Learning Analytics for Professional and Workplace Learning: A Literature Review

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Abstract. Despite the ubiquity of learning in the everyday life of most workplaces, the learning analytics community only has paid attention to such settings very recently. One probable reason for this oversight is the fact that learning in the workplace is often informal, hard to grasp and not univocally defined. This paper summarizes the state of the art of Workplace Learning Analytics (WPLA), extracted from a systematic literature review of five academic databases as well as other known sources in the WPLA community. Our analysis of existing proposals discusses particularly on the role of different conceptions of learning and their influence on the LA proposals' design and technology choices. We end the paper by discussing opportunities for future work in this emergent field.

Keywords: Workplace Learning · Professional development · Learning Analytics · Learning metaphors

1 Introduction

Workplace Learning (WPL) occurs across different formal and informal settings where professionals advance their competence, often through self-directed exploration or social exchange that is tightly connected to the processes and places of work [17]. Unlike learning in educational settings, WPL is often driven by personal interest or problems that appear in the work context, and typically lacks a pedagogical design to guide the learning process [24]. WPL typically consists of a strong interaction between formal training and informal learning, where both are motivated by job-based demands and contribute to workplace performance.

Despite the known importance of this kind of learning, Learning Analytics (LA) applications that focus specifically on workplace settings are rare. Some applications have been proposed under more general, overlapping denominations (e.g., 'community analytics' [23] or 'social learning analytics' [10]). Other proposals have focused on specific domains or professions, such as teaching [30] or healthcare [19]. Recent attempts have sought to unify and systematize these different efforts [27], under the term 'Workplace Learning Analytics' (WPLA).

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The aforementioned fragmentation can also be related with the different conceptions of learning existing within the emergent WPLA community, which can well be explained by the three metaphors of learning defined by Paavola and Hakkarainen [29]: some researchers conceive learning as individual process of acquiring or constructing knowledge (knowledge acquisition metaphor); others see it rather as a matter of social enculturation (participation metaphor); while for others learning is a collaborative and systematic development of common objects of activity (knowledge creation metaphor). These conceptions influence how learning is analyzed, leading to different kinds of LA technological proposals.

However, the recent emergence of this community and the lack of a systematic analysis of existing WPLA proposals, make it difficult to understand how LA can support different kinds of WPL. This paper provides such an overview by systematically reviewing WPLA literature and analyzing the different conceptions of learning underlying existing proposals. Our review (whose methodology is presented in Sect. 2) tackles three main goals:

1. Provide a descriptive overview of existing WPLA proposals: the work domains covered, target users, LA functionalities and data models, theoretical approaches to learning, research methods, barriers and limitations (Sect. 3).
2. Analyze the relationship between the different conceptions of WPL underlying WPLA -as defined by the aforementioned learning metaphors-, and the design and technological choices made (Sect. 4).
3. Elicit over- and under-explored areas of WPLA research, in order to outline potential lines of future research work (Sect. 5).

2 Methodology

In our review, we have followed the methodological guidelines proposed by Kitchenham and Charters [22]. We queried four academic databases for works in WPLA: Science Direct[1], IEEE Xplore[2], Springer Link[3] and ACM Digital Library[4]. Additionally, we used Google Scholar[5] to find grey literature and other references we might have overlooked. We also searched manually in specific literature sources in the area, namely the Journal of Learning Analytics[6] and a recent workshop on WPLA [27].

Our review focuses on LA studies devoted to support WPL and professional development. Given the recent emergence of the term and the fragmentation of this research community, other overlapping terms were also added to the query we used on these literature databases: 'educational data mining' (very related to LA and with a slightly longer history), 'adaptive learning systems' and 'intelligent tutoring systems' (to catch earlier works which have many commonalities

[1] http://www.sciencedirect.com.
[2] http://ieeexplore.ieee.org/Xplore/home.jsp.
[3] http://link.springer.com.
[4] http://dl.acm.org/dl.cfm.
[5] https://scholar.google.com.
[6] http://learning-analytics.info.

