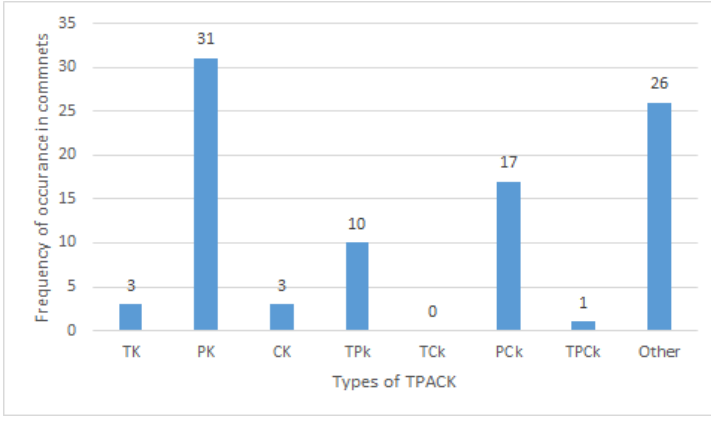

Figure 8. Types of TPACK knowledge activated during the peer-reflection tasks in the schools

5.2.4 Content of teachers´ collective reflections: MOOC community

During the second week of the MOOC, teachers were asked to review and comment a pattern-based design for collaborative learning created by other participants. The task was to write two comments; one comment after searching another design without the community awareness dashboard and one comment after using the community dashboard. We performed a content analysis of the comments with the whole comment as a unit of analysis based on the TPACK framework aiming to identify types of knowledge activated by teachers. Table 4 shows examples of teachers´ comments and TPACK codes.

Table 4. Analysis of group reflections based on TPACK in a peer-review task with/without the community dashboard in the MOOC.

Code	Meaning	Excerpt
TK	Use of computers without referencing to learning or teaching	"I have heard of Moodle but never had a chance to use it. After reading his post I did some research in order to understand how Moodle works. Afterward, I have realized that Moodle is much more complex than the Kahoot or the Popplet. It offers much more options than the other two programs, but I still do not mind using both Kahoot and Popplet programs."
PK	General teaching and learning strategies or learning activities.	"I completely agree with you on how Jigsaw can empower our students if planned right. I usually use Jigsaw in my reading lessons and for problem-solution essay braining storming. Using Jigsaw can trigger students' responsibility, autonomy, and eventually cooperation."
CK	Subject-matter regarding a specific topic.	"This would be a great topic for my advance business ESL class. They are mainly professionals who have to deal with these issues daily and they would all have a different perspective on making this very interesting."
TPk	Use of computers related to teaching/learning and classroom practice.	"It's a very interesting idea to reflect on forum publications with PyramidApp activities. But I'd like to ask you if there are rubrics or rules for forum posts? Do you discuss them in advance with students?"
TCk	Use of computers to represent subject matter knowledge.	"I chose this case from the visualizations, because its title deals with learning and technology, like mine "How gamification mechanisms can promote collaboration in Communities of Inquiry" and based on the existing comment, which I saw that someone had written about it. As for the relevance that exists between these two activities, I have to mention their collaborative nature and the fact that both of them can be organized and realized using a forum."
PCk	Teaching and learning strategies related to subject matter.	"I have never thought about using the Jigsaw tool for reading comprehension activities, and I really like what you have shared. The activity sounds really engaging and complete. My final degree project deals with English learning and reading motivation, and now I will take into account this tool and I'll try to put your activity into practice asap."

TPCk	Integrated use of computers related to teaching and learning strategies and content knowledge	"Hi, I like your idea of using Jigsaw for the issue. The issue itself is highly important, I also work with a similar set of issues at the university level, though in my case we discuss more about digital identity, branding, and professional social media interaction. Any tool to help share ideas and opinion of the peers on this subject is helpful for students."
Other	Social appraisal comments and other feedback.	"Very nice practice and very detailed description."

N=34 teachers participated in the task and wrote in total *N*=60 comments. The largest amount of comments included activation of integrated pedagogical and content knowledge (**PCk**=30%), then followed isolated pedagogical knowledge (**PK**=25%), and social appraisal comments (**Other**=25%). The integration of technological pedagogical knowledge was present in **TPCk**=8% of the comments and followed isolated content knowledge (**CK**=5%), integrated technological and pedagogical knowledge (**TPk**=3%) and isolated technological knowledge (**TK**=1%). Regarding the differences with/without the use of the community dashboard, more comments appeared with activation of either isolated content knowledge (**CK**) or integrated pedagogical and content knowledge (**PCk**) (Figure 9). One interpretation could be that teachers were able to see more titles of designs in the dashboard and they commented the ones with related content to their subject.

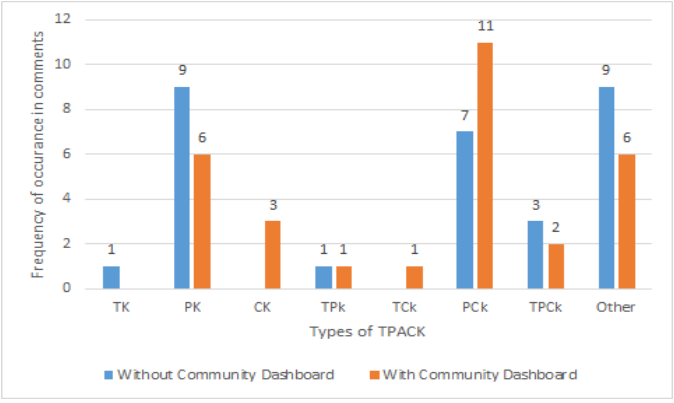

Figure 9. Types of TPACK knowledge activated during the peer-review task with/without using the community dashboard.

5.2.5 Perceived value of data-intensive collective inquiry: Communities of school teachers

RQ2: How do teachers perceive data-intensive collective inquiry processes?

To evaluate how teachers perceived data-intensive collective inquiry we conducted seven semi-structured interviews in the two schools covering 50% of the participants who performed classroom implementations. Table A.1 in the Appendix shows the interview questions. The question "Please explain your experience about the group reflections in the project" aimed to evaluate teachers´ collective reflections with student data (Table 5). We transcripted the interviews and analyzed segments with different or common topics. This resulted in 16 segments. Most of the segments (5) referred to the value of sharing problems, solutions and impressions for classroom implementations. Then followed topics such as the value of new information

and ideas by other teachers, the importance to have common spaces to discuss pedagogical issues and the value for jointly reflecting on such topics. Lastly, two segments referred to the importance of dedicating more time and to follow up reflection meeting which emerged after the professional activities.

Table 5. Sample of teachers´ answers in the question "Please explain your experience about the group reflections in the project"

Topic	Explanation	Excerpt	Frequency
Shared problems/solutions/ impressions	Valuing the shared problems, solutions and impressions for teachers´ practices.	"Participating in the reflections is useful to find joint solutions and have empathy with the same problems that others have."	5
Informative/New ideas	Valuing new information and ideas by others	"It can give you ideas of things that you have not applied."	3
Spaces for pedagogy	Valuing the common space to discuss aspects about pedagogy	"We have found a space to explain what our techniques are, our strategies ... and how they are applied. I find it interesting, it's more, it seems to me that this is necessary. In fact, I think it should be mandatory because we learn a lot. You really see some practices that work, and then also the reflections of the teachers in what they evaluate ... etc. it helps you to make a more plural panorama of all learning"	3
Valuable joint reflection	Valuing the joint reflections	"Whenever a reflection process is performed jointly, I think it is very important"	3
Follow up reflections	Dedicating more time for follow up reflections	"I decided to do it with X (of tutorial action) and generated spaces for reflection, not within the sessions-workshop, but ... so we reviewed activities that we did in tutoring ... and how to think about them to improve them, we suddenly decided to make a resource bank for tutorial action"	2

5.2.6 Perceived value of data-intensive collective inquiry: MOOC community

After the accomplishment of the MOOC, *N*=29 participants responded to two open-ended questions regarding the use of the community awareness dashboard. The first question was whether the community dashboard helped participants to be more aware of their community and how the community dashboard facilitated their tasks during the MOOC. Their comments were based on the time they spent using the dashboard. For example, some participants mentioned although they have used it for a limited period of time they were willing to understand the community through the dashboard. Other participants pointed out that it helped them to search and comment others' designs, reuse designs, get inspiration for ideas and understand the overall activity of the members during the MOOC. Moreover, they mentioned that it helped them to understand which tools were used during the course and their activities in specific time periods of the MOOC.

Regarding the second question, participants were asked to write a positive, a negative aspect and a recommendation relevant to the development of the community dashboard. Among the positive aspects was the realization of the sharing possibility in the community, the opportunity for data-informed search and the variety of the functionalities to continue the learning process in the course. However, they have also mentioned that in some cases the interpretation of information provided in the dashboard was hard, which lessen the benefits of using it. Further, they recommended user ratings for learning designs visualized in the dashboard and incorporation of the dashboard in more tasks during the training actions.

5.3 Results on the Inquiry Process

5.3.1 Use of the TILE inquiry tool: Communities of school teachers

In the schools, out of 33 teachers who participated in the PD program, 14 implemented CL activities with technology and documented a complete inquiry cycle with the TILE tool (see Figure 4). Teachers also used the PyramidApp tool (Manathunga & Hernández-Leo, 2018) to design and implement their collaborative activities. PyramidApp facilitates the creation and instantiation of collaborative learning activities based on the Pyramid pattern. This pattern proposes a collaboration flow structure in which learners interact in increasingly larger groups along a sequence of activities (Pyramid levels). A total of *N*=508 High school students participated in the implementation of the activities in the two schools.

We evaluated teachers' use of the TILE tool with the log data collected from ILDE. Figures 9-10 show frequency of use of the TILE tool in the two schools and timeline per week. In both schools, there were different types of engagement in the inquiry process (from the design to the reflection) according to the available time of teachers and their interest to conduct a classroom inquiry with technologies. Thus, 3-4 teachers were the most active in each school (used TILE more than 10 times) and the rest were involved in a lower level. Figure 10(B) and Figure 11(B) show the time periods in which the tool was used. Teachers initially formulated the problem, questions and data collection plan in December 2018 and reflected on the collected student data in February 2018. This pattern of use is shown in Figure 10(B) and Figure 11(B). In School 2, some teachers conducted a second inquiry cycle and thus more reflections on student data occurred in April 2018.

