

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 artefacts, 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.

Keywords

Learning design, teacher-led inquiry, learning analytics, school communities

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) (Kali, McKenney, & Sagy, 2015; Goodyear, 2015). Benefits of this approach are that teachers reflect on their own work and learn by designing (Kali, McKenney, & Sagy, 2015). In addition, the Learning Design (LD) field contributes with languages, practices and tools which guide teachers to effectively design and share artefacts for their students' 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 artefacts 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 optimise learning environments" (Ferguson, 2012).

Toward 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 et al., 2015). There is also a need to cultivate the practice of teachers acting upon learner data to improve learning design decisions i.e. data literacy and metacognitive processes (Schmitz et al., 2017; Michos, Manathunga, Hernández-Leo, 2016). 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 et al. (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 (e.g., with learning analytics).

Teacher reflective practice has a long tradition in teacher education and professional development. The works by Dewey (1993) 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, 2013). 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 socio-cultural system (Sannino, Engeström, & Lemos, 2016; Butler & Schnellert, 2012). 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: a) Definition of a “wondering” question which emerges from everyday practice; b) Development of a plan to collect data in the classroom; c) 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 et al., 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 et al., 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.
- *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 (Hernandez-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 artefacts generated by others related to the above four inquiry steps.

Figure 1: Teacher Inquiry tool for Learning dEsigns (TILE). Example at <https://ilde2.upf.edu/dolmen/ve/dui> (Michos, Hernández-Leo, & Albó, 2018).

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, 1987). 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: a) research questions mainly focus on “how” and “why”; b) behaviors in cases cannot be manipulated and c) 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*).