with what we now denominate LA). However, we did not include terms related to the transition between vocational schools or higher university and workplace learning, nor the use of LA to assess higher education activities outside the classroom. The query string we used to query those databases was:

("Learning Analytics" OR "Educational Data Mining" OR "educational datamining" OR "adaptive learning systems" OR "intelligent tutoring systems") AND ("workplace" OR "professional development")

The query was launched on September 2016. The references were obtained from the four databases were collected, as well as the 100 first results (out of 7520) from Google Scholar. Furthermore, we added resources known to us from previous work on the area of WPLA and we obtained a total amount of 1320 references. It should be noticed that there maybe variations in the way each search engine applies the query (e.g., some of them only search in title, abstract and keywords, others in the full text, and others also include metadata coming from reviews). Thus, once the papers were downloaded, we ran the query restricting it to the title, abstract and keywords to guarantee the same filtering criteria. As a result we obtained a subset of 263 articles and we considered the rest to be out of the scope of the review. We then manually removed duplicates and preliminary versions of other papers, ending up with a subset of 90 papers. Finally, we went through the 90 papers and we discarded those that were out of scope (e.g., the paper does not describe any data analysis or is not related to WPL), those that were not mature enough (e.g., papers whose length is less than 4 pages) and those of very low credibility or quality (e.g., papers whose low quality prevents understanding and assessing the contribution).

After this filtering, 30 papers were left to be reviewed in detail, forming the dataset for the rest of the analysis in the following sections. These 30 papers included 7 journal publications, 19 conference papers and 4 book chapters. The descriptions of these papers are summarized in Table 1.

Note that the reduction from 1320 initial results to 30 reviewed papers is mainly due to four aspects. First, we launched the same query in five different search engines so many of the results obtained were duplicated. Second, the search engines of some academic databases do not allow to search only the terms included in the title, keywords and abstract; hence, in many reference the terms that are relevant for us were cited but were not too relevant for the paper. Third, we added the keywords 'adaptive learning systems' and 'intelligent tutoring systems', thus obtaining an important number of papers related to these aspects but not to WPLA. Fourth, there was a significant percentage of very short and low quality papers, due to the immaturity of WPLA field.

3 Descriptive View of WPLA

This section provides a descriptive overview of existing WPLA proposals (first goal of the review). We analyzed the work domains covered in the proposals and their main target users (Subsect. 3.1); the technological approaches and the LA functionalities provided in the solutions (Subsect. 3.2); the theoretical approaches

Table 1. Overview of the reviewed papers in terms of type of their type of contribution (E. evaluation, I. implementation, M. methodological, T. theoretical), domain, target group (S. students, T. trainers, W. workers), data sources (I. interviews, Q. questionnaires, P. physical world data, S.L. system logs, U.G.D. user-generated documents, U.P. user profiles), functionality (A. awareness, A.S. adaptive system, C.P.F. communities of practice formation, F. activity feedback, I.P. improve participation, R. recommendations, P. predictions, S.N.V. social network visualization, Ta.V. task visualization, ToV. topic visualization, U.A. system use analysis, U.M. user modelling), information model (F. folksonomies, R.M. relational model or ontologies, S.M. statistical model, S.N. social network), technical context, learning metaphor (K.A. knowledge acquisition, K.C. knowledge creation, P. participation), evaluation type (A.D. validation using an artificial dataset, C.S. case study, E. experimental study, I.E. informal evaluation, O.S. observational study, P.C. proof of concept), evaluation methodology (M. mixed, Q. quantitative) and evaluation data (D. demographics, L. logs, O. observations, P. predictions, R. recordings, U.F. user feedback).