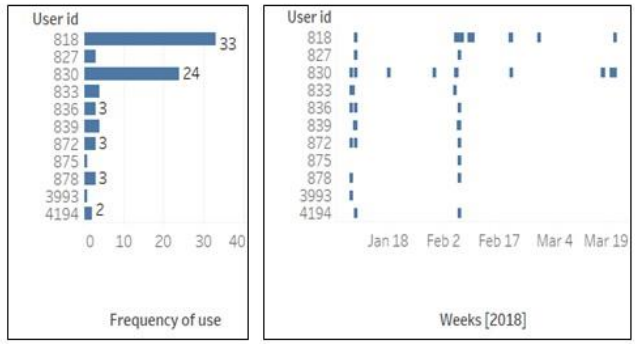

Figure 10. School 1: Frequency of TILE tool use (A) and timeline of use (B) by teachers

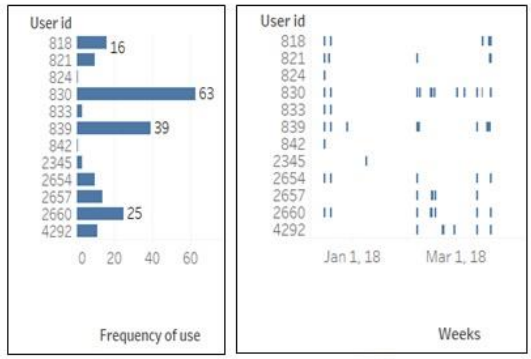

Figure 11. School 2: Frequency of TILE tool use (A) and timeline of use (B) by teachers

To further understand the teacher inquiry process, we performed a content analysis of the produced teacher artifacts with the TILE tool by extracting the main topics in each inquiry step. We analyzed a sample of four teacher artifacts in School 1 and a sample of six teacher artifacts in School 2 considering the most active teachers (see Table A.2-A.3). In School 1, the analysis shows that the initial problem and subsequent data-informed reflection referred to the content of the subject and its objectives. The teachers reflected on the learning design objectives and practicalities regarding implementations such as time management. However, in School 2, the initial inquiry problem and subsequent reflection referred to students´ individual and collaborative skills and reflections about perceived usefulness of the task by students. In both schools, the reflection was based on the collected data which were visualizations of students´ participation in the PyramidApp tool, the content of students´ responses and discussions in the Pyramid App tool and student feedback with google forms (see Figure A.1).

5.3.2 Use of ILDE tools for teacher inquiry: MOOC community

The teacher inquiry process in the MOOC was analyzed based on the created learning design artifacts. In this case, teachers did not implement their designs and they didn't use the TILE tool. To understand teachers´ inquiry process we analyzed their conceptualizations and learning designs. In particular, teachers used conceptualization templates to define their problem and authoring tools (PyramidApp, WebCollage) to describe all the details of their learning design. WebCollage enables the authoring and deployment of CSCL activities based on different patterns in a Virtual Learning Environment (VLE) (Villasclaras-Fernández, Hernández-Leo, Asensio-Pérez, & Dimitriadis, 2015). *N*=11 teachers deployed their learning designs in a VLE (Moodle). Table 1 shows the different activities during each week of the MOOC. We initially analyzed the amount of learning design artifacts created with the different tools in ILDE (conceptualization, authoring, and implementation tools) and we focused on the ten most active participants (higher number of produced artifacts). Figure 11 shows ten participants´ timeline of created learning design artifacts with different tools. During June 2017, participants worked more on the conceptualization of their design (blue points) and then specified their design solution with different tools. Some participants used the PyramiApp tool (Red points) to design a collaborative learning activity while others used WebCollage (Green points) and deployed it in the VLE (Orange points) Moodle. In the MOOC, participants did not experience an implementation with students, thus they were not able to reflect with student data. The inquiry

process followed in the MOOC varied among participants in the levels of engagement, types of tools used and time of engagement.

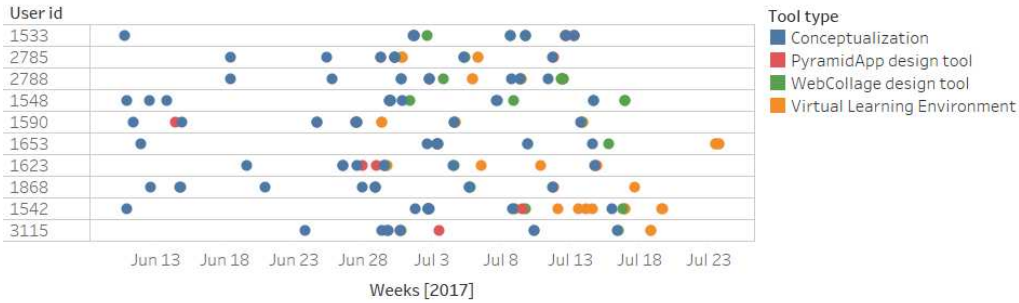

Figure 11. Timeline of participants created learning design artifacts with different ILDE tools. Blue points indicate conceptualization tools such as design templates. Red points indicate the use of the PyramidApp design tool while green points indicate the use of WebCollage design tool. Orange points indicate the deployment of the design in a VLE (Moodle).

To further understand the content of teacher inquiries we conducted an analysis of the learning design artifacts of those ten active participants. Table A.4 shows the content of the conceptualizations, problems defined by teachers and the proposed designs and solutions. The most common problem appeared in their inquiries was to increase student participation with more reflections and interactions among them. Other participants´ conceptualizations referred to student motivation, teamwork experience, and communication skills. The proposed solutions were either CL activities based on the Pyramid pattern with the help of the PyramidApp tool or based on the Jigsaw Pattern with the help of WebCollage tool and Moodle.

5.3.3 Perceived value of data-intensive inquiry: School communities

In schools, *N*=14 teachers implemented their learning designs and used the TILE tool for their inquiries. We conducted interviews with seven teachers (50%) and seven more teachers were asked to fulfill a questionnaire with open questions (see Table A.5). We conducted a thematic analysis of the main topics extracted from the interviews and the open questions regarding the perceived value of the teacher inquiry process with the TILE tool and the use of student data to inform learning design. Table A.6 and A.7 show the main topics and sample of teachers´ answers.

Teachers valued the systematic way to collect student information during classroom activities and the connection of their design expectations with their objective evaluation based on student data. Moreover, teachers explained that the teacher inquiry process is a practical way to reflect on the design and reflection on classroom implementations. They mentioned that the teacher inquiry process with the TILE tool provided awareness and orientation for key elements to reflect on design. According to the teachers, it was also a way to document the whole inquiry process for later review. Lastly, teachers mentioned in their interviews barriers for systematic teacher inquiry with student data. The barriers referred to the lack of available time, large student cohorts and difficulties with ICT tools.

Teachers also valued the use of data for improving future implementations of their learning designs. They appreciated the real-time collection of student information during learning activities´ implementations. Student feedback with questionnaires was also one aspect which was valuable for improving their learning designs. Teachers also explained the key elements for which student data can help. These elements were the identification of student misunderstandings, improvement of instructions and management of time during classroom activities.

5.3.4 Perceived usefulness of ILDE tools: MOOC community

To evaluate the inquiry process in the MOOC, we used three Likert scale questions (1-7) after the completion of the MOOC about the perceived usefulness of the ILDE tools (conceptualization, authoring, and implementation tools). *N*=34 participants responded to the questionnaire. Table 6 shows the percent of teachers´ responses about perceived usefulness of the tools. All tools (conceptualization, authoring, implementation) received high values by teachers. The highest values were given to conceptualization and authoring tools and the lowest to implementation tools. This was contradictory in the responses of 9 participants who deployed their designs in a VLE. In this case, they rated higher the implementation tools, followed by the authoring and conceptualization tools. The fact that few participants deployed their designs in a VLE can explain lower perceived usefulness of the implementation tools. In general, considering the use of the ILDE tools as the inquiry process in the MOOC, perceived usefulness varied according to participants´ engagement with the different tools.

Table 6. Percent of teachers´ responses about the usefulness of ILDE tools (*N*=34)

Question: The conceptualization, authoring, implementation features of ILDE are useful.							
	Disagree						Agree
Conceptualization tools	0	0	15	6	9	56	15
Authoring tools	0	0	9	6	15	47	21
Implementation tools	0	6	6	12	15	41	21

6. Cross-case analysis

The analysis of the proposed CIDA framework in the three case studies; two school communities and MOOC community, inform the articulation of the framework. Based on the three components; collective process, inquiry process, and technological support, we evaluated our research questions. Table 7 shows the main findings of the cross-case analysis in the two case studies.

Table 7. Cross-case analysis in three cases based on the framework and research questions.

CITA framework	**Cases**	**Research questions:** Does and how the framework helps to *study* and *support* participatory teacher design practice enhanced with data analytics?	
		RQ1: How do teachers engage with data-intensive collective inquiry processes?	**RQ2:** How do teachers perceive data-intensive collective inquiry processes?

	Technological Support			
Collective Process	ILDE, inILDE, TILE	School communities (two schools)	-Different online collective teacher participation between schools. -Collective participation was influenced by community dashboard. -Frequent pedagogical knowledge activation and social appraisals in teachers´ interactions.	-Value in sharing problems and solutions for classroom inquiry, ideas by teachers, common spaces for pedagogical reflections.
	ILDE, inILDE	MOOC community	-Collective participation decreased over time -Collective participation was influenced by community dashboard -Frequent integrated pedagogical content knowledge activation and social appraisals in teachers´ interactions	-Understanding the community, find and re-use design ideas, inspiration for design.
Inquiry Process	ILDE, inILDE, TILE	School communities (two schools)	-Different levels of engagement and elaboration in inquiry cycles. -Inquiry problem formulation was based on subject content, student skills, objectives. -Data-informed reflections focused on student feedback about the task and initial inquiry problem.	-A systematic and practical way to collect student data in classroom activities. -Documentations facilitate future reflections. -Awareness & orientation for teacher inquiry steps. -Data use informed instructions, time management, and student misunderstandings. -Factors to consider for performing teacher inquiry: lack of time, large student cohorts and familiarity with ICT tools.
	ILDE, inILDE	MOOC community	-Differences in levels of engagement, types of tools used and time of engagement -Inquiry problem formulation focused on student participation, reflection interactions, and collaborative skills	-Perceived usefulness of ILDE tools (conceptualization, authoring, implementation) varied according to participants´ engagement with each tool.