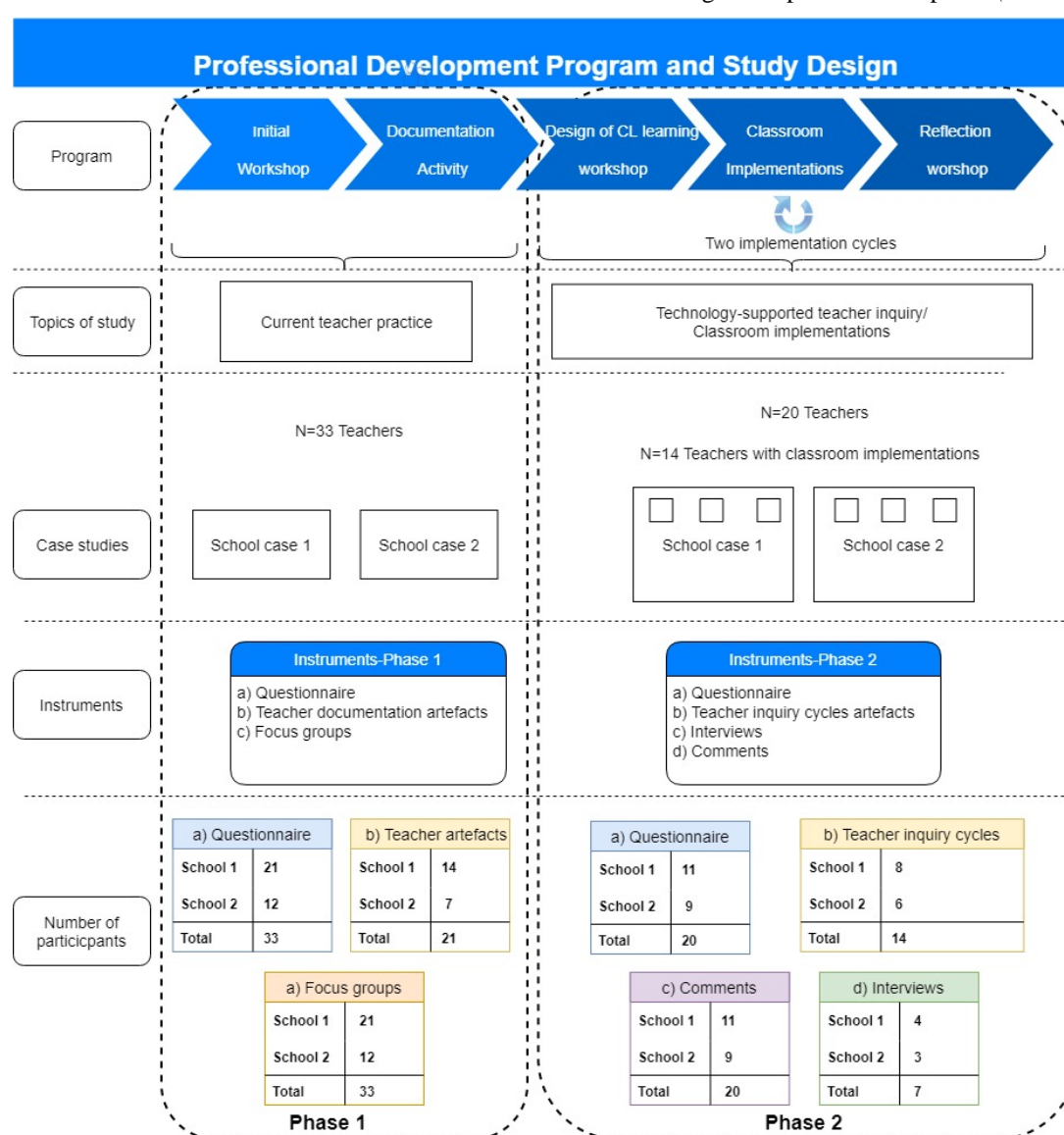


Figure 2: Professional Development Program and embedded multiple case study design in the two schools.

Context

The PD program focused on the meaningful use of ICT to a) train teachers as designers of 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 schools. Several

researchers were involved in the facilitation of the workshops. The study took place from November 2016 until February 2018. ILDE was the 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*, thirty-three teachers ($N=33$) participated in the study and the PD program (see appendix Table A.3). $N=20$ 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-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: a) learning design considering the design and documentation of learning activities by school teachers; b) formative evaluation of learning designs considering the collection of data and the informal reflection of teachers; and c) teacher collaboration. An initial questionnaire (see Table A.1 in appendix) aimed at analyzing the frequency of the above constructs and open questions, focus groups and teacher artefacts 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 a) technology-supported teacher inquiry b) formative evaluation and c) teacher collaboration. For the analysis, we used the documented artefacts from TILE, teacher

comments in ILDE and a questionnaire with open questions. Lastly, seven 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 A.2). 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, teacher artefacts) 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 A.4).

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 artefacts) 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 e.g., 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).