Ref	Cont	Domain	Target group	Data sources	Functionality	Inf. model	Tech. context	Metaphor	E. type	E. meth	E. data
[1]	T.	Generic	W.	U.P.	C.P.F.	S.N.	-	P.	A.D.	Q.	L.
[2]	I.	Education	W.	S.L.	I.P.	S.M.	-	P.	-	Q.	L.
[3]	I.	Public Services	S., T.	S.L., U.G.D.	S.N.V.	S.N.	MOOC	K.C.	-	-	-
[5]	I.	Education	W.	S.L., U.G.D.	U.A.	S.M.	Platform	P.	P.C.	Q.	L.
[6]	I.	Software dev	W.	S.L., U.G.D.	A.	R.M.	Platform	K.C.	O.E.	M.	O., U.F.
[7]	T.	Education	W.	S.L., U.G.D.	S.N.V.	S.N., F.	Application	P.	-	-	-
[9]	E.	Education	S.	U.P., Q.	S.N.V.	S.M.	LA Inf.	K.A.	A.D.	Q.	L.
[11]	T.	Education	W.	S.L., U.G.D.	-	S.N.	-	P.	P.F.	-	-
[12]	I.	Education	W.	U.G.D.	Ta.V.	-	Application	K.A.	P.F.	Q.	L.
[14]	M.	Education	W.	S.L., I.	S.N.V.	S.N.	Other tool	P.	C.S.	M.	U.F.
[13]	I.	Education	W	Q.	S.N.V.	S.N.	Application	P.	C.S.	M.	U.F.
[15]	I.	Research	W.	U.G.D.	To.V.	R.M.	-	K.C.	P.F.	Q.	L.
[16]	E.	Education	W.	P.	F.	S.M.	Application	K.A.	C.S.	M.	O., R.
[19]	T.M.	Medicine	S.	-	-	S.N.	-	P.	-	-	-
[20]	I.	Engineering	T.	S.L.	A.S.	-	Other tool	K.A.	I.E.	-	-
[21]	T.M.	Medicine	T.	U.P., Q.	S.N.V.	S.N.	VLE.	P.	E.S.	Q.	L.
[25]	I.	Business consultancy	T.	S.L.	A.S.	R.M.	VLE.	K.A.	-	-	-
[26]	I.	Medicine	W.	U.G.D.	Co.V.	S.M.	Other tool	K.A.	A.D.	Q.	L.
[28]	E.	Business consultancy	S.	U.G.D.	P.	R.M.	VLE.	K.A.	C.S.	-	P.
[31]	E.	Generic	S.	U.G.D.	R.	S.M.	Application	K.C.	C.S.	M.	U.F.
[33]	I.	Construction, Medicine	T.	S.L.	-	S.N., R.M.	LA Inf.	K.C.	C.S.	-	-
[32]	I.	Education	S.	S.L.	S.N.V., TaV., ToV.	S.N., R.M., F.	LA Inf.	K.C.	C.S.	M.	O., U.F.
[34]	T.I.	Medicine	T.	S.L.	R.	S.N.	LA Inf.	P.	C.S.	M.	O., U.F.
[35]	I.	Education	T.	S.L.	U.M.	F.	LA Inf.	K.C.	E.S.	Q.	L.
[40]	I.	Medicine, Education	S.	S.L.	Ta.V.	R.M.	LA Inf.	K.A.	-	-	-
[38]	I.	Generic	W.	S.L.	S.N.V.	R.M.	LA Inf.	K.A.	C.S.	M.	D., U.F., L.
[39]	E.	Education, manufacture	W.	S.L.	S.N.V.	R.M.	LA Inf.	K.A.	C.S.	M.	U.F., L.
[41]	E.	Education, manufacture	W.	S.L.	S.N.V.	S.N.	Other tool	K.A., P.	E.S.	M.	U.F.
[42]	E.	Education	S.	S.L., U.G.D.	To.V.	S.N., S.M.	Other tool	K.C.	A.D., C.E.	Q.	L.
[44]	T.	Education	W.	S.L., U.P.	-	S.N., S.M.	–	K.C.	P.C.	Q.	L.

to learning adopted by the authors (Subsect. 3.3); the research and evaluation methods (Subsect. 3.4); and finally the barriers and limitations (Subsect. 3.5).

