Ubiquitous Environments for Problem-Based Learning: A Bibliographic Review

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***Abstract*—This research presents a full paper in which we identify and systematize the new forms of access to information and communication experienced by contemporary society and their potentialities in the development of teaching environments. The called u-PBL corresponds to PBL combined with the use of ubiquitous environments for teachers, learning tools for learning activities and collaborative learning environments for students, ensuring meaningful learning. Studying the main works that report the use of u-PBL, benefits were found for the teaching-learning process. The methodology was a bibliographical review of the articles published between 2010 and 2018, in the bases Google Scholar and ScienceDirect. As a result of this analysis, emerged (i) environments adapted to different user profiles; (ii) different pedagogical activities in u-PBL; (iii) different methodologies of educational activities addressed when using u-PBL; and (iv) different technological languages implementing the environments used. It was concluded that u-PBL could be applied as a teaching-learning aid tool, acting directly and/or indirectly in areas such as Health, Computing, Environment, etc. Also, the need for studies that report the development of u-PBL interfaces that allow constant immersion of the student into the teaching-learning environment.**

***Index Terms*—Problem-Based Learning, Ubiquitous Technology, Ubiquitous Problem-Based Learning.**

I. Introduction

The advancement of computer technologies, such as the internet and mobile phones, has cooperated for the development of several areas. Education is one of the areas affected by this scenario, constantly needing to seek to enhance the teaching-learning process. Considering that the globalization of information is increasingly present, the pedagogy of reproduction goes in the opposite direction [1] and points out as a challenge of the learning processes the development of constructivist methodologies that allow the student to attend school not only to listen to the lesson, but to become an author of his own knowledge, enabling him to develop his ability to research and elaborate.

Active Learning emerges as an area where the student is encouraged to be the author of their learning process, to produce knowledge. In it, the student is encouraged to read, write, discuss and be engaged in solving problems, thus ensuring the development of their analysis, synthesis and evaluation capacities [2] and [3]. Among Active approaches, Problem-Based Learning (PBL) is one of the most outstanding strategies, because it is an engaging and motivational [4] experiential learning, in which students are close to the immediate details of the problem and the proposed solution [5].

The main characteristic of PBL is the use of problems that are embedded in students' everyday reality, which can be a motivator in the learning process, creating a highly interactive and practice oriented multidisciplinary and integrated knowledge base [6] and [7] with a unique characterization. When we look in the literature for the main advantages of using PBL, factors such as the development of reflexive knowledge, the development of metacognitive, self-directed and collaborative abilities are pointed out [8]. These advantages, by themselves, already value the PBL methodology a lot, and ([4], [5], [8]) point out that the great difference of the PBL for other methodologies is the degree of motivation can infer in students during their learning process and the practical factor that their activities propose. On the other hand, [8] indicates that this motivation, although it is one of the main appeals of the methodology, is still not fully achieved by current practices.

The relation between motivation and problematization in learning is pointed out by [5] and [4] as the emphatic element that allows the PBL method to generate external elements of motivation enlargement. However, this pedagogical strategy does not present an individualized form of incentive to the problematization of the task, being restricted to the processes of motivation of the students in group. This characteristic imposes difficulties on learning processes by limiting: (a) the personalization of the process, taking into account individual characteristics about the construction of knowledge, time spent on study and educational infrastructure; and (b) the self-learning decisions related to the study routines, which when

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taken in a non-effective way, can cause demotivation.

Provided by the advances in Internet connections and the evolution of ubiquitous environments, a new society design emerges that results from the intrusion of virtual communication channels and access to information while life is happening [9]. Based on this, the use of mobile and ubiquitous technologies to support processes such as the PBL becomes a research area in order to identify its potential for collaboration for active learning.

This work presents a literary revision directed to the use of Ubiquitous Technologies developed to deal with factors such as Reflection, Cooperation, Motivation and Availability of Information/Explanation, highlighted by [8], in learning environments, directing the investigation, more specifically, to the report of works that present the ubiquitous technologies developed as support to the PBL process.

This article is organized as follows: in section II, the method and steps performed in the development of the study are presented; in section III, the references involved in the work are addressed, emphasizing the relations between Ubiquitous Technologies and the teaching-learning processes; in section IV, we present works that present the development of Ubiquitous Technologies to support the PBL process; in section V, the discussions about the research are presented; Finally, in section VI, final considerations are presented on the objectives reached by the study and the future steps of the research are outlined.