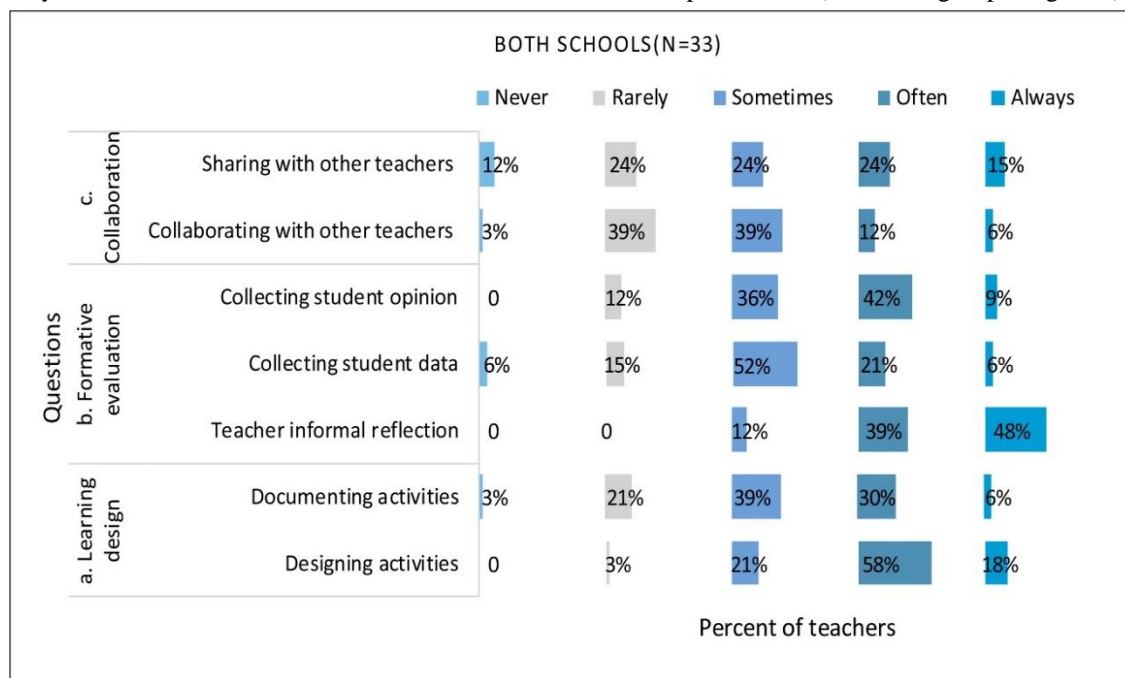


Figure 3: Teachers' responses about frequency of design and documentation of activities, formative evaluation and teacher collaboration in the two Schools (Likert scale 1-5-Always)

Current teacher inquiry practice in School 1			
	Questionnaire (Open questions)	Focus groups	Teacher artefacts
Learning design	<p>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." <i>TS1.a</i></p> <p>Resources and subject websites (4): "Sites,weebly"<i>TS1.f</i>, "Video, photography, evaluation tables, subject websites." <i>TS1.g</i></p>	<p>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."</p>	<ul style="list-style-type: none"> • Group tasks (6) • Student instruction (4) • Objectives (3) • Fases, steps, time (3)
Formative evaluation	<p>Student feedback questionnaire (7): "We carry out an evaluation about the satisfaction of the course with a survey, but not related to each activity." <i>TS1.m</i></p> <p>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" <i>TS1.e</i>, "I often go and look and take notes about what they are doing" <i>TS1.a</i></p> <p>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." <i>TS1.i</i></p>	<p>Students' self-evaluation: "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."</p>	<ul style="list-style-type: none"> • Assessment rubrics (1) • Observation notes (1)
Teacher collaboration	<p>Google drive/LMS/Emails(5): "Google drive, virtual environment, mail..." <i>TS1.g</i></p> <p>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." <i>TS1.i</i></p>	(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 evaluations and teacher collaboration based on a questionnaire, focus groups and teacher-generated artefacts.

Teachers' documentations in ILDE show characteristics of their designs and reflective documentations (see Figure 5 for an example of teacher artefact). 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).

ACTIVITY: "Letter to myself"			
COURSE LEVEL	High school	MATERIALS	<ul style="list-style-type: none"> • A blank sheet • A pen
SCOPE	<ul style="list-style-type: none"> • Reflection, evaluation • Effort culture 	OBSERVATIONS	<p><u>February 2017 (first-year high school students):</u></p> <p>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.</p>
OBJECTIVES	<ul style="list-style-type: none"> • 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	<ol style="list-style-type: none"> 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. <p>Time: 40 minutes</p>		

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

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.

Technology-supported teacher inquiry

In School 1, eight 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 20-30 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 4 steps of the inquiry process and the available student data.