Regarding the *collective process*, there was a decrease in online teacher participation throughout the time in all cases; communities of school teachers and MOOC community. The TPD activities in schools and the learning activities in the MOOC explain teachers´ online participation patterns. However, teachers in one

of the schools engaged longer with ILDE independently of the TPD activities. They also implemented more learning activities, and this could explain why they were interested to use again ILDE. Teacher participation patterns align with relevant literature about factors in sustaining participation in formally-organized online teacher communities. These factors often include the available "free" time for teachers, lack of familiarity in working with asynchronous ways and the moderation by program leaders (Lantz-Andersson, Lundin & Selwyn, 2018).

In all cases, the use of the community awareness dashboard influenced the collective participation of the teachers. The most active teachers used more frequently the dashboard compared to the less active ones and this shows that one characteristic of active participants´ role was the monitoring of their community. Thus, the integration of a community awareness dashboard in an online teacher community provides added value to key community members as they can better search information and regulate their contribution behavior in their community (Michos & Hernández-Leo, 2018; Klamma, 2013). Both active and inactive participants were able to reflect and understand the collective participation which can resolve problems derived from asynchronous communication.

In the communities of school teachers, the content of teachers´ collective reflections shows evidence of higher pedagogical knowledge activated in their comments and this was combined with social appraisals. In the MOOC community, teachers activated more integrated pedagogical content knowledge with frequent social appraisals. However, the proposed task by facilitators was different. In the school community, teachers reflected on learning design implementations with student data and in the MOOC case, teachers reflected on other teachers´ conceptual designs with other teachers´ data. One interpretation could be that teachers´ collective reflection with learning analytics leads to more pedagogically-oriented discussions whereas reflections on conceptual designs lead to integrated pedagogical and content discussion. In all cases, teachers´ comments were lacking the integration of technology with pedagogy and content and this is contradictory in studies about teachers´ design teams (Boschman, McKenney, Voogt, 2015; Kali, Markauskaite, Goodyear, & Ward, 2011). A combination of different coding schemes would shed more light about teachers' collective reflections with educational data (e.g. the coding scheme by Boschman, McKenney, Voogt, 2015 about practical, internal and external constraints of teachers). The different types of TPACK activated during teachers' reflections shows evidence of pedagogical knowledge building in the three investigated inquiry communities.

The *collective process* was positively received by teachers in schools. The main argument based on their interviews was that it helps to share problems and solutions for classroom inquiry, to learn new ideas by others and have shared spaces for collective reflections. These elements include common characteristics in professional teacher communities (Popp & Goldman, 2016). Moreover, in the MOOC, teachers explained that the community dashboard facilitated understanding of their community and inspiration from others' design ideas. The perceived value of sharing within the community aligns with the content analysis of their comments and shows that sharing enables knowledge building about learning design and teaching practice (Hong et al., 2019).

Teacher engagement in the *inquiry process* and the content of their inquiries shows value in cultivating teacher reflective practice. Additionally, the sharing of reflective documentations enabled collaborative inquiry and co-regulation for teaching problems and solutions (Butler & Schnellert, 2012). Log data

analysis about the use of the TILE inquiry tool shows different levels of engagement in the school community. Teachers engagement with the *inquiry process* aligns with results about the *collective process* as teachers´ working life and available time are important factors for online teacher participation and can explain this behavior (Lantz-Andersson, Lundin & Selwyn, 2018). Teachers defined their inquiry problems based on their subject content, learning design objectives and students´ skills. Their reflections drew upon the available student data and referred back to the initial inquiry problems and students´ perception about the task. In the MOOC case, teachers´ inquiry process was analyzed based on learning design tools available in ILDE. In this case, teachers also showed varied levels of high and low engagement and their inquiry problems referred to student participation, students´ interaction and students´ collaborative skills.

The *inquiry process* included the implementation of collaborative learning activities and the collection and interpretation of student data. Teachers valued the real-time collection of student data during the implementation of learning activities, the orientation to perform inquiries with the TILE tool and the documentation of the whole inquiry process. Teachers mentioned key elements for which learning analytics can be used for learning design like the improvement of instructions, time management and identification of student misunderstandings (Michos, Hernández-Leo, Albó, 2018). In the MOOC community, teachers perceived useful the range of conceptualization, authoring tools but less useful the implementation tools because they did not implement their learning designs which further shows that the whole design life-cycle can be more meaningful and informative for teachers (Asensio-Pérez et al., 2017).

7. Discussion and Conclusions

Design approaches for teachers facilitate reflection on the integration of new technologies into their everyday teaching practices. Increasing studies acknowledge the shifting from individual to collective teacher practices for anytime and self-directed professional learning (Prestridge, 2019). To support collective teacher practices, web-technologies are used for the sharing of teacher artifacts, resources, collective contributions, and knowledge exchange.

In this paper, we propose the CIDA framework to study and support the collective and inquiry process of teachers as designers in technological environments. The framework was articulated after performing the following steps: a) two studies in teacher communities related to learning design and learning analytics (Michos & Hernández-Leo, 2018; Michos, Hernández-Leo, & Albo, 2018), b) a literature review in frameworks about collective inquiry for knowledge building with technologies. The framework includes three interconnected components to support teachers as designers: the *inquiry process*, the *collective process,* and *technological support*. Regarding *technological support*, ILDE was used for creating and sharing learning designs. A community awareness dashboard (inILDE) was implemented into ILDE to support the *collective process* with data analytics and an inquiry tool for teachers (TILE) was implemented to support the *inquiry process* with learning analytics. Towards cultivating teacher reflective practices, we showed how data collected from teachers in the web-based platform and data collected from students in TEL scenarios can inform teacher collective inquiry. We provide evidence from three inquiry communities of teachers; two communities of school teachers and a MOOC community who were involved in TPD programs. In these programs, teachers reflected upon the teacher and student data (learning designs and learning analytics).

The results obtained from the three case studies inform further the practical implementation of the CIDA framework:

- TPD programs need to consider teacher training in reflective learning design with learning analytics. In this context, teachers online and face-to-face discussions can build technological, pedagogical and content knowledge. Guidance by program coordinators (e.g., tutor facilitated discussion) need to be integrated into the TPD programs so that teachers develop integrated TPACK knowledge.
- The asynchronous and varied levels of teachers´ engagement with collective inquiry can be supported with community platforms and community awareness tools which display aggregated teacher data.
- The implementation of the whole inquiry cycle by teachers adds more value to the collective knowledge which can be shared, re-used and discussed.
- Different teacher roles can emerge and can be further supported according to teachers´ available time. Active and key community members can implement their learning designs while other members can contribute with peer-feedback or re-use some solutions proposed by active members.
- Technological support needs to consider the types of artifacts produced by different inquiry tools so that teachers can share, reuse, discuss and analyze the inquiry process. This can further support the collective process.

The contribution of this paper can inform research in the context of teachers as designers of learning environments (Laurillard, 2013; Goodyear, 2015; Kali, McKenney, & Sagy, 2015; Persico, Pozzi, & Goodyear, 2018) and future implementation in related TPD programs with technologies. Moreover, this paper informs the strand of research about teacher professional learning in web-based communities (Tseng & Kuo, 2014; Hong et al., 2019; Prestridge, 2019) by providing empirical evidence of teacher engagement and perceptions. The CIDA framework and its elements can inspire and guide future research in teacher communities who use other technologies such as social networks (e.g., Twitter, Facebook) or Virtual Learning Environments (e.g. Moodle). Last, this paper proposes technologies and data analytics supports for inquiry communities of teachers and it is connected with research in (collaborative) teacher inquiry (Butler, & Schnellert, 2012; Mor, Ferguson, & Wasson, 2015)

Additionally, the framework can provide design guidance to practitioners. Teachers and teacher educators can use elements of the CIDA framework to develop skills related to digital pedagogy and reflect upon TPD programs with technologies. System developers can also use the framework as an integrated view of teacher design practices with technologies. This will allow the development of tools for teachers and teacher communities similar to the ones proposed in this paper. As a conclusion, the contribution of this paper aims to inform researchers, teachers and system developers by considering the three interconnected components: the *inquiry process*, the *collective process,* and *technological support*.

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Appendix

Table A.1 Sample of interview questions about the collective teacher inquiry process (*N=7*).

	Collective teacher inquiry
1.	Please explain your experience about the group reflections in the project.
a.	Which is the utility of having access to documented inquiry cycles of other teachers?
b.	Are there benefits or challenges to reuse others´ documented inquiries?
c.	Are you willing to share your documented inquiries with other teachers within your school? Why? And outside the school?

