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The use of LMS to support PBL practices: A systematic review

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Abstract: *Problem-Based Learning (PBL) is a constructivist teaching methodology, created in the late sixties, with an active learning process performed by the student to solve a proposed problem, meticulously specified to provide acquisition of knowledge by discovery. This article proposes a systematic literature review of publications on the subject, which involve the use of Learning Management Systems (LMS) for implementing networked PBL, i.e. PBL procedures over the Internet, either partially or totally. It was found that PBL network had been the subject of interest of the academic community from different angles: development of theoretical and computational models to support the design of activities for networked PBL activities; evaluation of LMS technologies to support networked PBL;evaluation of the practice of networked PBL supported by LMS technologies; and the development of plug-ins that add functionality to the LMS Moodle to make it able to support specific PBL models performed through the Internet.*

Keywords -*Learning Management System, LMS, PBL, Problem-based learning*

I. Introduction

Problem-Based Learning, or PBL, is a learning method created by Howard Barrows and his colleagues from McMaster University, Canada, in the late sixties [1]. The traditional teaching method involves the presentation of theoretical concepts, followed by their use in the real contexts based on examples and exercises. PBL inverts this logic and uses case studies to make the students learn the theoretical concepts by trying to solve a problem simulating close to the real life situations [2]. The problems used in PBL are meticulously designed to make the students acquire all the theoretical concepts needed for a course while exercise some skills related to social interaction, such as working in group, leadership, conflict resolution, communication, and collaboration [3]. In fact, the problem designed for PBL might be a problem diagnosis, a presentation, a report, or any artifact which is the result of the learning process.

Al-Dous and Samaka [4] summarize the main steps to implement PBL:

1. Introduction – First, the teacher presents the problem to the students who must understand what they need to do to solve the problem and how to divide the tasks among the group participants.
2. Identification – The students must identify the knowledge and skills needed for the problem solution.
3. Planning – The teacher organizes the group creation in a way that allows a significant learning for each component. Furthermore, the groups must perform the division of tasks and establish deadlines that must be met by each student.
4. Execution – It is the stage when the problem-solving work is effectively carried out, including information search, study, procedures, and preparation of expository material or product.
5. Report – It involves presenting the results of the work done, whether in a discursive form or a documentary form.

The PBL method "has a formative approach, encouraging the pursuit of knowledge, intellectual autonomy and sharing of the built knowledge" [5]. Thus the solution of the designed problem works as a motivator for the student to learn the necessary theoretical concepts and to exercise the process skills. These process skills involve individual and social skills that are important for the professional practice, such as taking decisions, making self-assessments, having initiative, working collaboratively in groups, resolution of conflicts, practicing communication, and knowledge sharing. It implies that evaluating the results of a PBL activity involves observing the student's ability to do analysis, judgment, reflection, and decision-making. Consequently, the learning assessment must also include the student's ability to act proactively, with autonomy, using clear communication, and demonstrating competence for teamwork [6].

Consequently, the student is also an important evaluator of this formative process in PBL, either through peer review or self-assessment. Woods [3] presents some aspects of formative assessment by stating that "the group should be encouraged to reflect on their performance in the PBL process, including its adherence, communication skills, respect for others, and individual contribution."

Based on these premises, the PBL method has spread out and has evolved to be used in various other educational institutions around the world, not just in health sciences, but also in other fields such as engineering and pedagogy.

With the advent of the intensive use of information and communication technologies in educational processes, there were some initiatives which tried to use information systems to manage the implementation of PBL over the Internet, which was called network PBL. More recently, during the last two decades, with the emergence of Learning Management Systems (LMS), also known as Virtual Learning Environments (VLE), it opened a new technologic front to support the networked PBL. The PBL method created at the McMaster University has been implemented backed by LMS technologies, either counting on just its native functionalities or with plug-ins that add features to fit them to specific PBL models [7].