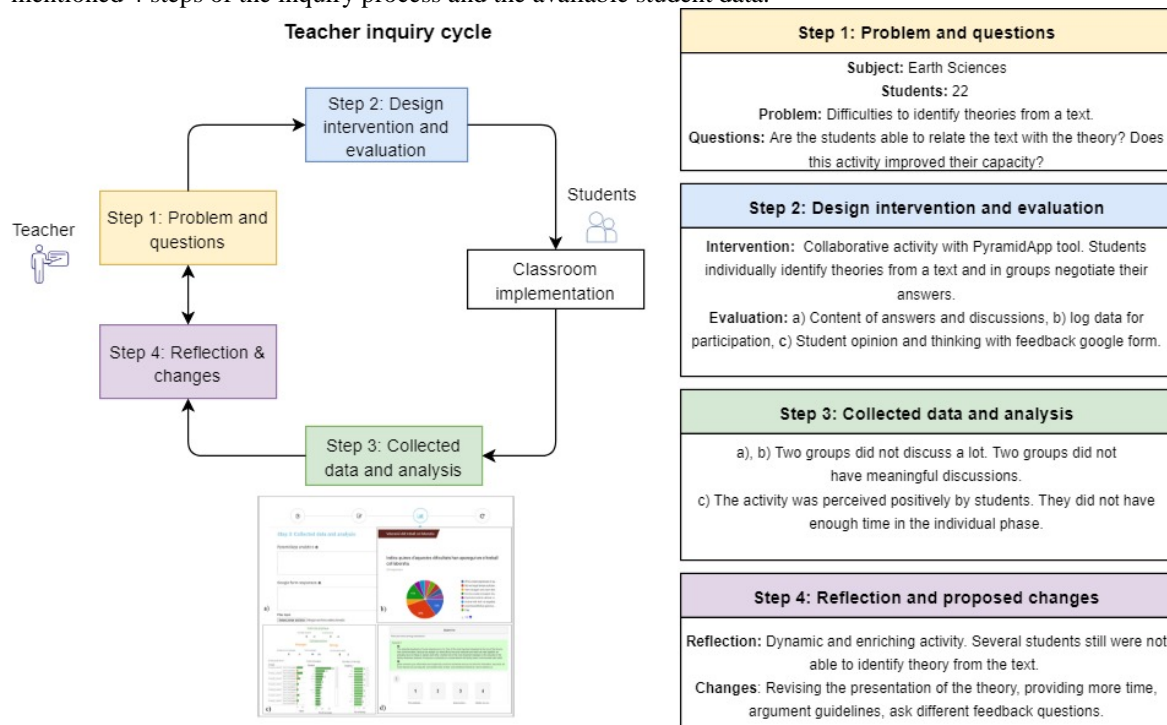


Figure 6: Example of what a teacher produced with the TILE tool. Access to the TILE tool at <https://ilde2.upf.edu/dolmen/ve/dui>

Table A.4 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 artefacts 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 artefacts included a reflection about time management. Lastly, joint reflections from 8 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 (e.g., per activity, unit, semester) and the need to devote time for documentation (see Table A.7 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 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.

Teacher inquiry with technology in School 1			
	Questionnaire (Open questions)	Interviews	Comments in ILDE
Teacher inquiry (TILE)	<p>Systematic way/collection (3): "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." <i>TS1.c</i></p> <p>Expectations and objective evaluations (3): "A good summary of learning objectives and teacher expectations and how the activity was in reality" <i>TS1.k</i></p> <p>Practical (3): "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" <i>TS1.g</i></p>	<p>Documentation for review: "If you have well documented the whole process, then you can make a summary. It is something that could help in future plans" <i>TS1.e</i></p> <p>Collecting objective data: "Surely the teachers would have more objective data" <i>TS1.c</i></p> <p>Limited time, many students: "The time to implement it. Moving from theory to practice is difficult, time is an impediment" <i>TS1.b</i>.</p>	(No comments related to that topic)
Formative evaluation	<p>Collecting information (3): "The most interesting thing about the tool is to collect the information generated during an activity in which it can not normally be collected. Highly interesting to be able to apply it to classes" <i>TS1.c</i></p> <p>Feedback from students (3): "Important feedback from the students to know whether the same activity should be proposed again or modified" <i>TS1.f</i></p> <p>Reflections / Improvement (3): "Reflecting on any activity carried out in the classroom always allows for improvement." <i>TS1.g</i></p>	<p>Student misunderstanding: "The monitoring of discussions allows to see that students did not understand the concept which you wanted to transmit." <i>TS1.c</i></p>	<p>Student participation (3)</p> <p>Student misunderstanding (2)</p> <p>Collecting information (2)</p>
Teacher collaboration	<p>Useful (3): "It is clearly useful to see what the colleagues do in their class and sometimes there are no spaces to share" <i>TS1.g</i></p> <p>Improvement (3): "It is enriching and allows you to improve your designs although activities of other subjects not always contribute to the designs in your area." <i>TS1.s</i></p> <p>Initial stage of design (2): "Especially when you start it is important to have ideas to know how to plan the activity you want to raise and see what kind of approach of the activity may not work." <i>TS1.f</i></p>	<p>Gaining knowledge: "It always allows you to reflect and gain knowledge from people who have more time than you." <i>TS1.e</i></p> <p>Shared problem-solving: "I think it is very helpful to know how other teachers face problems. We realize that we almost have the same problems." <i>TS1.a</i></p> <p>Differences between subjects: "It is a challenge to re-use student feedback gained in other subjects" <i>TS1.b</i></p>	(No comments related to that topic)