3.1 Domain and Target Users

Although the papers analyzed cover applications of LA in several work domains, a large part of the proposals (16 papers) focus on education, aiming to analyze or support teacher learning. We can also find multiple proposals in the domain of medicine (6). The rest of the papers apply WPLA to very diverse domains, including business consultancy (2), car manufacture (2), software development (1), research (1), public service (1), engineering (1) and construction (1). Three of the papers apply proposals to multiple (or generic) professional domains.

More than half of the analyzed workplace LA proposals target workers themselves as learners (16), in informal learning situations. The rest of the proposals consider more formal settings (e.g., training courses) and the LA solutions are aimed at trainers (5), students/apprentices (6) or both (3).

3.2 Technological Approaches and LA Functionalities

In order to understand existing technological approaches to WPLA, we should first understand the different kinds of contributions that make up the set of analyzed papers. Most of the analyzed papers (20) are proposals of technological systems, often focusing on data visualization aspects (15), the data collection infrastructure (12), or other aspects such as recommender systems (2). Seven of the contributions proposed analysis methods for WPLA (without necessarily proposing a technological application in the workplace setting). Another group of proposals (5) focused on the analysis of a particular WPL situation (e.g., correlational analyses). Finally, only one instance was found of proposals for conceptual frameworks, or data models.

The LA proposals that have been made in WPL purportedly provide a wide variety of benefits for its use (which are also closely linked to the functionalities offered by the system implementations). Among the most common benefits cited are: understanding and supporting communities of practice and other informal social networks occurring in the workplace (12); tracking of work practices (e.g., to infer the evolution of learners' competences – 6). Additionally, other benefits were also cited including supporting assessment, self- and team-awareness, the understanding of learning situations and the adaptation of training.

Regarding the technical context (i.e. the technical ecosystem used at the workplace), we can see that, in many cases, there is only one tool used by the learners or whose data is exploited. In some cases (5) such tool is the contribution of the paper where in other cases (5) it is other application whose data is collected and processed. In other cases, the technological environment counts on an infrastructure that allows (at least potentially) to coherently process data from different applications. In some cases (8), the environment counts on an infrastructure that was explicitly designed for LA. In other situations the infrastructure is

not explicitly meant for LA: it may be a Virtual Learning Environment (VLE) (3), a MOOC (1) or other kind of platforms (2).

WPLA systems follow the general trends found in other sub-areas of LA regarding data sources [36]: system logs are by far the most commonly used data source (19). The analysis of learning artifacts (alone or in combination with logs – 11) is also common. Profile data (4), questionnaires (3), interviews (1) or audio input (1) are far less common. Nevertheless, it is noteworthy that quite a few proposals use more than one kind of data source, or from more than one platform (11). These proposals include infrastructures specifically designed to collect and integrate data for WPLA (needed in many cases in which work practices and WPL processes lack a clear central data source). WPLA proposals also represent and model their information in a variety of ways, being the most common: as social networks, tied to the social network analyses and visualizations, and the focus on workplace communities of practice (13); as ontological or relational models, used for a variety of purposes, from recommendations to assessment or awareness (9); as statistical models, used often in analyses of learning settings or analytic method proposals, aimed to track practices or understand a WPL situation (8); or as folksonomies, used to collect the emerging and unexpected concepts that appear in a community of learners (3).

3.3 Theoretical Approaches

To start untangling the reasons behind the technological choices summarized above, we have looked at how proposals' focus on a particular learning theory guides the processes of collecting, managing and representing data to extract meaningful information. This is not only a major challenge in the LA community [18]; it is even more critical in the workplace, where often a curriculum or pedagogical design are not available to guide the analytics. Nonetheless, some contributions (6) do not make their theoretical stance explicit at all. For this reason it is sometimes difficult to understand the assumptions that guide the creation of existing WPLA applications and infrastructures. In order to solve this difficulty and allow the synthesis of the proposals, we used the three metaphors of learning proposed by Paavola and Hakkarainen [29] -knowledge acquisition, participation and knowledge creation- as an analytical lens to classify the papers. These metaphors are "closely connected to the way knowledge is understood in different conceptions of learning" [29]. The paper classification was an overall qualitative assessment, emitted by looking at their theoretical stance, technical realisation (especially the information model they employ) and the general stance authors took towards learning in the solution they proposed. Whenever possible we related each paper to a learning metaphor.