1.The Focus Questions

In order to contribute to the use of LMS to implement networked PBL, with or without plug-ins, it is necessary to know the state of the art on this subject. Thus, this article has the purpose of answering the following focal questions: What did the scholars study so far regarding networked PBL with the support of LMS or similar technologies? What technologies have been used to enable such a paradigm? What prospect studies bring to the future of networked PBL? This study presents a systematic review of articles on the subject to answer these questions, focusing on the use of LMS for the implementation of networked PBL.

2.Objectives

As a primary objective, this systematic research aims to map the focus of study that scholars have been conducting on the use of networked PBL in teaching practices. The goal is to bring the understanding of how it has been made, the results achieved by the implementers, and the improvement perspectives of technologies that support the method.Within the primary objective of this research, we can highlight the following secondary objectives:

1. Identify the key technologies used to support the implementation of networked PBL.
2. Determine the perspectives that the studies might indicate about the future of networked PBL.

II. Methodology

This systematic research involves searching multidisciplinary publications in indexed journals through different databases. To reach the articles to be included in this study, two criteria classes were used: selection and exclusion.

1.Selection Criteria

This research used the following search criteria:

1. Searched databases: Scopus, Web of Knowledge, ProQuest, EBSCOhost, and Scielo.
2. Idioms: the search results involve publications written in English, in Portuguese, and in Spanish.
3. Publication period: from 1990 to 2015, since the use of networked PBL only became feasible with the advent of the Internet, which emerged in the early nineties.
4. Search arguments: (PBL 'or' ABP) 'and' (LMS 'or' AVA 'or' EVA). It includes the acronyms for PBL and LMS and its equivalents in Portuguese (ABP for Aprendizagem Baseada em Problemas and AVA for Ambientes Virtuais de Aprendizagem) and Spanish (ABP for Aprendizaje Basado en Problemas and EVA for Entorno Virtual de Aprendizaje). The use of only acronyms had the purpose of restricting the selection to those articles most focused on the main research topics.
5. Fields searched: Title, abstract and keywords of each article. In the case of databases whose search engine did not allow the use of these three types of data, the field used to search was only the summary of the publication.
6. Publication types: only articles in indexed journals and scientific conferences proceedings.

The selection criteria did not include books and book chapters because the content of such publications likely reflects the article contents, indexed in specialized or multidisciplinary journals.

Once the publication selection, it started up their analysis. First, the authors sweep of the data concerning the title and author of each publication to eliminate duplicity among the items found in different databases. After, the exclusion criteria were applied, described in the next section.

2.Exclusion Criteria

Once made the selection of publications and the elimination of duplicate results, the researchers performed a full reading of the selected publications. As the result, there was a purge process of some of the articles based on the exclusion criteria listed below.

1. Idiom: were excluded articles whose contents in a language other than English, Portuguese, or Spanish.
2. Publication type: only primary education should be part of the research, which resulted in the exclusion of systematic reviews.
3. Theme out of scope: publications whose subjects did not fit in the research scope were discarded from the results. It happened due to the exclusive use of acronyms as search arguments. Only articles that effectively address the research topic remained in the reference list.

At the end of the exclusion phase, the selected publications were ready for the qualitative analysis of their content. The next section presents the results of this analysis.

III. Results

The Fig. 1 illustrates the processes of searching, selection, and exclusion performed in this systematic research. Furthermore, it also provides the first bibliometric results.