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.

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 A.7, 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 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.

Current teacher inquiry practice in School 2			
	Questionnaire (Open questions)	Focus groups	Teacher artefacts
Learning design	<p>Photos and videos (3): "Not everything is always described in detailed, but the modifications are incorporated into the program. In addition, we use videos and photos to document experiences" TS2.d</p> <p>Personal agenda (2): "I write the activities with dates, to an exclusive notebook. Sometimes I also point them to a custom calendar and my personal agenda" TS2.f</p>	<p>Student instruction: "I document the instructions which I give to students in a word document and I upload the materials in the LMS"</p>	<ul style="list-style-type: none"> • Resources (5) • Activity description (4) • Objectives (3)
Formative evaluation	<p>Student feedback questionnaires (7): "At the end of each quarter, I do an evaluation with the students of each subject. Generally, they have to value numerically (1-10) different items and I ask them to comment specially the items in which the ratings are lower." TS2.a</p> <p>Observation notes (5): "I collect information about activities in observation and evaluation notes" TS2.e</p>	<p>Observation: "I only observe if it works or not, if the material was useful for its purpose or not."</p>	<ul style="list-style-type: none"> • Instructions for evaluation (1) • Observation notes(1)
Teacher collaboration	<p>Same subject teachers (3): "I share with my department colleagues and especially with the partner with whom we work on the same subject" TS2.g</p>	<p>Informal sharing (3): "We share in the teacher staff room like: "I used a movie, I will send it to you..." and we are always like that." TS2.d "Yes, you did it like this last year "I did it that way and it worked very good with me" TS2.i "Yes, spontaneously." TS2.b</p>	<p>(No data related to that topic)</p>

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 artefacts.

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, six out of 12 teachers implemented and documented their inquiry cycle with the TILE tool (see a sample in Table A.4.). Four out of six teacher artefacts show that the initial problem and reflections were focused on individual and collaborative skills of students. Moreover, all teacher artefacts 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 by 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 A.1. 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, Formative evaluation). Moreover, they highlighted the need to improve guidance and instructions and the monitoring of the collaborative process (see table A.6).