Table A.2. School 1: Sample of teachers´ inquiries produced by the TILE tool

Teacher code*	**TS1.a**	**TS1.b**	**TS1.c**
Subject	Economics and Business	Philosophy	Biology and Earth Sciences
Teaching experience	24 years	25 years	20 years
Problem/Questions	Collaborative conclusions from a questionnaire	Brainstorming to define a concept	Brainstorming to define a concept
Intervention / Evaluation	CL activity about conclusions in collected data from students	CL about initial definitions and final conclusions	CL about initial definitions
Collected student data	Engagement, content, observation notes	Engagement, content	Engagement, content, observation notes
Reflections for learning (re) design	Time management, off-task discussions, student understanding, emerged open student attitude, improving instructions before-during task	Time management, achieved brainstorming, management of students´ groups, teacher´s presentation of the task	Time management, off-task discussions, control of the tool, participatory approach, collecting students´ ideas

**TS1= Teacher in School 1*

Table A.3. School 2: Sample of teachers´ inquiries produced by the TILE tool

Teacher code	**TS2.a**	**TS2.b**	**TS2.c**	**TS2.a**	**TS2.g**
Subject	Biology and Chemistry	Earth Sciences	Maths and Technology	Biology and Chemistry	Philosophy
Teaching experience	5 years	14 years	7 years	5 years	25 years
Problem/Questions	Identifying theories from a text in groups	Students distraction in group work	Equity of participation, increasing motivation	Initiate discussion for a subject, instructions provided to students	Collaborative discussion. Contributing own ideas in a discussion.
Intervention / Evaluation	CL text comprehension activity with quotes about theory	CL problem-solving activity	CL problem-solving activity	CL activity for discussion and negotiation	CL activity for discussion of course concepts.
Collected student data	Engagement, content, student feedback	Student feedback peer-assessment	Student feedback	Engagement, content, student feedback	Engagement, content
Reflections for learning (re) design	Time management, off-task discussion, revising feedback questions, dynamic-enriching activity, improved student capacity	Time management, distraction in groups, preparing students for complex task with smaller activities	Time management, increased participation, better role distribution	Technical problems, instructions before the activity, elicitations of ideas	Increased participation, time management, improved argumentation

**TS2= Teacher in School 2*

Table A.4 MOOC community: Sample of learning design artifacts

User id	**Conceptualization / Problem**	**Design / Solution**	**Educational Level**
1533	CL activity about students who do not know each other. Triggering more reflections.	Pyramid activity with Pyramid app	Higher Education

2785	Promote more interactions and reflections between students with different ages and interests.	Pyramid activity with PyramidApp tool	Higher Education
2788	More arguments and elaboration on teaching methods.	Jigsaw activity in Moodle	Teacher training
1548	CL activity about reflection on arts.	Jigsaw which includes the use of Kahoot	Teacher training
1590	CL activity about threats of social networking.	Jigsaw activity in Moodle	Secondary Education
1653	Teamwork on constructing UML diagrams. More experience in teamwork.	Jigsaw activity in Moodle	Higher Education
1623	Understanding key concepts of the causes and effects of overpopulation.	Pyramid activity with PyramidApp	Not specified
1868	Reflect on a theoretical framework with a collaborative activity. Increase student participation.	Pyramid activity with PyramidApp	Higher Education
1542	Gamification to motivate students.	Jigsaw activity in Moodle	Higher Education
3115	Develop communication skills with active interactions.	Jigsaw activity in Moodle	Secondary Education

Table A.5 Sample of interview questions about the teacher inquiry process (*N=7*).

1.	**Technology-supported teacher inquiry**
a.	Please explain your experience with the design, implementation and reflection of the learning designs which you created. Which were the main challenges or problems? Did you overcome them? How?
b.	What could be the role of technology to facilitate a teacher-inquiry cycle?
c.	What do you think are the challenges for you or other teachers to perform inquiries with technology? (e.g. with the use of the TILE tool, with the use of Google forms, PyramidApp to collect data).
2.	**Formative evaluation**
a.	Which collected data and technologies were especially useful for the improvement of your design?
b.	Can you give an example of data use for improving your learning design?

Table A.6 Main topics and sample of teachers´ answers about the teacher inquiry process based on questionnaire and interviews.

Questionnaire			**Interviews**		
Topics	**Explanation**	**Excerpts**	**Topics**	**Explanation**	**Excerpts**
Systematic way/ Collection (3)	Facilitating systematic way to collect student data.	"It allows to collect data in a systematic way. We often do it only in an intuitive way and this way even allows you to reflect in real time, when you have fresher the inputs received from the students." TS1.c	**Documentation for review**	Facilitating documentation for reflection.	"If you have well documented the whole process, then you can make a summary. It is something that could help in future plans." TS1.e
Expectations & Objective evaluations (3)	Facilitating the connection between teachers´ expectations and evaluation	"A good summary of learning objectives and teacher expectations and how the activity was in reality." TS1.k	**Collecting objective data**	Facilitating the collection of objective student data.	"Surely the teachers would have more objective data." TS1.c

Practical (3)	Practical way to reflect on learning design	"It is practical as it forces you to think about the activity from the beginning, do not do the activity directly, but it forces you to write the goal and turn around before moving on." TS1.g	**Awareness / Orientation:**	Provides orientation and key elements for reflection.	The fact that it is separated in different steps helps you to be more aware of what you're doing" TS2.a
Awareness / Orientation (3):	Provides orientation and key elements for reflection	"It summarizes the most important elements (problem, questions, data, reflections) to improve the design." TS2.a	**Limited time/ Many students**	Lack of time and large student cohorts hinder frequent teacher inquiries.	"The time to implement it. Moving from theory to practice is difficult, time is an impediment." TS1.b
			Technical difficulties	Difficulties and familiarity with ICT tools.	"In the implementation, I had some difficulties but basically technical difficulties." TS2.d

Table A.7 Main topics and sample of teachers´ answers about data use for learning design based on questionnaire and interviews.

Questionnaire			**Interviews**		
Topics	**Explanation**	**Excerpts**	**Topics**	**Explanation**	**Excerpts**
Collecting information (5)	Facilitating the collection of student information.	"The most interesting thing about the tool is to collect the information generated during an activity in which it cannot normally be collected. Very interesting to be able to apply it to classes."	**Student misunderstanding**	Identifying student misunderstandings.	The monitoring of discussions allows seeing that students did not understand the concept which you wanted to transmit.
Student feedback (6)	Using student feedback for informing learning design.	"It is important to have feedback from the students to know whether the same activity should be proposed again or modified."	**Student feedback**	Using student feedback for informing learning design.	"I used more the student feedback than the other provided data." TS2.d
Reflections / Improvement (3)	Reflection on learning designs informs their improvement.	"Reflecting on any activity carried out in the classroom always allows for improvement."	**Time & Instructions**	Important to consider time & instructions during enactment.	"They indicated that they were stressed and had not given time to develop a good argument." TS2.a
Time & Instructions (2)	Important to consider time & instructions during enactment.	"It is necessary to find the way to adjust the time and to explain with ease the operation of the activity to the students."			

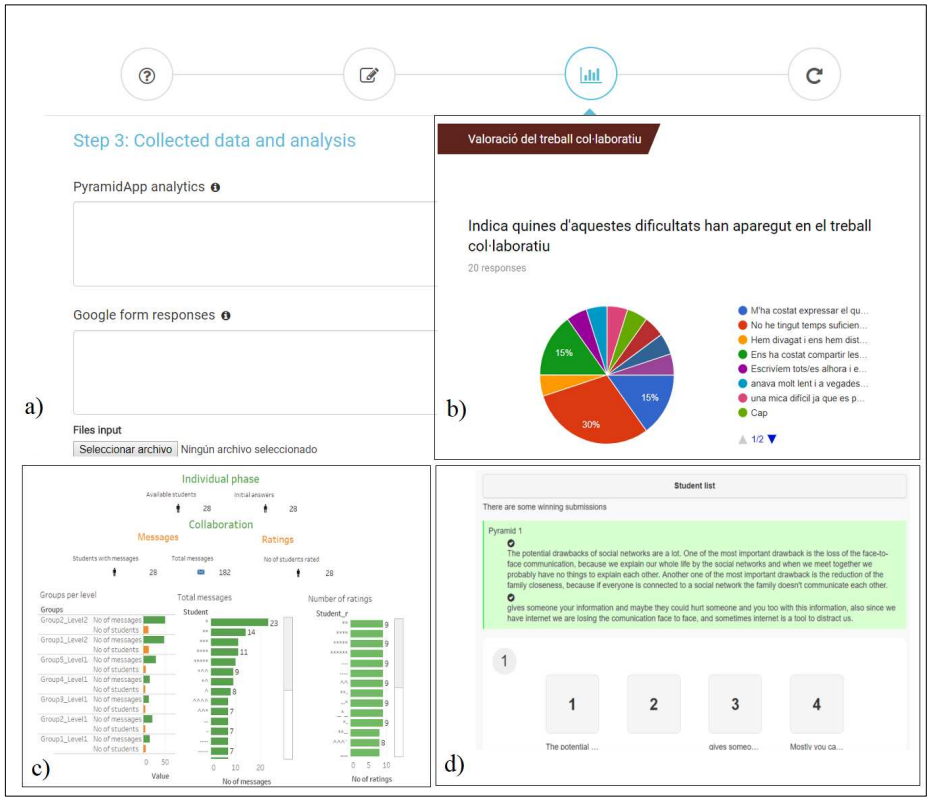

Figure A.1 Example of student data in the 3rd step of the TILE tool. a) TILE tool; b) Student feedback; c) Engagement analytics during the collaborative activity; d) Content of student answers and discussions in the collaborative activity

APPENDIX A: TECHNOLOGICAL SUPPORT & SOLUTIONS

Appendix A is dedicated to the proposed technological solutions which are the result of the three DBR cycles conducted during this thesis work. The technological solutions are example prototypes that support the articulation of the CIDA framework presented in Chapter 4. Appendix A1 complements Chapter 2 and presents figures about the iterative design of the inILDE community dashboard and social network graphs about the study of collective teacher participation presented in section 2.2. Appendix A2 complements Chapter 3 and presents the iterative design of the TILE tool from text-based and Excel-based prototypes to a web-based interactive tool. Related to Chapter 3 about teacher inquiry, Appendix A3 introduces Ld-Feedback, a mobile tool for gathering student and teacher feedback regarding the implementation of learning designs. Ld-Feedback tool was developed with the aim to support data-informed teacher inquiry. A demonstration paper about Ld-Feedback was presented in the EC-TEL 2017 Conference and the complete article is included in Appendix A3. All the proposed technological solutions have been implemented into ILDE installations and are currently available to ILDE community members

A1: inILDE: A community analytics dashboard for learning designs

As explained in Chapter 2, a community analytics dashboard was designed and implemented into the GUI of ILDE. The dashboard[6] was iteratively designed from prototypical visualizations in Tableau to real-time data visualizations using the JavaScript libraries d3.js[7] and chart.js[8]. The detailed study about the design, implementation, and evaluation of the dashboard was presented in Chapter 2. Figure

[6] The dashboard is openly available at https://ilde.upf.edu/pg/lds/inilde/
[7] https://d3js.org/
[8] https://www.chartjs.org/

A1 shows screenshots of the dashboard from visualizations prototypes to real-time visualization in the ILDE´s GUI.