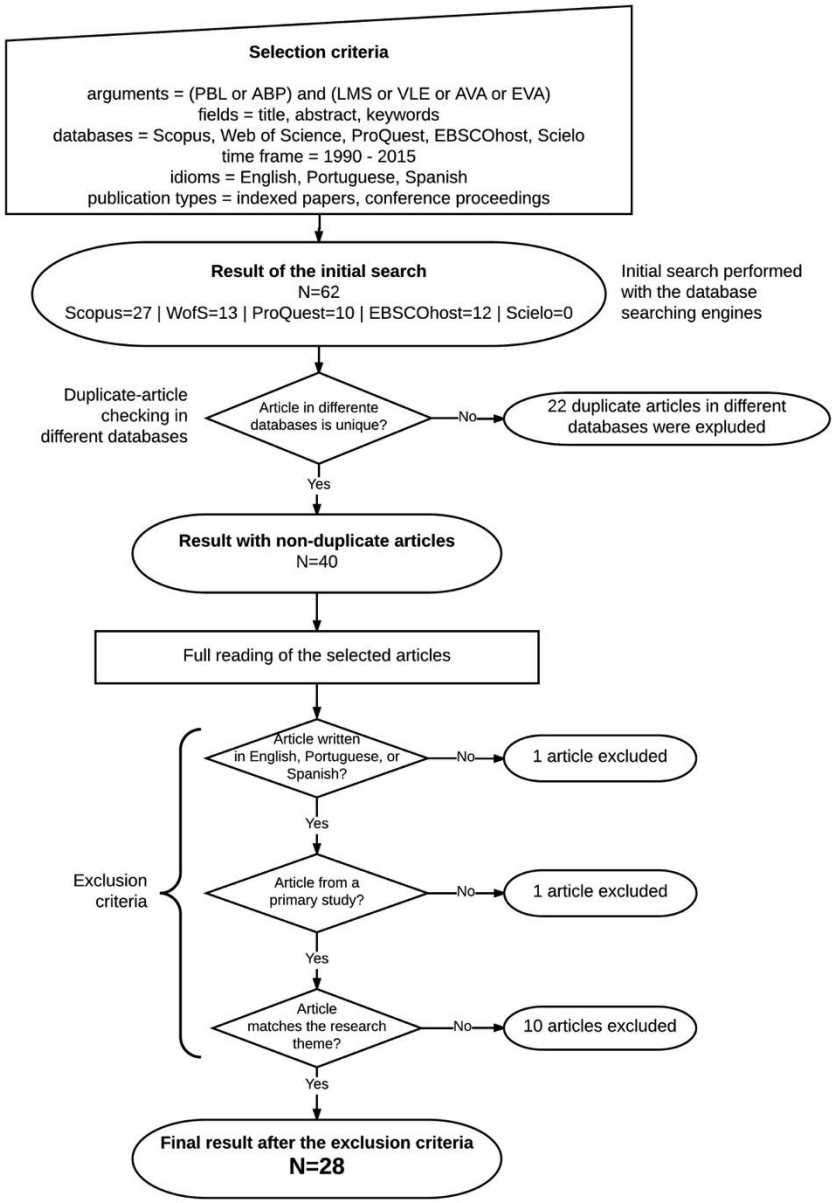

Figure 1. Scheme of the systematic research processes of this study.

1.Bibliometry

The Fig. 1 also indicates that this systematic research resulted in 29 publications. They are spread over eleven years, from 2005 to 2015, as shown in Fig. 2. It demonstrates that there is a regularity of articles that fit criteria of selection and exclusion of this research. Regarding idiom, there was only one article in Portuguese,

another in Spanish, and all the other 26 publications in English. There was not any preponderance of one author on others.

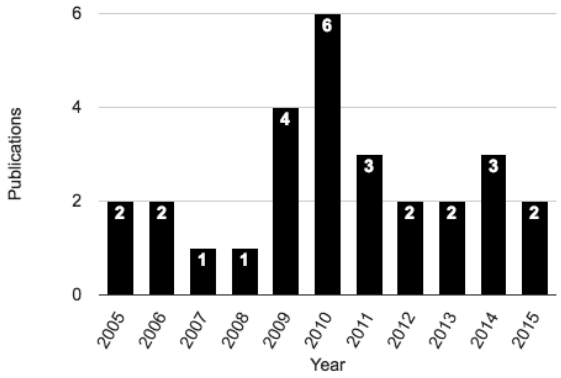

Figure 2. Distribution of publications over the years.