	Questionnaire (Open questions)	Interviews	Comments in ILDE
Teacher inquiry (TILE)	Orientation / Key elements (3): "It summarizes the most important elements (problem, questions, data, reflections) to improve the design" <i>TS1.a</i>	Documentation for review: "It is stored and you can check it in a simple and fast way" <i>TS2.c</i> Awareness / Orientation: "The fact that it is separated in different steps helps you to be more aware of what you're doing" <i>TS2.a</i> Technical difficulties: "In the implementation I had some difficulties but basically technical difficulties" <i>TS2.d</i>	(No comments related to that topic)
Formative evaluation	Collecting information (3): "It provides a lot of information and is very useful in evaluating the development and result of the activity, but it is necessary to monitor that the amount of information is not excessive and hinders the agility of the analysis." <i>TS2.h</i> Feedback from students (2): "In this type of activities, I am very interested in the satisfaction and perception of the learning by the students." <i>TS1.b</i> Time + Instructions (2): "It is necessary to find the way to adjust the time and to explain with ease the operation of the activity to the students." <i>TS2.i</i>	Student feedback: I used more the student feedback than the other provided data" <i>TS2.d</i> Adjusting time + instructions: "They indicated that they were stressed and had not given time to develop a good argument." <i>TS2.a</i>	Student feedback (3) Time + Instructions (6)
Teacher collaboration	Useful (3) : "I really like the idea of sharing materials and reflections with colleagues." <i>TS2.g</i> Shared problem-solving (1) : "It is interesting to share teacher inquiry cycles with multiple entries (problems and possible actions)." <i>TS2.e</i>	Continuous improvements: "The benefit is not starting from scratch. It facilitates continuous improvement." <i>TS1.a</i> Methodology application: "Even if is a teacher of another subject, I would not be evaluating the content, but the application itself." <i>TS2.c</i>	(No comments related to that topic)

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.

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 (e.g., problem, reflection) which usually they perform informally (See Table A.7, 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 artefacts 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 (Schmitz et al., 2017; Marcos, Miguel, & Tillema, 2009).

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 (e.g., 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 (e.g. between teachers or teachers-students) (Prieto et al., 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 (e.g., 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 (e.g., 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' behaviour 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 et al., 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.

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Appendix

Table A.1.: Questionnaire about the current teacher inquiry practice in the two schools (N=33).

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.

Table A.2.: Sample of Interview questions about the teacher inquiry process (N=7).

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?

Table A.3.: Phase 1: Teachers' demographics in the two schools

		School 1 (N=21)		School 2 (N=12)		Both schools (N=33)	
		N	Percentage	N	Percentage	N	Percentage
Gender	<i>Female</i>	12	57	7	58	19	58
	<i>Male</i>	9	43	5	42	14	42
Age	<i>20-34</i>	5	25	4	33	9	27
	<i>35-44</i>	9	45	4	33	13	39
	<i>45-54</i>	6	30	4	33	10	30
	<i>55+</i>	1	5	0	0	1	3
	<i>Teaching experience</i>	3	14	3	33	6	18
	<i>6-10</i>	5	24	4	44	9	27
	<i>11-15</i>	4	19	1	11	5	15
	<i>16-20</i>	5	24	1	11	6	18
	<i>21 or more</i>	4	19	3	33	7	21
	<i>Teaching subjects</i>	1	5	0	0	1	3
	<i>Arts/Music</i>	2	9	0	0	2	6
	<i>Language</i>	1	5	1	11	2	6
	<i>Foreign Language</i>	3	14	1	11	4	12
	<i>Social sciences</i>	2	9	0	0	2	6
	<i>Maths</i>	3	14	5	41	8	24
	<i>Science</i>	9	42	5	41	14	42
	<i>Other</i>						

Table A.4: Phase 2: Sample of classroom implementations and teacher inquiry cycles in the two schools

	School 1			School 2		
Teacher code*	T S1.a	T S1.b	T S1.c	T S2.a	TS2.b	TS2.c
Subject	Economics and Business	Philosophy	Biology and Earth Sciences	Biology and Chemistry	Earth Sciences	Maths and technology
Teaching experience	24 years	25 years	20 years	5 years	14 years	7 years
Problem/ Questions	Collaborative conclusions from a questionnaire	Brainstorming to define a concept	Brainstorming to define a concept	Identify theories from text in groups	Student distraction in group work	Equity of participation, increasing motivation
Intervention/ Evaluation	CL activity about conclusions in collected data from students	CL about initial definitions and final conclusions	CL about initial definitions	CL text comprehension activity with quotes about theory	CL activity-solving a case	CL activity-solving a case
Collected student data	Engagement, Content, Observations notes	Engagement, Content	Engagement, Content, Observation notes	Engagement, Content, Student feedback	Student feedback, peer-assessment	Student feedback
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	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