II. Metodology

To reach the objective of this work, the researches were done in the bases ScienceDirect[1] and Google Scholar[2]. Initially, we selected works that combined the terms "Ubiquitous Technologies", "Education" and "Ubiquitous Learning", in order to analyze how ubiquitous technologies are currently used in learning processes. Initially, 25 papers with the highest relevance indexes, classified by the bases used, and published between 2010 and 2018, were selected. Of these 25, we selected 10 that had the greatest wealth of content regarding the topics addressed, which have their analysis presented in section III. In a second moment, in order to direct more directly the main objective of the work, 5 papers were selected from the 25 initial works, which, in addition to having already mentioned the terms already mentioned for the initial selection, included in their reports also the occurrence of the term " Problem-Based Learning". An analysis of this state of the art is presented in section IV and its relevant discussions are presented in section V.

III. Use of Ubiquitous Technologies in Education

We live in a society that increasingly evolves its way of access to information and communication between people. Provided by the advances in Internet connections and the evolution of ubiquitous environments, available to students based on the potential created by the use of mobile devices and applications, a new society design emerges, resulting from the intrusion of virtual communication channels and access to information while life is going on [9]. In his work, [8] emphasizes four important characteristics that active learning environments must have, and which we believe are extensive to ubiquitous learning environments, such as reflection, cooperation, motivation and just-in-time instructions. The ability of reflection is fundamental for the construction of a knowledge capable of being recovered from one environment to the application in another. The cooperation enables students to collaborate in the open exchange of ideas and involvement with all members present in the learning process. Motivation is a very important feature in learning environments, as students work through their own interests, challenges or feelings of satisfaction. Finally, the ability to provide direct instruction on a just-in-time basis is extremely important for successful learning environments, since, at a time when students are dealing with a problem and being confronted, an intervention at the moment can be beneficial.

The following is an analysis of the work that portrays the current use of ubiquitous technologies in learning processes. At first, general information about each work is described, accompanied by an analysis of the functionalities proposed by them and the identification of the characteristics proposed by [8]. At the close of the section, table 1 is presented, which shows an overview with the quantification of the presence of these characteristics in the studies studied.

The work of [10] relates to factors (criteria, strategies and questions) that need to be considered when developing a Context-Aware U-Learning. The authors present definitions of concepts that are inherent to the theme, highlighting the difference between U-Computing, calling a special case of M-Learning, and U-Learning, defining as Context-Aware Learning, composed of mobile service, wireless communication and sensors. Following his report, the work presents potential uses of U-Learning, setting the example in a system for plant identification, composed of wireless network, RFID sensors with tags in the plants and PDA with RFID readers for students. In the sample environment, 4 cases are described:

- Case 1 - Identification of plants following a guide, where the system assists, with questions and answers, the path that the student has to go through until discovering the plant. This form of activity enables the individualization of the task;
- Case 2 - Identification without guide, where the student will visualize the characteristics of the registered plants and reflecting on those that physically appear in front of him. This form of activity encourages reflection on the part of the student;
- Case 3 - Identification of plants, by consulting the database at the time of the research. Activity that provides just-in-time assistance by the system;
- Case 4 - Cooperative solution between 4 students who must communicate via Ubiquitous Technology to assemble a map with buildings and streets of the campus where they are present.

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

[2]https://scholar.google.com.br/

In [11] paper, reports a government project in Japan to encourage and provide the integration of ubiquitous technologies through the use of ubiquitous networks of free access, use of ICTs and constant updating of the network environment. In the course of the article, a selection of projects for assisted language learning for mobile devices are analyzed, taking into account the background of Japanese language learning by foreign students. In his reports, the article presents the following works studied in Mobile Assisted Language Learning (MALL):

- Mobile Phone in [12] technology that includes mobile phone sending of English vocabulary by SMS or mobile e-mail, and sending small videos and 3D animations via mobile phone for visual explanations about the English language;
- iTree, [13] a system developed at Tkyo University that generates a visual representation of student participation in the class discussion board, as a branch that develops in real time as the student contributes. This system stands out for promoting collaboration between students and encouraging their participation;
- Colaborative Learning Support Sysytem with Ubquous Enviroment (CLUE), [14] system for international students to learn the Japanese language in real-world situations. It presents as an example a functionality to learn ”expressions of courtesy” that is one of the most difficult characteristics of a foreign student to learn. It promotes suggestions of languages and conversations based on the context of the user, such as: physical, social, environment, age, etc., such as indicating expressions of the environment around where the user is walking, which is configured as a character individual of each student and just-in-time with regard to the availability of instruction;
- Personalized Knowledge Awareness Map [15] a system that creates a knowledge map for the student, contextualizing the individual support sites of each creation and making available information in other situations so they can reflect on information in the real world.