2.Results and Discussions

The study of literature obtained from this systematic research allowed to reach some findings of the state of the art use of virtual learning environments for the implementation of learning methods based on networked PBL. Based on the focus of this research, the analysis identified four different categories of studies found in systematic research based on their focus:

1. Models for designing networked PBL activities.
2. Evaluation of technologies for implementing networked PBL.
3. Evaluation of networked PBL implementations.
4. The use of a plug-in to enable Moodle to support specific PBL models.

Below, each category has their respective analysis presented with tables that summarize the article's content accordingly to their particular details when specified: type of LMS involved, research methodology, and the educational field (for categories 3 and 4). Always when possible, it was indicated the number of participants in each research.

2.1 Category 1 – Focus on Models for Designing Networked PBL Activities

This group of references involved six of the twenty-eight studies selected in this systematic research (N=6). These are studies that present models focused on the development of technologies or methods that enable the implementation of PBL over the Internet.

Table 1. Category 1 of publications.

Ref.	Author(s)/Year	Summary Description	Details
[8]	McHugo and Hall (2005)	The article details of developing an LMS to implement PBL in a specific context, describing the evaluation of the specifications for the development of such technology. It also details a modular way conceived to support different functionalities the LMS may have in the future.	LMS Moodle Qualitative Research
[9]	Sallaberry (2005)	It purposes a modeling language called CPM (Co-operative Pbl Meta-model), based on UML (Unified Modeling Language), to model a PBL lesson. The goal is to describe the learning scenario in question formally through a model that can be understood by both the educational designers as by developers of computer systems. It demonstrates concisely how the modeling technique was used to guide the creation of PBL activities using the LMS Moodle.	LMS Moodle Research method not specified
[10]	Díez-Rodriguez, Morales-Luna, and Olmedo-Aguirre (2008)	Assuming that "seek, find, share and publish information are important parts of the PBL method," it proposes not a model, but an ontology to optimize the search and publishing learning objects deposited in an LMS, whose content is relevant to the context-based learning PBL.	LMS Enemoci Qualitative Research
[11]	Garcia-Robles (2009)	It presents the design of a PBL lesson based on IMS-LD (Instructional Management System - Learning Design), which is an international standard used to guide the design of learning objects to enable interoperability of content between different compliant LMS.	LMS Moodle Qualitative Research
[12]	Page, Thorsteinsson, and Niculescu (2009)	It proposes a model for the creation of educational activities that provide knowledge sharing in the context of networked PBL.	LMS and research method not specified
[13]	Fontes, Valentim, and Mendes Neto (2014)	It purposes a model for designing PBL activities based on Multi-Agent System (MAS).	LMS Moodle Purposive Research

All cases of this group have a purely technological approach, without much detail about how the impact model in implementing the PBL method in practice educator. These studies are mostly developed by researchers from the technology field, seeking a way to standardize the creation of PBL activities through the

use of meta-languages that enables the modeling of learning processes. They either contextualize the study in a specific educational setting or restrict their approach to the theoretical model to build a PBL activity in computational level, regardless the educational scenario in which it can be used.

In sum, the studies of this category have a strong theoretical appeal since they seek for models to guide the design of PBL activities from the computational point of view. Their main goal is to ensure standardization of the design of PBL activities and the technological interoperability of what is designed. Nonetheless, their approach is critical to developing LMS technologies that support PBL activities. The model IMS-LD used by Garcia-Robles (2009) to create a PBL lesson, for instance, is the same employed in the plug-in development of Ali, Samaka and Shaban (2012).

2.2 Category 2 – Focus on Evaluating Technologies for Implementing Networked PBL

Few articles (N=4) focused specifically on proposing or testing technology to implement networked PBL compose the second category. At first, the Category 2 has few references and its studies seem to be similar to the studies of the Category 3. However, after a deeper analysis, it is clear that their approaches are different. The Category 2 studies focus on the effectiveness of the technology that supports the implementation of PBL, without detailing the learning process itself. On the other hand, the Category 3 studies focus the improvement of the already used PBL method with the support of LMS. The main concern is with the pedagogical results rather than the used technology. Then, it justifies the existence of a category specifically for those studies focused on the assessment of the technology used for networked PBL. Table 2 below presents the descriptions of each study of this category.