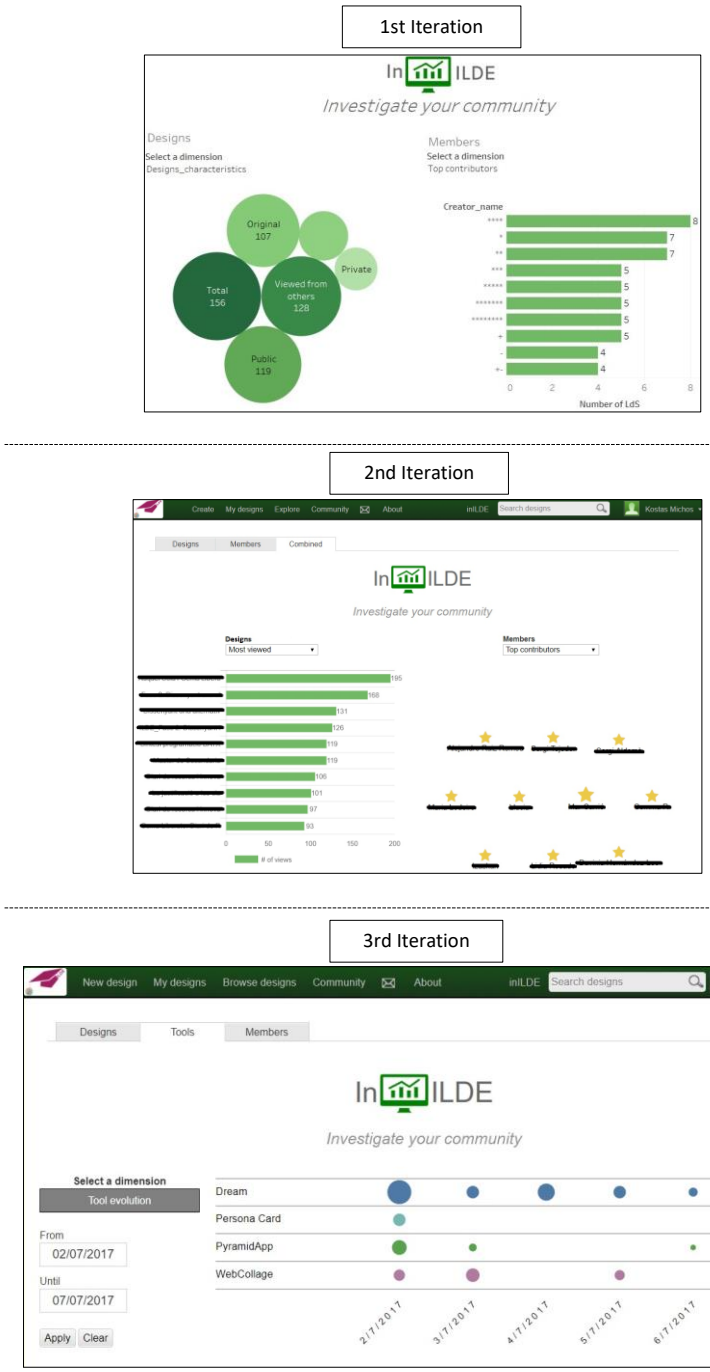

Figure A1. Iterative design of the community analytics dashboard-inILDE

Additional analysis about community analytics for learning design was performed during the thesis work. Before the development of the dashboard, we conducted a study about the collective teacher participation and interactions in three different educational communities who used ILDE. These ILDE installations have been used in the context of two MOOCs for learning design and an open community for learning design. The detailed study is presented in Section 2.2. This Appendix presents figures about SNA graphs which are not included in the published article [Pub2] due to space restrictions. As explained in this article we constructed in each community two directed, weighted networks based on the following relationship: a views network which was representing the one user (node x) viewed the learning design artifact (edge) of another user (node y). Another network represented interactions with comments when a user (node x) commented the learning design artifact (edge) of another user (node y). Network statistics and interpretations of the results are presented in the published article [Pub2]. Figure A2 shows views networks in two MOOCs while Figure A3 shows comments networks respectively.

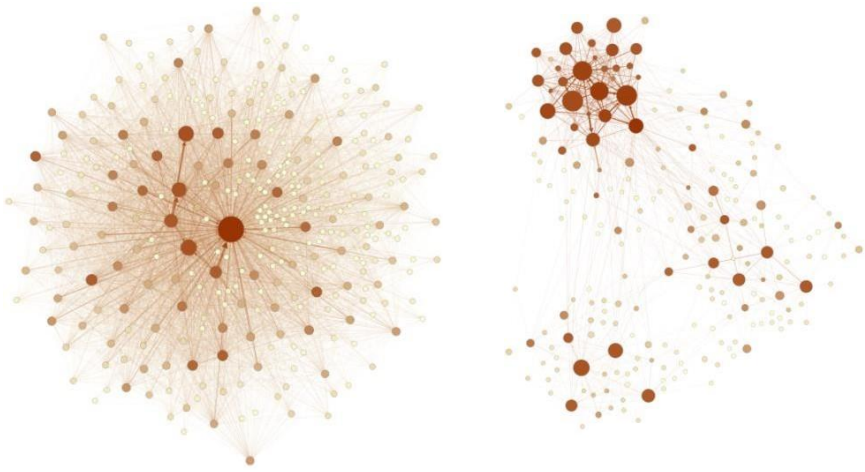

Figure A2. ILDE-MOOC1: Views network (left), ILDE-MOOC2: Views network (right). Dark nodes represent higher volume of views.

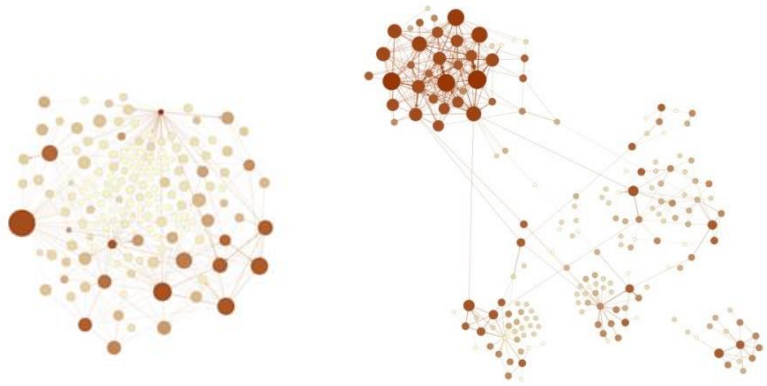

Figure A3. ILDE-MOOC1: Comments network (left), ILDE-MOOC2: Comments network (right). Dark nodes represent higher volume of comments.

Another open community ILDE-demo was analyzed. Figure A.4 shows views network and comments network in this openly available community.

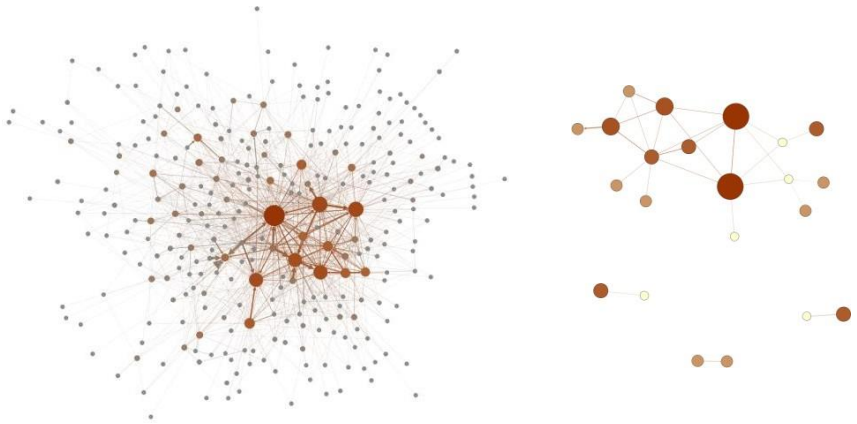

Figure A4. ILDE-demo: Views network (left), ILDE-demo: Comments network (right). Dark nodes represent higher volume of comments.

The above analysis informed the design of the inILDE dashboard for supporting community members´ awareness about the collective participation in ILDE. As shown in Figure A1, the design of the dashboard did not include data visualizations with SNA graphs because they were perceived more complex by teachers.

A.2: TILE: Teacher-led Inquiry for Learning dEsigns

As explained in Chapter 3, a teacher inquiry tool (TILE) was developed to support teachers in data-informed learning design processes. The detailed study about current teacher inquiry practices and the use of TILE[9] in two High schools was also presented in Chapter 3. Appendix A2 shows the GUI of TILE and the iterative design from text-based and Excel-based prototypes to a web-based interactive tool. Figures A5-A8 show the four steps of the current GUI of TILE while Figure A9 presents the iterative design of TILE.