*TS1= Teacher in School 1, TS2=Teacher in School 2

Table A.5: Main topics of teacher group reflections and excerpts of their comments in School 1

Topic and description	Excerpts
Level of participation: comment about student participation	"14 of the students who participated did not provide any answer." "The activity has been performed irregularly by the students."
Limited understanding of the activity: comment about student misunderstanding	"It seems they didn't clearly understand the purpose of the activity." "Some answers did not respond to the goals of the activity. Instead of a conclusion they made an assessment."
Ease to collect student data: comment about ease of data collection	"It is practical to quickly and globally collect the opinion of the students."
Proposed improvements: comment about improvements in the design based on the data	"It would be better to have a presentation before the activity and clarify the objectives." "It might be good to do a test before directly entering this dynamic to make a final assessment."
Assumptions: comment about teacher assumptions based on the data	"[...] These two factors suggest that some of the students did not know how to use the tool or did not have enough time to complete it."
Positive realization: comment about positive experience based on the data	"I see it was a good experiment with this group." "It seems to me a very interesting activity."

Table A.6: Main topics of teacher group reflections and excerpts of comments in School 2

Topics and description	Excerpts
Student feedback: comment about the collected data about student feedback	<p>"Positive assessment indicates that it is a methodology well received by students."</p> <p>"The collaborative aspect is highlighted in several student comments."</p> <p>"The activity seems suitable for learning. The students showed satisfaction for their learning and the methodology."</p> <p>"In this group their perceptions about the task (objectives, participation, learning) seem very interesting and makes them very aware of what and how they are learning."</p>
Help-seeking behavior: comment about the help-seeking behavior of students	<p>"In the student feedback, your item-question 'I asked for help when I needed it?' received low ratings. We may need to know beforehand if students needed help during the task" "You may need to revise how students can help each other to solve the task since student feedback indicates that they have not requested help. Or maybe it was not necessary (?)."</p>
Time and pace of the activity: comment about the time and pace of the intervention	<p>"I guess at the beginning the pace is difficult to control." "There is a general feeling of lack of time by the students." "According to feedback, more than 30% of students say they have not had enough time to think. Therefore, surely, the timing of the activity should be checked to allow reading and reflection."</p>
Ease to collect student data: comment about ease of data collection	<p>"I think...it allows you to follow the process of the students in the chat."</p> <p>"It makes a comprehension activity dynamic and generates debate among the students. It also offers data that can be reviewed to improve the activity."</p>
Improving instructions before-during the task: comment about the instructions offered to students for the enactment of the intervention	<p>"Arguing guidelines could be set to make more profitable valuations," "Its should be improved and facilitated the presentation of the activity and have mechanisms to facilitate the understanding of what will be done."</p>
Familiarity of students with the tool: comment about student familiarity with digital tool	<p>"I think it would be useful a demonstration-tutorial or have some video on how to do it to facilitate the use of the tool."</p>

Table A.7.: Excerpts from teacher interviews in the two Schools

Topic	Excerpt
Teacher inquiry cycle (TILE)	<p>"If we would be doing it in all the didactic activities, it would be great." TS1.c., Philosophy Teacher, School 1</p> <p>"I think we intuitively ended up doing this process, but we did not have it documented. [...]but I also wonder ... Is it necessary to document it? I do not know ... surely the teachers would have more objective data, but it is also a bureaucratization of a process" TS1.d, Biology teacher, School 1</p> <p>"The idea of the cycle is very good, but I can not do it for each class. I have to do it by unit or by quarters" TS1.e, History teacher, School 1</p> <p>"The fact that it's separated in different steps helps you to be more aware of what you're doing. In the step "Problem and Questions" the formulation of a question was one thing that I liked a lot because then, maybe you evaluate it after a long time, and it allows you to go back at the beginning" TS2.a, Biology and Chemistry teacher, School 2</p> <p>"A good and interesting change because it shows me where I can fail. Maybe I emphasize on some of the steps and not on the others. The more visible is this, the better I build the didactic sequence. Good, good and necessary." "I usually do the review in the summer and see what has worked and what has not. But if I</p>