Table 2. Category 2 of publications.

Ref.	Author(s)/Year	Summary Description	Details
[14]	Hoic-Boizic, Mormar, and Boticki (2009)	They reduced the dropout rate of a course using a proprietary LMS to support networked PBL. They report the very positive impressions from the part of the students on the networked PBL paradigm.	LMS AHyCo Mixed Research Methods Computing school (n=15)
[15]	Ku and Shang (2010)	It proposes a tool specialized in implementing networked PBL, called uPBL, to be used with mobile devices. It presents the results of an experiment done in a school, whose teachers and students expressed their level of satisfaction with the use of networked PBL and with the software functionalities.	Software uPBL Qualitative Research
[16]	Barnard-Ashton (2010)	It presents the experiment done at first using Google Docs to build text collaboratively. After finished, the teacher published the texts on the LMS WebCT. In the following year, the same students used the Moodle's wiki, but the tool was used just for disseminating the final text, built with the use of MS Word.	Google Docs LMS WebCT[1] LMS Moodle (Wiki) Qualitative Research
[17]	Onan, Gürlen, and Turan (2014)	It uses Moodle auditing tools to perform Computing Assisted Auditing Techniques (CAAT) to analyze the student performance in a PBL based course.	LMS Moodle Quantitative Research

It is important to highlight that in general the conclusions obtained from the articles of this category demonstrate that the LMSs, as they are nowadays, are not adequate for networked PBL. Ku and Shang [15] justify their framework proposal with that fact that LMSs do not offer an appropriate collaborative learning experience. Barnard-Ashton [16] states that the difficulty to use the Moodle's wiki for collaborative work made the students use MS Word to build the collective text, using the wiki just for publishing the final content. The same had happened before with the utilization of the WebCT's wiki as well. The document was built collaboratively with the use of Google Docs, not with the wiki's functions. Onan, Gürlen, and Turan [17] are emphatic in saying that the Moodle's auditing tools are poor and counterproductive; although their conclusion is that the LMS "was sufficient for meeting the basic data requirements for educational auditing." They go further suggesting the development of a CAAT plug-in for Moodle to facilitate the student participation analysis in networked PBL performed with this LMS. Then, it may be a clue that the articles of the Category 4, which focus the plug-in development for making Moodle more suitable for networked PBL, are on the right track.

2.3 Category 3 – Focus on Evaluating Networked PBL Processes Supported by LMS

Most of the articles gathered in this systematic research belong to this category (N=14), as presented in Table 3. They are focused on experimenting PBL in education scenarios which are shifting from traditional teaching methods to PBL, or which are adding online support for the already-in-use PBL method. Their goal was to observe the effectiveness of the introduction of the technology to support networked PBL, evaluating the education process as a whole, not only the technology as in Category 2.

[1]The company Blackboard® acquired the LMS WebCT in 2007, discontinuing the software after.

Although the PBL originates in the health field and this systematic review identified the interest of networked PBL in this area, it also arouses interest in other fields. The Table 3 indicates that 6 out of the 14 articles in this category are related to healthcare studies, the same number of publications whose PBL implementation was done in computing and engineering educational contexts. Institutions from different sectors are experimenting the networked PBL and getting outstanding results from the experiences.