The **knowledge acquisition metaphor** includes theories that assume individuals as the basic unit of learning. Learners have to acquire, construct and represent the concepts of the domain in their internal memory [29]. The acquisition metaphor is therefore concerned with the construction of internal representations. This construction of existing knowledge is seen as an individualistic process that leads to the transmission and possession of knowledge [29]. It is

connected to an understanding of the mind as a container, which is filled by the learning process [4].

Eleven proposals were classified as following the knowledge acquisition metaphor. We included all the papers based on theories of assessment (3), as well as papers focusing on self-regulated learning theories (4). Other theories cited are cognitive apprenticeship (1), assessment design (1), self-regulated learning (1), learning by doing (1) and competence-based knowledge-space theory (1).

The **participation metaphor** and its related theories (e.g., communities of practice and situated learning) assume that learning happens by participating in cultural practices that shape cognitive activity in manifold ways [29,37]. It represents a continuous, interactive and discourse-based process that includes the negotiation of norms [37]. Through this contextualized and activity-based socialization, learners adopt the skills that are recognized in the community. Thus, learning is understood as a form of enculturation.

The 11 papers that followed the participation metaphor all drew on social learning theories, especially communities of practice or situated learning theories. In line with the social character of workplace and professional learning, a variety of social learning theories motivated many of the analyzed WPLA approaches. Among these theories, the most cited ones are communities of practice (4), learning networks (4) and social networks (2). Other theories include collective learning (1), learning communities (1), connectivism (1) and social constructivism (1).

Finally, the **knowledge creation metaphor** deals with the collaborative and systematic development of common objects of activity [29], such as in theories of knowledge building [4], organizational knowledge creation, meaning making [43] and knowledge maturing. This metaphor focuses on the creation, uptake [43] and development of new materials and conceptual artifacts. Hence, this metaphor is concerned with the way individuals collaboratively develop these mediating artifacts in interaction with the learning community. Its focus is on the temporal evolution of objects and practices emerging in concrete object-mediated reciprocal communication and collaboration. Hence, these theories follow socio-constructivist approaches, in which knowledge is socially constructed.

Theories that have motivated the 9 papers in this category include knowledge building and knowledge creation theories, but also informal WPL and social learning theories. Knowledge creation models (e.g., knowledge building, maturing, scaling-up informal learning) were mentioned by 5 papers, and networked learning and connectivism were the starting point for another 4. Other theories cited were group awareness (1), scaffolding (1) and situated learning (1).

3.4 Research Methods and Evaluation

The methodological approaches followed in the 30 papers under review can be broadly classified in four categories. The largest set of papers (13) follows the traditional methodological approach of presenting and evaluating a proposal. Another significant cluster (8) spans several research iterations, combining top-down and bottom-up approaches, which allow them to carry out exploratory

and evaluative work. There are also papers (4) that explore certain aspects in a bottom-up fashion, inferring theory or trends from available datasets. Finally, 5 papers are exclusively theoretical proposals that draw from previous literature.

Concerning their evaluation, 6 of the analyzed papers do not portray an evaluation. In other examples (9), the purpose of the evaluation is merely to provide a proof of concept, or to illustrate the potential of the proposal. The proposals describe more formal evaluations that often assess rather technical aspects such as the performance, accuracy, or efficacy of the proposal (6), or constructs related with acceptance and adoption: usability (3), user interest and perceived usefulness (2), impact on users (4), or the applicability of the proposal in an authentic setting (1).

The evaluation methodologies shows a balance between quantitative methods (11) and mixed methods that combined qualitative and quantitative techniques (10). A wide variety of data sources are also used. Most of the papers rely on either artificial (4) or real data sets and logs (10). In addition, these sources are often triangulated mainly with user feedback (9) and observations (4).

Regarding user involvement in the evaluations, it is noteworthy that only 13 of the reviewed papers report on the user involvement. The addressed users are typically workplace learners, labeled as 'employees' (9) or 'students' (2). Trainers (2) or company managers (1) are also involved in some of the evaluations.