	<p>collect data throughout the year, the review I do in the summer will be much better because I will be able to consult all this information, which maybe I did not remember.” TS2.d, Philosophy teacher, School 2</p> <p>“I think the steps have helped me. Even so, it depends on what things are important to share this reflection together with other teachers” TS2.c, Math and technology teacher, School 2</p>
Formative evaluation	<p>“In the feedback of the students, they indicated that they were stressed and had not enough time to develop a good argument. I realized from their feedback that 20 minutes was not enough... that I had to use all the time” TS2.a, Biology and Chemistry teacher, School 2</p> <p>“[]..For example, having the discussions of the students allows you to see that, sometimes, they have not understood the concept you wanted to convey. Sometimes they all tell you that they have understood and it is not like that.” TS1.d, Biology teacher, School 1</p>
Teacher collaboration	<p>“It is useful to find joint solutions and have empathy with the same problems that others have.”, TS1.d, History teacher, School 1</p> <p>“I have the feeling that sometimes more have been given in informal spaces, in the staff room, while we are eating, that we are commenting "I have used this", "this has helped me for that" ... etc.” We do not have many spaces for shared reflection with other teachers.” “For example, the implementation of X gave me an idea to apply it in another subject.” TS2.a, Biology and Chemistry teacher, School 2.</p> <p>“It is very useful because you can always find a way to connect with your subject.” “To know that in mathematics the students are working in groups ... and see, for example that, my students work individually. It is nice to be able to compare your classes with other teachers ... It seems super important to see the strategies of others.” TS2.d, Philosophy teacher, School 2</p> <p>“It is useful to see how other teachers think in the teacher inquiry cycle.” TS2.c, Math and technology teacher, School 2</p>

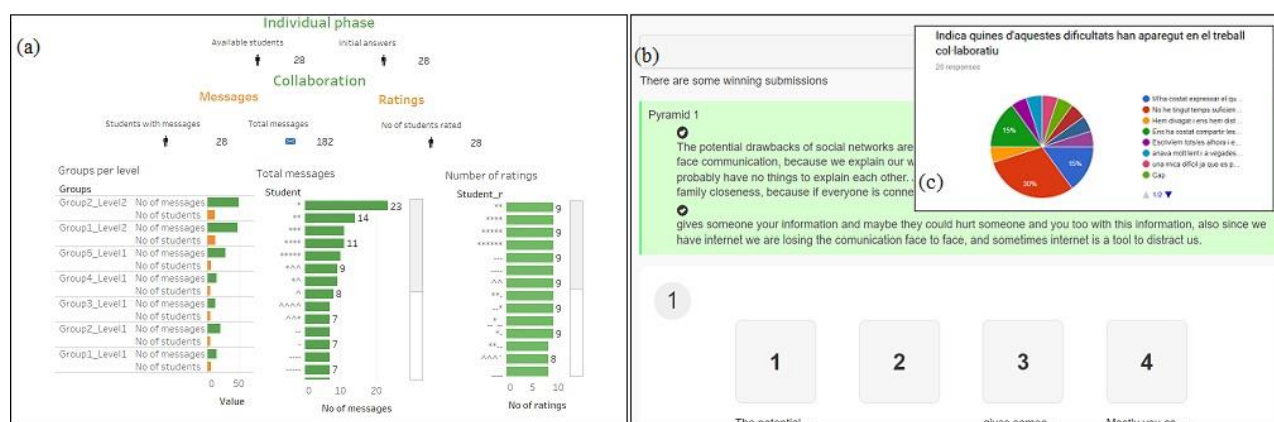


Figure A1: Example of collected data in inquiry cycle (TILE): a) Engagement analytics during the collaborative activity; b) Content of student answers and discussions in the collaborative activity; c) Student feedback;