In fact, the number of Category 3 studies demonstrates the interest of the academic community in validating the use of networked PBL for the improvement of educational processes in different contexts. As can be observed in Table 3, some articles report the experience of implementing networked PBL to evaluate the effectiveness of adding virtual processes in existing PBL practice. On the other hand, there are studies focused on describing the migration from the traditional learning method directly to networked PBL, i.e., already counting on virtual resources to implement this active learning style. Regardless whether how networked PBL is described in the reported study cases or pilot projects, most of the Category 3 articles depict the method implementation and present the perceptions obtained from the stakeholders about the process. Except for some details related to the LMS usability issues or students resistance for online activities, the general impression was very positive about the networked PBL, with many compliments declared by students and instructors. It demonstrates that this is just a matter of time to make networked PBL, counting on better framework usability, obtain more and more adopters.

Table 3. Category 3 of publications.

Ref	Author(s)/Year	Summary Description	Details
[18]	McHarg and McLachlan (2006)	They examined the effectiveness of the use of an LMS for networked PBL. The first-year students did not readily share information through the LMS, although they demonstrate positive learning outcomes.	LMS Blackboard® Mixed Research Methods Medical school (n=104)
[19]	De Leng et al (2006)	They examined the effects of the use of LMS for networked PBL. The students appreciated the links to resources and multimedia content, but they did not feel stimulated for interacting virtually during the self-study phase.	LMS Blackboard® Quantitative Research Medical school (n=355)
[20]	Mackway-Jones Carley, and Kiroy (2006)	It describes the gradual shift from the expositive to PBL classes. To overcome the student's difficulty in participating in all on-site sessions, they used an LMS to implement networked PBL. It presents no detailed results.	LMS Moodle Descriptive article Medical school
[21]	Samar et al (2009)	Groups of 8-10 students undertook networked PBL. The log analysis showed a strong relationship between the collaboration in the forums and the grades obtained by the groups from knowledge construction in the wikis.	LMS Moodle Quantitative Research Computing school (n=1300)
[22]	Williams et al (2010)	It describes the implementation of networked PBL, resulting in better academic performance and socialization of the students, the perception of skill acquisition and better socialization, with a lower dropout rate.	LMS Blackboard® Mixed Research Methods Chemistry school (n=84)
[23]	Peachey et al (2010)	It reports an experience with grade-8 pupils, required to solve questions designed by the teacher. The result should be published on the LMS wiki to be edited by a peer, developing pupils' research and analytical skills.	LMS Moodle (Wiki) Descriptive article Basic school
[24]	Abajo et al (2010)	It reports that most of the students considered the implementation of networked PBL an excellent pedagogical improvement, fostering instant socialization, student engagement, and better academic performance.	LMS Moodle Mixed Research Methods Engineering school (n=22)
[25]	Bridges, Botelho, and Tsant (2010)	Interactive White Boards were installed in PBL tutorial rooms supported by standard LMS do delivery in-house and open-access materials for the students, increasing their engagement with the learning process.	LMS not specified Ethnographic Research Dentistry school (n=8)
[26]	Arevalo and Jimenez (2011)	The students had to develop software counting on content delivery and communication resources provided by the LMS. The students demonstrated a better learning, motivation, interest, and involvement than in typical classes.	LMS Moodle Qualitative Research Computing school (n=15)
[27]	Rosembaum et al (2012)	The students took a blended course with collaborative work. They presented positive impressions on using networked PBL. They appreciated the flexibility and location convenience, although they had low LMS activity.	LMS Moodle Qualitative Research Dentistry school (n=6)
[28]	Tomkinson (2012)	It describes a pilot project of networked PBL that assessed the learning outcomes and processes. The study assessed the collaborative learning positively and considered the method feasible, although some LMS issues.	LMS Blackboard® Likert Scale (Quantitative) Engineering school (n=15)
[29]	Tianton and Teemuangsai (2013)	It describes the development of four scaffolding modules for collaborative problem-based learning through networked PBL. The participants demonstrated satisfaction on the use of the developed scaffolding modules.	LMS Moodle Qualitative Research Computing school (n=22)
[30]	Regueiro-Gómez et al (2013)	It depicts a study case that implemented networked PBL in a blended course. The students demonstrated a high interest in the learning and social processes. They were up to develop other networked PBL blended courses.	LMS Moodle Qualitative Research Engineering school (n=23)
[31]	Tirado and Santos (2014)	It analyzes the relationship between the students' activity in networked PBL with the quality of their academic outcomes produced by the student groups. It concludes that the epistemic activities happen in forum and wiki, and that there is a relationship between co-assessment and performance in the course.	LMS Moodle Quantitative Research Psychology school (n=36)