The literary review presented in the paper by [16], starts from the premise of the lack of a ubiquitous computing environment that contemplates the context-awareness whole. It points to the awareness of the context as the primary factor for the intelligence of the ubiquitous learning environment, it defines that this context (location, user data, activities, etc.) is in constant modification and that therefore these environments must be flexible to absorb these changes. In their research, they do not identify environments developed to present this flexibility, and point out only that there are specific developments for specific tasks, which they rate as more of the same. To base their affirmations, they present works with the portrait of some environments, of which 3 are described as follows:

- Context-Aware Writing System (C-Writing), [17] - Environment for students reading, writing, observing and discussing contents accessible via PDA. The system detects the student's position via RFID and triggers some content from their database. Displays chat for conversation among students during activities;
- Concept Map-Oriented Mindtool for Cohoborative U-Learning (CMMCUL), [18] - It is a tool for the construction of the conceptual map of the student. Allow the student to create your map and share it on servers on the internet. It allows students to compare their book-based map with learning objects from their real world, thus reflecting and updating their map online. Keeps the teacher informed of the student's current map;
- Context-Aware of Ubiquitous Learning System Using an Innovative Vizualization System, [19] In this paper the authors propose a system that relates the student to the register (via Ubiquitous Learning Log - ULL) of knowledge and acquired learning experiences. The resulting ULL is made available in a ubiquitous learning system called System for Capturing and Reminding of Learning Log (SCROLL), which presents to the student, when indicated, their knowledge organized by their context, thus providing reflection on what has been learned.

TABLE I
AIM OF THE STUDIES STUDIED, REGARDING THE CHARACTERISTICS OF [8]

Work	Reflection	Cooperation	Motivation	Just-in-Time
[10]	X	X	X	X
[12]			X	
[13]		X	X	
[14]			X	X
[15]	X		X	
[17]		X	X	X
[18]	X		X	X
[19]	X		X	

At the end of this section, Table I presents an overview of the characteristics highlighted by [8] that were identified in each study analyzed.

The data presented in this table will be used for further analysis in the discussions chapter.

IV. Problem Based Learning in Ubiquitous Environments

Based on the appearance of the new virtual paths already indicated by [9], one of the areas that is gaining strength is the use of mobile and ubiquitous technologies to support the PBL process. The called u-PBL is a PBL option that relies on the combined use of environments for teacher instruction, learning activity building tools, and ubiquitous collaborative learning environment for students ensuring meaningful learning [20].

This section aims to present a bibliographical analysis of the works found in the literature on u-PBL, with focuses in the environments developed to implement u-PBL ubiquitous learning processes and studies developed from them.

In his work entitled ”A context-aware ubiquitous learning environment for conducting complex science experiments.”, [21] present a ubiquitous context-sensitive (u-learning) learning environment developed to assist novice researchers in complex scientific experiments, set in a case study.

The proposed environment is composed of a Specialist Instructional System, a Learning Portfolio Database and a Tutorial Strategies Knowledge Base, described below:

- Learning Portfolio Database - Location of the environment where the parameters required for the Expert System infer are stored. In this database, parameters such as the Student Context (obtained via sensors), Environment Context (informed by sensors in rooms and equipment), Student Feedback (informed via mobile application), Student Profile and Online Behavior (list of available equipment and activities programmed for them), are obtained and stored so that the Expert System can read and, through analysis of the rules parameterized in the Tutorial Strategies Knowledge Base, adaptive and active for students to learn in the u-learning environment;
- Knowledge base of mentoring strategy - Location of the environment where are parameterized if - them rules that will be used by the Inference mechanism of the Expert System to instruct the activities whenever the if condition is satisfied. As an example, we note that if the student matches if "The student is currently operating the X-ray diffractometer" and "The ambient temperature is above 25 C", the system should them "Stop operation" and " Send temperature warning message ".
- Specialist instruction system - System logic that performs the role of a virtual expert with mastery in the study experience. Uses the knowledge stored by the physical specialists (teachers/tutors) in the Tutorial Strategy Knowledge Base to instruct students during their activities/experiments.

The work of [20] is the first work of this bibliographic review where the term Ubiquitous Problem-based Learning (u-PBL) is found. In the article "The framework of the PBL strategy integrated in LMS and the ubiquitous learning environment", the authors point out the great difficulty in developing e-learning environments with effective pedagogical practices within the Learning Management System (LMS). In order to contribute to this problem, a framework in the form of LMS for u-PBL practices is proposed, seeking to provide a connectivity between students and teachers that can provide support, cooperation and creation during the PBL process. In its proposal, the framework is divided into 3 parts:

- Teacher interface - Environment for creation and monitoring of the project and its activities, including tools to support them (Chats, Chat Rooms, Project Gantt, etc.);
- Student interface - Environment where students have access to the project and the activities created by the teacher, also with tools to execute them, exchange information with colleagues and build the solution;
- Data base and handheld interface - Ubiquitous environment made possible by wireless technology, where via PDA are provided assistance, information and related topics, in a timely manner, that are pre-programmed for activity in space and time, by the teacher.