3.5 Barriers and Limitations

To better understand the current state and maturity of existing WPLA proposals, we extracted the limitations highlighted by the authors, and the barriers they found when applying LA in a workplace. Five of the papers reported limitations related to the data gathering (e.g., [14,16]). According to the authors, part of the learning process is not tracked, and therefore, the analyses are built on incomplete data. Another typical limitation is that the volume of data is insufficient due to low number of users or scarce interaction with the systems (e.g., [2,31]). These two obstacles -incomplete and scarce data- have a crucial impact on the accuracy of the results.

Regarding the data processing, several papers (6) mention limitations on the automation of the data analyses (e.g., [7,12]). In some cases, the analysis process required manual human intervention (e.g., providing or curating data). Apart from being time consuming, such manual steps make the success of the proposal dependent on the motivation and quality of the users' work. Other technical problems refer to time (1 - [41]) and scalability (1 - [44]) constraints.

In those cases where the analytics outputs were fed back to users, the authors sometimes highlighted limitations due to the usability of the proposed solution (e.g., [13,25]), especially regarding the understanding of indicators and visualizations. This hints to crucial role of users' data literacy: to make data-driven decisions, consumers of LA solutions need to be aware of the limitations of the analyses, and have the skills to interpret the results in their own context.

Finally, as it is often the case in research efforts in their early stages, several papers (7) acknowledge limitations in terms of generalizability of the results

(e.g., [2,38]). To address this issue, they propose to conduct long-term evaluations with larger or different user groups in the future.

4 Discussion: The Three Metaphors of Learning in WPLA

In our previous analysis we used the three learning metaphors [29] to group the proposals that share similar conceptions of learning (see Sect. 3.3). We also realized that these conceptions of learning had an impact on the LA services offered and the design and implementation decisions taken to develop the LA services (see Table 1). Current section further discusses this impact grouping the proposals according to the learning metaphors they followed. Thus, we tackle the second goal of the review.

A first group of proposals followed the **knowledge acquisition metaphor**. They used ontologies or other relational information models more often, in order to represent the knowledge that was to be acquired. The main use cases of this kind of proposals were related to the building of user models from work activities in order to diagnose work-related competences. This information was then used either to give formative feedback for reflection (e.g., about tracked activities or progression along some learning goal), or to make automatic adaptation decisions (e.g., recommending items to learn, or suggesting scaffolding). Feedback was typically given in the form of visualizations (e.g., dashboards or open learner models). In several cases, the learning goals were derived from business or workplace demands (e.g., workplace tasks) that had then be turned into an ontology or similar model allowing the tracking of progression along these goals.

These approaches are limited because they are usually built upon a fixed model of the learning domain. Hence, there are less opportunities of detecting emergent learning. Besides, this kind of proposals have a stronger potential for guiding learners through diverse forms of scaffolding. Knowledge acquisition approaches would benefit from research into transitions between educational institutions and the workplace. They could be using ontologies developed as part of educational curricula or for professional certification, rather than building on frameworks developed ad-hoc, as this would enhance their scope and impact.

Another group of proposals followed the **participation metaphor**. In almost all these cases, the information collected was represented as a social network and several different Social Network Analysis (SNA) techniques were used. The information inferred from the analyses is used to promote the participation among learners, either by identifying similarities that help to build groups, by creating awareness of learning networks or by giving community managers tools to improve participation.

Well in line with the idea of learning as participation, the main use cases were on fostering participation in communities, building groups by identifying similarities, creating awareness of the professional network and giving community managers tools to improve participation. Participation approaches create awareness for emerging learning and possibilities for collaboration. However,

these approaches sometimes assume that mere participation will improve learning. And while those approaches built on knowledge acquisition can usually draw on self-regulated learning theory to explain how explicating learning goals benefits metacognitive strategies, it is not clear whether the awareness of the social network has any impact on learning.