It is important to notice that all studies of the Category 3 specified which LMS they used to validate networked PBL in real educational context. Nine out of the fourteen studies used Moodle, whereas four articles

mentioned the use of Blackboard®, and just one author declared the use of a proprietary and locally developed LMS. This information points out the preponderance of Moodle between experiments with networked PBL, reflecting the spread of this LMS among educational institutions around the world. According to Ali, Samaka, and Shaban [7], Moodle had 54% market penetration at the beginning of this decade. This preponderance of Moodle, coupled with the fact it is free software, makes this LMS an attractive option for the dissemination of any plug-in designed to enhance its functionalities dedicated to networked PBL.

2.4 Category 4 – Focus on Using Plug-in to Enable Moodle to Support Specific PBL Models.

Ali, Al-Dous and Samaka [32] report that the networked PBL count with three different implementations approaches from the technological perspective. The first one corresponds to the use of standalone systems that were developed specifically to support a PBL model. In general, these systems were developed to attend specific educational scenarios of the sponsor institutions [33]. The second approach involves the use of an LMS with its standard functionalities, as described in the Category 3 studies. The third approach involves the development of plug-ins to enhance the original functionalities of an LMS to enable it to attend a specific PBL model. This category presents this last approach, with two plug-ins described in the four articles listed in Table 4.

Table 4. Category 4 of publications.

Ref	Author(s) and Year	Summary Description	Details
[34]	Sancho et al (2011)	It describes the main functions of the Moodle plug-in Nucleo: Vermut's Inventory of Learning Styles, Group Management, and Soft Skills Evaluation. It declares that different courses use the plug-in, and they are collecting more data about how Nucleo affects motivation and soft-skill improvement, among other software enhancements.	LMS Moodle (plug-in Nucleo) Descriptive article
[7]	Ali, Samaka, and Shaban (2011)	The article describes the need, design, and development of a conceptual model for a networked PBL plug-in for Moodle. Moreover, it gives a panoramic view of the standalone systems focused on networked PBL as well as the use of Web 2.0 for implementing such method.	LMS Moodle (plug-in ePBL) Descriptive article
[32]	Ali, Al-Dous, Samaka (2015)	This article reviews and discusses the implementation approaches for developing PBL plug-ins for Moodle. It describes the main PBL models, justifies the use of Moodle as LMS, presents the technological challenges, compares ePBL to Nucleo, and discuss languages for modeling learning activities.	LMS Moodle (plug-in ePBL) Descriptive article
[4]	Al-Dous and Samaka (2015)	This article describes the methodology for developing the Moodle plug-in ePBL and its main functionalities. Furthermore, it presents a research which demonstrates the positive evaluation of the plug-in performed by teachers (n_T) for the design-time environment and by students (n_S) for the run-time environment.	LMS Moodle (plug-in ePBL) Quantitative Research Engineering school (n_T=8, n_S=12)

The two additive technologies (plug-ins) to adapt the Moodle for specific networked PBL are Nucleo, sponsored by the Complutense University of Madrid [34], and ePBL, sponsored by the Qatar University [7].

Nucleo is composed of a set of five different plug-ins to act synchronously, each one being responsible for different functionality in the implementation of networked PBL. It makes Moodle manage PBL processes according to Vermunt's Inventory Learning Styles [35], which involves automatically identify the student's support needs, grouping and assigning a task to them accordingly to their profiles. It also has a functionality to support the soft-skill progress assessment and self/group evaluation, preconized by Woods [3]. What underlies the Nucleo construction philosophy can be synthesized by the concern to provide remote collaboration, by quoting Sancho et al. [34] "group cohesion and cooperation are some of the key factors for the success of PBL strategies. Then, just providing remote communication tools for students does not guarantee the emergence of social interactions that lead to effective collaboration".