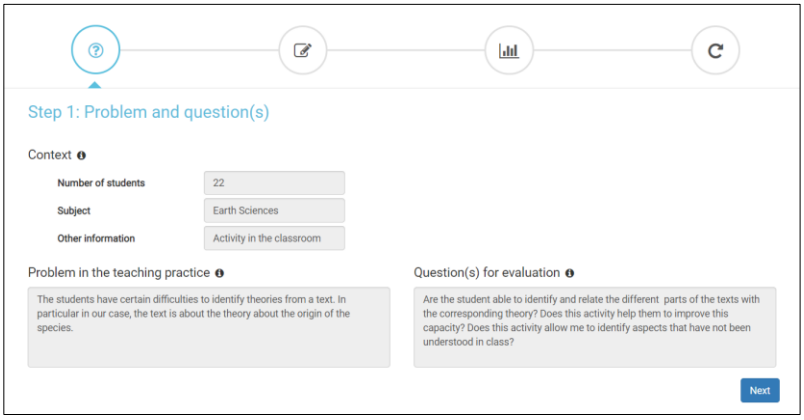

Figure A5. Step 1 in TILE tool: Problem formulation and Questions

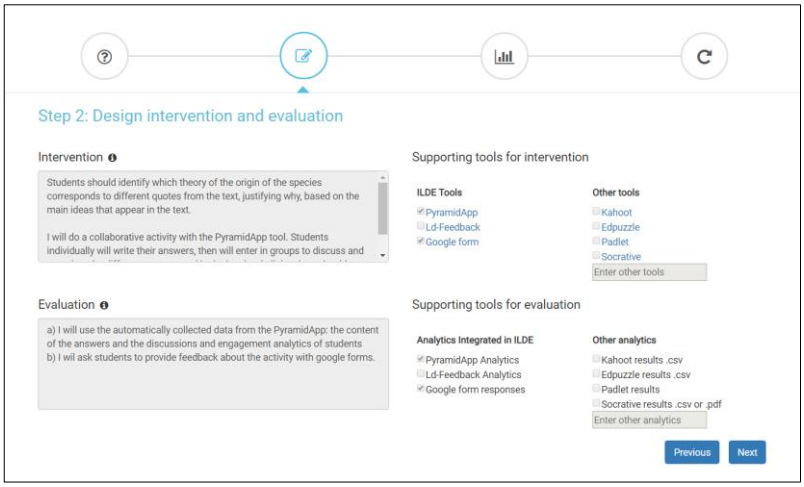

Figure A6. Step 2 in TILE tool: Intervention and evaluation design

[9] An example of a complete teacher inquiry cycle with anonymized student data is available at https://ilde2.upf.edu/dolmen/ve/dui

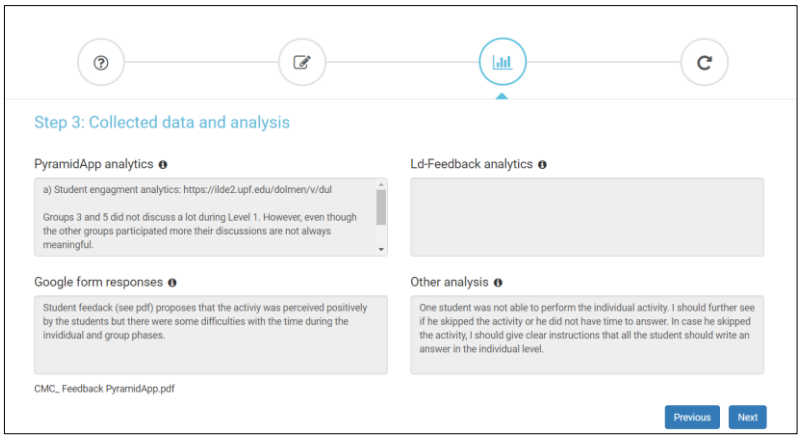

Figure A7. Step 3 in TILE tool: Reporting of collected data and analysis

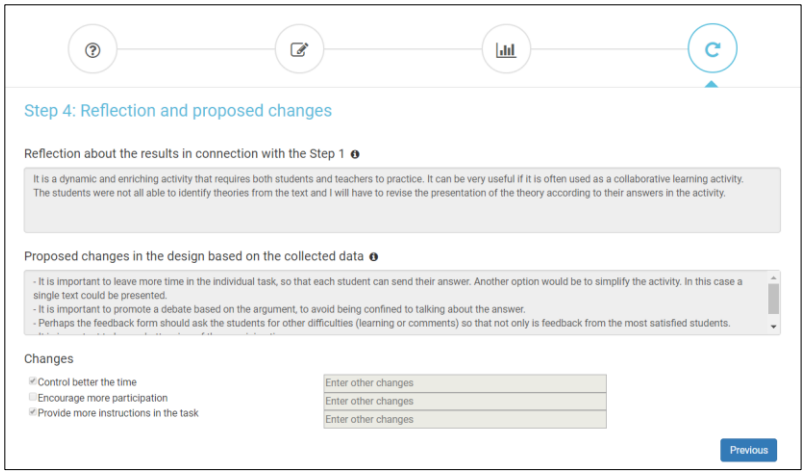

Figure A8. Step 4 in TILE tool: Reflection and proposed instructional changes

As explained in Chapter 3 (Section 3.1), TILE was iteratively designed during a TPD program for High School teachers. We initially used text-based and Excel-based prototypes to structure the inquiry process in 4 steps. Based on the feedback received by teachers, we developed TILE as a web-based interactive tool which was integrated with learning design tools into ILDE. TILE users can create a teacher inquiry cycle and share it within an ILDE installation.

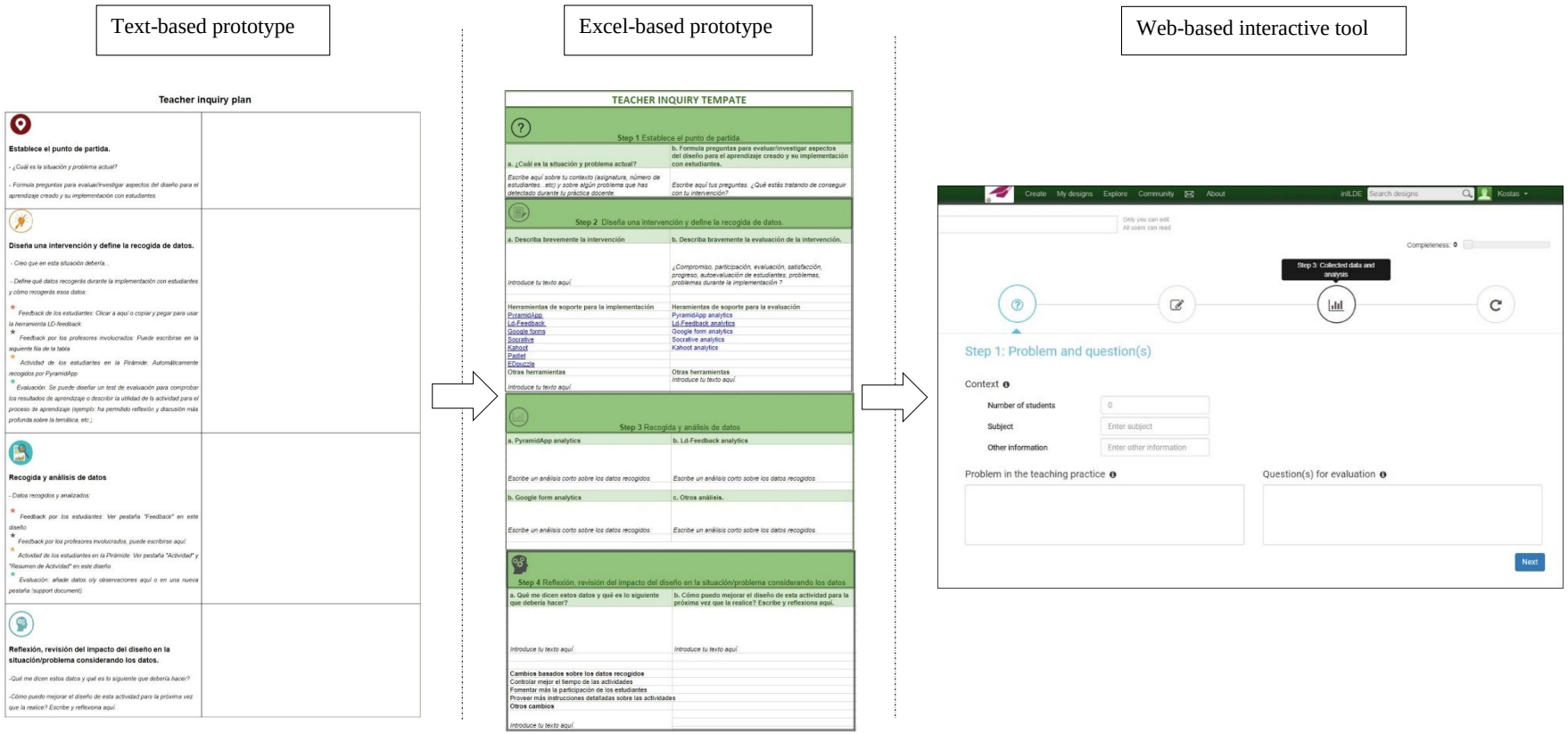

Figure A9. Iterative design of the teacher inquiry tool-TILE

A3: Ld-Feedback App: Connecting Learning Designs with Students' and Teachers' Perceived Experiences.

During the analysis phase of the 1st DBR cycle, we evaluated teachers´ collective information needs about learning designs (see Chapter 2, section 2.1). One of the needs referred to teaching experiences gained from the implementation of learning designs and student related information. Toward supporting this, we developed a mobile tool (Ld-Feedback App) for gathering feedback about the implementation of learning designs. The tool is also integrated into ILDE installation and users can explore learning designs together with feedback reports generated by Ld-Feedback. The Ld-Feedback App[10] was presented as a demonstration conference paper and was published in the proceedings of the EC-TEL 2017 conference. Appendix A3 presents the complete article about the Ld-Feedback App as follows:

Michos, K., Fernández, A., Hernández-Leo, D., & Calvo, R. (2017). Ld-Feedback App: Connecting Learning Designs with Students' and Teachers' Perceived Experiences. *In European Conference on Technology Enhanced Learning* (pp. 509-512). Springer, Cham (LNCS). https://doi.org/10.1007/978-3-319-66610-5_51

[10] The Ld-Feedback App is openly available at https://ilde.upf.edu/feedback.

Ld-Feedback App: Connecting Learning Designs with Students' and Teachers' Perceived Experiences

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Abstract. This demonstration paper presents the Ld-Feedback mobile application. A variety of learning design tools were developed during the last years. However, there is still lack of substantial understanding on how learning designs are implemented and experienced by students and teachers. Ld-Feedback is connected with the Integrated Learning Design Environment (ILDE) and allows students and teachers to provide feedback during and after the implementation of learning designs. Two interfaces allow teachers to create feedback forms and generate reports for their learning designs' implementations. Students and teachers access feedback forms to evaluate learning designs with ratings and comments. The development of the application aims at facilitating teacher-led inquiry by providing data informed insights for learning designs within communities of educators.