Another issue with social networks is that they are usually built on similarity, but learning sometimes benefits from dissimilar others. An interesting proposal in this direction is made by one of the reviewed papers [31] who suggest dissimilar users to provoke learning. For the future, we see a good opportunity for participation oriented approaches to explore similarity and dissimilarity of learners in social networks and the effect on learning and forming of the community.

The third group of proposals followed the **knowledge creation metaphor**. The technologies employed in these proposals were very diverse. They included social networks, ontologies and folksonomies, but also analyses of natural language texts and topic modeling. In several cases their data models create implicit or explicit networks of actors and artifacts (e.g., documents or concepts) that are sometimes enriched with semantic relationships. This is because in "trialogical learning" relations need to be established between learners and their mediating artefacts (e.g., documents or concepts). In several cases, a number of different technologies were used at the same time which might suggest that in order to understand knowledge creation, a broader range of technologies are needed.

The downside of the proposals building in the knowledge creation metaphor are the very small numbers of participants. While this is a general problem in WPL settings, it is likely to be especially prevalent in knowledge creation approaches, as these originate from research in group cognition and, hence, take smaller groups as a unit of analysis. Hence, it would be interesting to see proposals focusing on large scale communities, on knowledge building in organizations, or even in cross-organizational networks.

5 Conclusions and Future Lines of Research

This section summarizes the conclusions of the paper and reflects on the underexplored areas and the potential lines of future research work. Thus, we tackle the third goal of the review.

Our analysis of 30 Workplace Learning Analytics (WPLA) proposals highlights several conclusions about the state of the art in this area. A first insight is that the field is still in an early stage of development, when compared to other areas of LA. The number of existing WPLA proposals is still relatively small, and features many contributions with a limited evaluation. However, the fact that most of the publications available appeared in the last few years is a clear symptom that WPLA is a growing community. The analysis also shows that the WPLA community is still somewhat fragmented. Many of the papers analyzed were published under different keywords, some of which we collected when querying research databases (e.g., 'adaptive learning systems' or 'teaching analytics'). Nonetheless, there may be other terms that we did not consider and can provide further insight on this and other related fields.

The provision and adoption of WPLA solutions are higher in education and healthcare sectors. In both cases, the professionals involved share some routines that contribute to the applicability of WPLA (e.g., need for being up to date, need for reflection processes). On the contrary, other sectors (e.g., construction) could be more challenging in order to receive LA support due to the lack of trackable evidence in their current activity. Additionally very few existing proposals are targeted at, and evaluated in, multiple domains. These facts put into question the generalizability of current proposals' results, but also poses an interesting challenge for future WPLA research.

We can also draw insights from the technological makeup of current WPLA proposals. Most of the proposals only collect and process one type of data (e.g., system logs), while WPLA could potentially be enriched by exploring other types of data sources. We foresee a big potential in MultiModal Learning Analytics (MMLA) [8], although they are still very rare in WPLA. MMLA may help to overcome the problems of incomplete and scarce data caused by the low number interactions between users and a systems, thus reducing the burden that the manual data gathering may entail and increasing the chances of WPLA adoption. The data analyses and visualization also require special attention by the WPLA community. It is required to identify relevant indicators for the target users. Furthermore, the users' data literacy and their data-consuming experience should be taken into account when designing visualization interfaces. With respect to the evaluation of the proposals, most of them support the learning process indirectly, either promoting awareness, scaffolding the community of practice, or recommending resources. However, there are few evaluations that measure learning-related constructs directly, maybe due to the difficulty of accessing learners and their data. Further studies that demonstrate the effectiveness of WPLA solutions for learning are needed.

A very positive aspect of the WPLA community is the strong focus on theory that most of the analyzed papers have. As our previous discussion shows, the theoretical approaches taken by the proposals –which we grouped into three learning metaphors– have a big impact on the functionalities they offer, and on the technologies chosen to provide them. This impact is especially notorious on the data models of the proposals, as the way learning is understood conditions which data should be retrieve to analyze a learning situation and how these data should be structured. The relatively low occurrence of WPLA proposals based on knowledge creation assumptions is surprising if we take into account their importance for WPL, but it also indicates a promising path for future research.

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