Thus, the operation of Nucleo encourages students to collaborate remotely with each other in small groups, using the paradigm of serious games. It means that the student groups receive social recognition for overcoming the challenges of the proposed problem. Moreover, the group components evaluate the student's social skills regarding leadership, innovation, communication, teamwork, commitment, and practice. The student can perform the assessment of both cognitive and social skills, the peers and the teacher [34].

The plug-in ePBL has its working algorithm fixedly based on the Woods PBL model [3]. Ali, Al-Dous, and Samaka [32] state categorically that the plug-in ePBL strictly reflects the procedures for implementing the PBL method advocated by Woods, including workflow, group dynamics and activity scenarios [3]. Al-Dous and Samaka [4] describe the plug-in ePBL with emphasis on some interface screens and the operating logic of both the project (design-time environment) environment and the application environment

(run-time environment).

ePBL makes use of Moodle resources to perform part of their PBL process management tasks, with the built-in functionality just what the LMS does not offer to strictly follow the PBL model advocated by Woods [3]. The plug-in provides tight control of phases, activities, tools, and resources. Moreover, it provides functions for the student to make self-assessment, be assessed by group peers, by classmates, and by the teacher, whether using a numerical scale or rubric [7]. In sum, ePBL helps the teacher to organize the PBL procedures during the design time and facilitates the PBL implementation during the run time.

The article also presents the assessment on the plug-in use, held at Qatar University, in a blended course context. They highlight positive research results, although they used a positivist epistemology counting on only 8 participants [4]. It contrasts with the research methodologies found in Category 3 studies, most of them used interpretativist approach (see Table 3), even though involving a larger number of participants. Those studies that used a positivist approach had between tens to several hundreds of participants.

IV. Conclusion

Although this systematic research, because of the use only of acronyms in its search arguments, did not include all the references that it could if it had used the complete names related to the acronyms, it revealed important information about networked PBL. The research results gave the directions for future research on this topic, besides it made clear the importance of networked PBL for scholars around the world.

The selected studies focus primarily on validating networked PBL in an educational context, most of them using Moodle in its native form. In fact, 19 out of the 28 studies of this systematic research use the LMS Moodle. It can be a deciding factor for anyone prone to develop research or technology for networked PBL with LMS. Not coincidentally that the articles of the Category 4 use Moodle to develop plug-ins to implement networked PBL. Then, the use of Moodle must be present in most of the future studies on networked PBL.

Different articles criticize Moodle [4, 7, 32, 34] due to the lack of adequacy to support the more complex PBL implementations. However, no criticizing article depicted the procedures were performed to reach the conclusion that Moodle functionalities do not cover all the networked PBL demands. As Moodle is a complex tool, with a huge set of configurations, it is important to investigate and to be explicit about how adequate Moodle is to meet the networked PBL implementation demands. On the other hand, as cited by Ali, Samaka, and Shaban, there are many variations of PBL [7]. Then, to assess Moodle adequacy to networked PBL, it is necessary beforehand to define which PBL model Moodle must meet.

Assuming that the future of networked PBL will keep involving the use of LMS, whether equipped with plug-ins or not, it is important to address the students' resistance to engage networked PBL. After all, interaction, usability, and aesthetics influence the user engagement in the use of software or online applications [36]. Although only Tomkinson [28], among the selected articles of this research, have mentioned students' resistance in using the LMS technology, it is important to investigate the impact of the quality of the LMS user interface to avoid that it undermines the adherence to networked PBL.

This conclusion is important to define priorities for future research in this field. Based on this study, the researchers will do other investigations aiming to fill the identified gaps, already adjusting the scope to focus the use of Moodle plug-ins on implementing networked PBL.

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