Keywords: Learning design · Student and teacher feedback · Teacher inquiry · Redesign · Communities of educators

1 Introduction

Learning Design (LD) is the field that studies how teachers/designers revise learning activities towards more pedagogically informed decisions to achieve educational objectives [1]. One of the main directions is on how the tacit work of teachers/designers can be represented and shared among educational practitioners [2]. A variety of digital tools were developed to support LD [3] while web-based platforms allow educators to share their learning designs, e.g. LAMS community [4], Learning Designer [5], ILDE [6]. However, limited work so far focuses on "what happens after the design process" [7]. Although LD representations provide a result of the decision making process of the teacher/designer, few information is available for previous particularizations of a learning design, the learners' preferences of the delivery mode and reflection about the teachers' run-time experience [8]. Data-informed learning designs when implemented with learning technologies can take advantage from the digital footprints of students like learning analytics visualizations but teachers/designers often need qualitative data and understanding of how students perceived their learning experience to better inform the redesign of learning activities [9, 10].

É. Lavoué et al. (Eds.): EC-TEL 2017, LNCS 10474, pp. 509–512, 2017.
DOI: 10.1007/978-3-319-66610-5_51

Mobile apps have been increasingly adopted by educators for the facilitation of their teaching and learning. Mobile tools enable teachers to capture real time information from class activities, to move beyond the classroom setting and even author learning activities [11]. In the ecosystem of LD tools few authoring tools connect elements of the design-time with the run-time evaluation of learning designs. An empirical study of a mobile application for location game-based learning presents visualizations of students' activities' enactment to enable teachers revise their learning design [12]. The visualizations supported teacher inquiry with awareness information of students' activity. These studies show the value of learning analytics but they also conclude that students' and teachers' opinion about the implementation of learning activities would also be highly relevant to understand the impact of learning designs. The tool described in this paper aims at facilitating the collection and reporting of this type of feedback information. The approach considered in the design of the tool is generic in that the tool can be applied to multiple types of learning designs, not being specific to particular learning designs tools.

2 Ld-Feedback Mobile App

Ld-Feedback is a mobile application which allows students and teachers to provide feedback regarding the implementation of learning designs created with multiple tools. To achieve that, the application is connected with the Integrated Learning Design Environment (ILDE), a web-based community platform for the creation, co-creation and sharing of learning designs [6]. The application includes two interfaces for supporting teachers and students in providing feedback for learning designs' implementations. Ld-Feedback also runs in non-mobiles devices such as laptops and tablets.

The teacher interface allows teachers to create forms called "Feedback Check". The user selects from a dropdown list one learning design created in ILDE and associates the feedback check to the particular learning design. The feedback is authored by the teacher (e.g. feedback for the whole learning design or partial for a learning activity). The form consists of a default template with items regarding the effectiveness of the whole learning design which can be edited by the teacher. The default template includes three items about students' subjective learning, level of engagement and enjoyment but the teacher can also edit the default items or add other items. Two additional options allow users to enable feedback comments from students and presentation of the results to students. Once the Feedback Check is ready, the teacher can start a feedback session and a code for students is auto generated.

The students can insert the code in the student interface and rate the items in a scale (2 = Awful, 4 = Not very good, 6 = Good, 8 = Very good, 10 = Brilliant) as they were edited by the teacher. Students can write comments about their general experience of the particular learning session. The items of the feedback form depend on the teacher inquiry problem addressed within the particular learning design.

The teacher can stop the feedback session from the professor interface and view the results of the feedback check as a report. Moreover, he/she can enable the presentation of the results to the students so they become aware of their class. The report shows the

overall rating between 2-10 and the rating of each item following by all the comments provided by students (Fig. 1). The reports can be visualized in the Ld-Feedback App or in the context of ILDE.

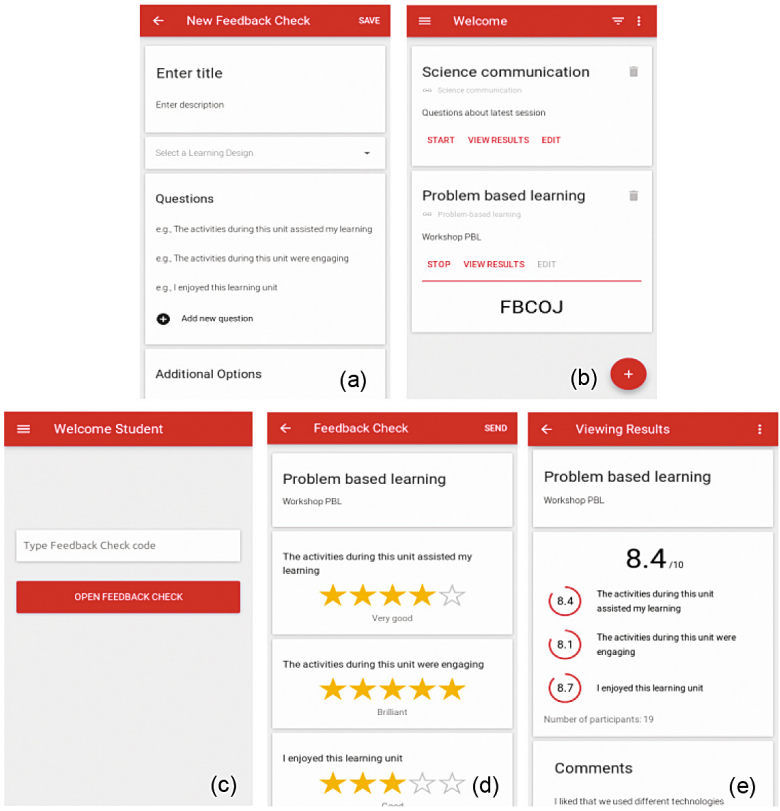

Fig. 1. Screenshots of the Ld-Feedback App. (a) & (b) Teacher interface, (c) & (d) student interface, (e) visualization of students' responses.

A first illustrative case was used in a teacher workshop as part of a project for data informed learning designs within communities of teachers. The Ld-Feedback App was used by the facilitator of the workshop to evaluate elements of the workshops' learning design. Initial teachers' opinion as students in this case was that Ld-Feedback is a useful teacher support tool and its strong point is the intuitive and simple to use interface.

3 Conclusion

This paper presented the Ld-Feedback App, a mobile application which associates learning designs with feedback forms and enables students and teachers to report about their experience. A new generation of data-informed learning design tools aims to support teacher-led inquiry. The experiences of the different stakeholders including teachers and students when using the application will better show how data analytics

can inform the quality of learning experiences. Implementations of learning designs from a community of teachers would also reveal effectiveness of different learning-teaching strategies.

Acknowledgments. This research is partly funded by RecerCaixa CoT project and the Spanish Ministry of Economy and Competitiveness under RESET (TIN2014-53199-C3-3-R) and the Maria de Maeztu Units of Excellence Programme (MDM-2015-0502). DHL is a Serra Hunter Fellow. The authors want to sincerely thank Pablo Abenia for the support to the development of this application.

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APPENDIX B: INSTRUMENTS IN EVALUATION STUDIES

During the evaluation studies, we used different instruments to evaluate teachers´ perceptions about the proposed technological solutions and the overall experience about the collective inquiry framework and the TPD programs. Appendix B presents the content of the research instruments used in the 1st cycle of the DBR methodology about the design and evaluation of the inILDE dashboard. Additionally, this Appendix presents instruments about the evaluation of teacher inquiry cycles with the TILE tool in the 2nd and 3rd DBR cycle. Last, Appendix B includes links to published datasets and instruments which are openly available in Zenodo[11]. Main results and additional instruments about the evaluation studies were presented in Chapters 2, 3 and 4.

During the 1st DBR cycle, we iteratively developed and evaluated the inILDE community dashboard. We initially designed prototypical visualizations in Tableau and used real-data sets from three educational communities (two High schools and a pre-service teacher community). Teachers were presented with the prototypical visualizations of the dashboard during face-to-face TPD workshops and a post-questionnaire was used to evaluate the perceived usefulness of the visualizations for specific use cases. The questions referred to the three different tabs of the dashboard about aggregated community information for the created designs, the learning design tools and the community members. Moreover, teachers were asked to mention positive, negative elements of the dashboard and recommendations for improvements. Figure A10 shows a sample of the questionnaire in Google forms. In the second iteration, we improved the design of the dashboard based on initial feedback and integrated real-time visualization into the ILDE GUI.

[11] https://zenodo.org/

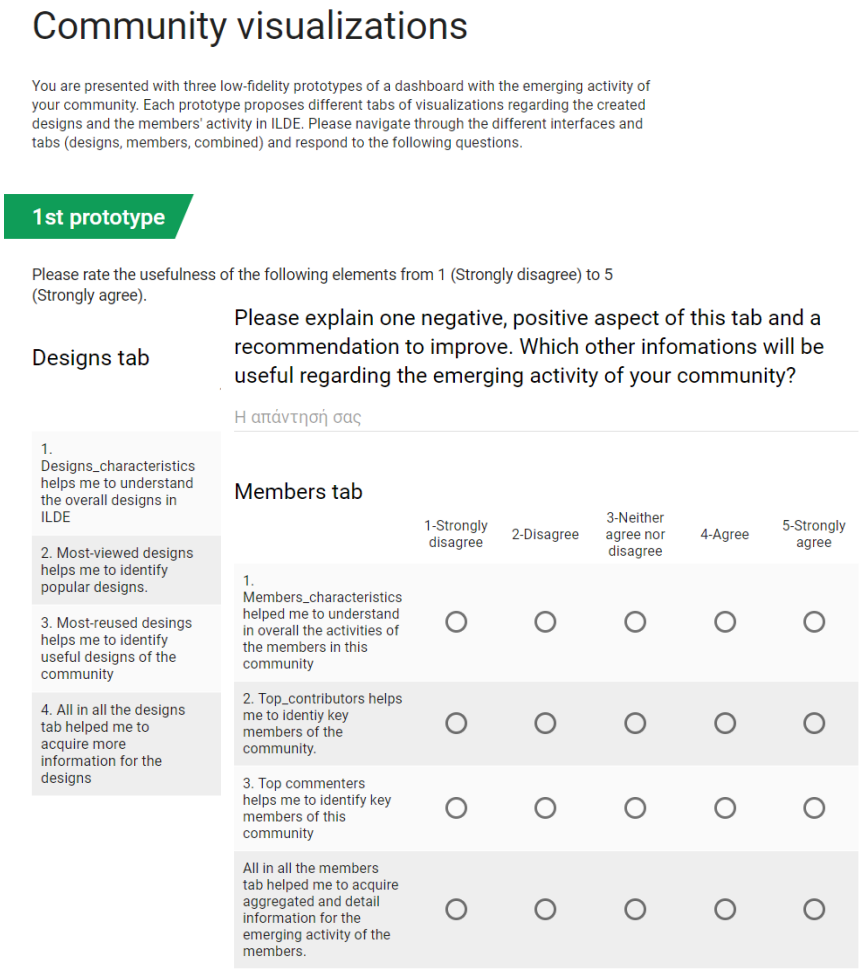

Figure A10. A sample of questions about the evaluation of prototypical community visualizations.

In the final evaluation, we implemented the inILDE dashboard in a MOOC for learning design which lasted six weeks. After the completion of the MOOC, the participating teachers were asked to respond to a questionnaire about the perceived user experience of the dashboard. The questionnaire was constructed based on the UMUX items (Finstad, 2010) and was available in the final MOOC questionnaire in the Canvas platform. Table A1 shows the items of the questionnaire.

Table A1. User Metric for User Experience-UMUX questionnaire for evaluating the user experience of the community dashboard inILDE

Question: Please indicate if you used the inILDE community dashboard during the course. If you indicated yes, please respond to the following questions: (Likert scale: 1-Strongly disagree, 7-Strongly agree)
1.Effectiveness. Question: The capabilities of the inILDE community panel meet my requirements.
2.Satisfaction. Question: Using the inILDE community panel is a frustrating experience.
3. Overall. Question: The inILDE community panel is easy to use.
4. Efficiency. Question: I had to spend too much time interacting with the interface of the inILDE community panel.

During the 2nd DBR cycle, we analysed current teacher inquiry practices in schools based on three constructs: a) learning design, b) formative evaluation of learning activities, and c) teacher collaboration. The questionnaire was designed based on the research question [RQ2a] and related work in a teacher inquiry study in school communities (Butler & Schnellert, 2012). Table A2 shows the items of the questionnaire.

Table A2. Questionnaire about the current teacher inquiry practice in the two schools.

	What is the current teacher-led inquiry practice in different school communities?
	Likert scale: 1-Never, 2-Rarely, 3-Sometimes, 4-Often, 5-Always
a.	**Learning design**
1.	How often do you design your own learning activities for your students?
2.	How often do you document the learning activities which you do with your students? ("Documenting" means writing in detail the descriptions of the activities, e.g. tasks, tools and resources used, etc.)
3.	Please provide comments for your answers (if you use tools to document activities, indicate which tools).
b.	**Formative evaluation of learning activities**

4	How often do you reflect (e.g. using your own feelings, thoughts) about the impact of the learning activities to improve them for the next course or lesson?
5	How often do you collect data from what students do in the learning activities to understand their impact?
6	How often do you collect data for the students´ opinion about the learning activities?
7	Please provide comments for your answers. If you use tools for these aspects, indicate which tools.
c.	**Teacher collaboration**
8	How often do you collaborate with other teachers in the design of activities?
9	How often do you share with other teachers the activities which you design?
10	Please provide comments for your answers. If you use tools to work with other teachers, indicate which tools.

N=*14* teachers implemented technology-supported collaborative learning activities in their classrooms and documented a whole teacher inquiry cycle with the TILE tool. After the implementations, we selected *N*=7 teachers from both schools and conducted semi-structured, face-to-face 40 minutes interviews. A sample of interview questions is presented in Table A3.

Table A3. Sample of interview questions about the teacher inquiry process.

a.	**Technology-supported teacher inquiry**
1.	Please explain your experience with the design, implementation, and reflection of the learning designs which you created. Which were the main challenges or problems? Did you overcome them? How?
2.	What could be the role of technology to facilitate a teacher-inquiry cycle?
3.	What do you think are the challenges for you or other teachers to perform inquiries with technology? (e.g. with the use of the TILE tool, with the use of Google forms, PyramidApp to collect data).
b.	**Formative evaluation**
4	Which collected data and technologies were especially useful for the improvement of your design.
5	Can you give an example of data use for improving your learning design?
c.	**Teacher collaboration**
6	Which is the utility of having access to documented inquiry cycles of other teachers?
7	Are there benefits or challenges to reuse others´ documented inquiries?

8	Are you willing to share your documented inquiries with other teachers within your school? Why? And outside the school?

In the 3rd DBR cycle, we coded teachers´ online comments based on the TPACK framework (Koehler & Mishra, 2005) to understand the types of knowledge activated during joint teacher reflections with student data. The complete study and data analysis of the 3rd DBR cycle is presented in Chapter 4. Table A4 shows the coding scheme and excerpts of teachers´ online comments.

Table A4. Coding scheme based on the TPACK framework.

Code	Meaning	Excerpt
TK	Use of computers without referencing to learning or teaching	"We have reached similar conclusions regarding the use of the tool."
PK	General teaching and learning strategies or learning activities.	"The activity seems suitable for learning. The students show satisfaction for the learning and the methodology used."
CK	Subject-matter regarding discussions.	"The discussions between the group members are in the form of chat, with incomplete and little-argued answers."
TPk	Use of computers related to teaching/learning and classroom practice.	"The activity is very good in favoring the participation of all the students in making a conclusion. However, the data shows that the number of students' responses is not equal. It may be due to connection problems, so I think it is very important to be able to keep pace with what is happening in class (if they do not respond to technical problems, connection to the internet or for lack of ideas) to be able to make an assessment, which may not show the statistics."
TCk	Use of computers to represent subject matter knowledge.	(Not present in teachers' comments)
PCk	Teaching and learning strategies related to subject matter.	"Students need more guidance in how to ask questions and answers in a debate. There is a lot of difference in how they talk about each other as they write the final answer. I think it's

		important because the debate is not enriched."
TPCk	Integrated use of computers related to teaching and learning strategies and content knowledge	"It is an interesting activity. It makes a comprehension work dynamic and generates debate among the students. The technology enables the collection of data that can be reviewed to improve the activity."
Other	Social appraisal comments and other feedback.	"Very good activity, very interesting reflections arise."

During the thesis work, we included part of the above instruments as supplementary material together with the published articles. Moreover, we published open datasets in the open research repository Zenodo. The datasets are available as follows:

- Michos, K., & Hernández-Leo, D. (2018). Supporting awareness in communities of learning design practice [Data set]. Zenodo. http://doi.org/10.5281/zenodo.1209079

- Hernández-Leo, D., & Michos., K . (2018). Understanding collective behavior of learning design communities [Data set]. Zenodo. http://doi.org/10.5281/zenodo.1207447

- Michos, K, & Hernández-Leo, D., Albó, L. (2018). Teacher-led inquiry in technology-supported school communities [Data set]. Zenodo. http://doi.org/10.5281/zenodo.1403643

APPENDIX C: ADDITIONAL RELATED PUBLICATIONS

Appendix C includes two additional publications related to the thesis work. The articles present two studies in the Higher Education context about the connection between LD and LA and relate with Chapter 3 about studying and supporting the inquiry process of teachers as designers. The first related publication presents an embedded case study in a workshop for blended learning with MOOCs. In this study, teachers were provided with paper-based prototypes of learning analytics visualizations regarding student achievements, progress, engagement, and satisfaction. Teachers were asked to reflect on how these types of learning analytics can inform redesign elements of their blended learning courses. The second related publication presents a study about four university teachers/instructors who conducted MOOCs in the FutureLearn platform. The teachers were provided with learning analytics reports from the courses they have offered combined with student's surveys.

The first article was published in CEUR proceedings of the Fourth International Workshop on Teaching Analytics co-located with the EC-TEL 2016 Conference:

Michos, K., & Hernández Leo, D. (2016). Towards understanding the potential of teaching analytics within educational communities. In *Vatrapu R, Kickmeier-Rust M, Ginon B, Bull S. IWTA 2016 International Workshop on Teaching Analytics. Proceedings of the Fourth International Workshop on Teaching Analytics, in conjunction with EC-TEL 2016, Lyon, France. p. 1-8.* CEUR Workshop Proceedings.

Abstract
The use of learning analytics in ICT-rich learning environments assists teachers to (re)design their learning scenarios. Teacher inquiry is a process of intentional and systematic research of teachers into their students´ learning. When teachers work in small groups or

communities and present results of their practice more interpretations are generated around the use and meaning of this data. In this workshop paper we present preliminary research about four dimensions of learning analytics (engagement, assessment, progression, satisfaction), and their visualization as teaching analytics, that are hypothesized to be relevant to help teachers in the (re)design of their learning scenarios. Moreover, we evaluate teachers' acceptance of exchanging these types of analytics within their teaching community. A workshop for blended MOOCs design (N=20 participants) showed that although all the analytics dimensions were valuable, assessment data was the most useful dimension for (re)designing while data about the engagement of students was the less useful. Educational practitioners also showed interest in knowing a combination of specific data (e.g. achievements related with the satisfaction of students). Last, most participants expressed their willingness to share visual learning analytics related to their designs with their colleagues. The role of contextual information to interpret the learning analytics was recognized as important.

The second article was published in CEUR proceedings of the Work in Progress papers of the Experience and Research Tracks at EMOOCs Conference 2017

Michos, K., Hernández Leo, D., & Jiménez-Morales, M. (2017). How educators value data analytics about their MOOCs. In *Delgado Kloos C, Jermann P, Pérez-Sanagustín M, Seaton D, White S, Jansen D, Calise M, editors. EMOOCs 2017 Conference 2017, May 22-26, Leganés, Spain, p. 77-82.* CEUR Workshop Proceedings.

Abstract

A range of data analytics is provided to educators about the profile, behavior and satisfaction of students participating in a Massive Open Online Course (MOOC). However, limited research has been conducted on how this informs the redesign of next MOOC editions. This work-in-progress paper presents a study of 4 MOOC educators from Universitat Pompeu Fabra regarding 3 MOOCs offered on the FutureLearn platform. The objective was to evaluate the usefulness and understandability of different types of data analytics of the courses they have offered with respect to specific monitoring goals. Preliminary results show that educators perceived the same

information sources and data visualizations differently, satisfaction surveys and comments in the forum were among the most useful information but it was difficult to associate data analytics with the monitoring goals. Further studies for the alignment of educators´ monitoring needs for redesign purposes and the development of appropriate support tools are suggested

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