In the paper by [22], The problem-refining progress of 5th graders ubiquitous inquiry., a u-PBL system developed to promote a collaborative environment for students is presented. For the implementation of the system, also 3 modules are presented supporting the PBL process, focused on the group task. The modules that make up the system are described below:

- Online Discussion Module - A channel where students can communicate with each other and with teachers, so that they can collaborate with each other and get support for doubts and achievements of activities;
- Green Laboratory Module - A tool that provides a virtual environment for performing activities. It is designed to allow students to update and share all their ecological observation information;
- Electronic Library Module - Database that serves as support to the students during their process of knowledge construction. In this module, students can check information already registered and/or describe and record new information that may be used by other students in the future. In this library are also available the teachers, materials to support the tasks.

In the work of [23], the authors present a model for the development of serious games, called UCHALLENGE, which uses ubiquity to provide interactions and enable the real environment to be part of a playful learning. To achieve greater student motivation and to provide greater autonomy to the student, the PBL approach was chosen. The model seeks to: i) adapt different domains; ii) to create problems and challenges; iii) provide environment for the teacher to choose the context that the information will be offered; iv) provide management with the teacher of when each step happens; v) storage of results; and vi) teacher-student interaction channel.

To support this proposal, 2 modules were developed:

- Tutor Module - which provides an environment for the teacher to create learning objects, problems, challenges; and manage when each step happens;
- Student Module - where the student receives the start for the stages of the game and the scenario with the interaction of the steps with the learning objects.

To validate the proposal, the paper presents a case study based on the History of the Middle Ages, with aspects about the Crusades and how they relate to the present day. For practice to be carried out, a game is set up where a park simulates a medieval forest, and the teacher records learning objects that must be arranged in different places and steps that the student will go through. In the end, the teacher sends feedback to students about their performance in the activity.

In the paper by [24], the authors propose a framework that aggregates the concepts of the ADDIE model, PBL process, Scaffolding and Ubiquitous Learning Enviroment. This framework implements the following modules:

- Ubiquitous Learning Enviroment - responsible for managing the learning environment to promote the PBL. It consists of mobile devices, wireless communication, student data and student context;

TABLE II
AIM OF THE STUDIES ABOUT UBIQUITOUS TECHNOLOGIES FOR PBL, REGARDING THE CHARACTERISTICS OF [8].

Work	Reflection	Cooperation	Motivation	Just-in-Time
[21]			X	
[20]		X	X	
[22]		X	X	
[23]	X	X	X	
[24]			X	X

- PBL - technique students will use to solve the problem;
- U-Scaffolding - module that assists and supports students to solve their problems. It helps through the context of the student, taking into account their activities, their location, etc. and supports the student by reminding him about information, coaching him, and setting up possible conversation environments for counseling with his tutor.

V. DISCUSSION

Based on the analysis of the work presented in the previous section, Table II presents a description of the characteristics highlighted by [8] that were identified in each work of Ubiquitous Technology for PBL studied.

The data in table II are better understood from the following discussions, work to work, presented below.

In the analysis of the limitations of the [21] study, the authors identified the importance of the student's relationship with the system, since their actions after are determinant for the success of the process, while failure to execute the instructions may make the experiment risky and/or with inaccurate results. Another limitation was related to the need for student feedback, since the system can only judge errors, failures and provide useful instructions, based on accurate data detected in the environment and/or provided by the student during the process.

This work represented one of the first efforts for the development of environments for u-learning, having its value linked to the structure of the proposal that was created, which served to develop other proposals and researches to be presented below. This segment regarding the use of the PBL was motivated by the observation that this methodology has not yet been able to contribute with questions such as the instigation for reflection of the students, the cooperation between them and their motivation.

In the conclusive study about the [20] article, it was possible to identify that from the activities programmed through the teacher interface and the ubiquity provided by the hand interface via the student's PDA, the system can have an important contextualized environment during the activities of the learning process. On the other hand, it was also possible to note that this contextualization is limited by the teacher's prior definition of activities, limiting the time and space of their performances, thus not adding to the possibilities that the student's everyday life can bring to their educational process.

In the analysis of the work of [23], it is possible to identify the benefits that the provision of information related to subproblems brings to the learning process carried out by the student, but also leads us to reflect as to the autonomy of this student as to its process, since the sequence of the activity, and along with it, of the materials arranged, is planned by the teacher and only executed by the student. Another point of grace identified in the proposal is related to feedback, which exists, but not just-in-time, and does not provide the student with the support of the tutor at the time of execution of his/her activities.

Analyzing the work of [24], it is possible to identify possibilities for building motivational environments and with just-in-time support, but we can not identify possibilities for cooperation, nor functionalities that instigate reflection of the learned.

VI. CONCLUSION

During the study presented in this paper, we discuss some of the current needs regarding the development of new educational practices. Also in our study, we pointed out the potentialities that the use of ubiquitous environments can provide in teaching and learning processes. Based on this, so that we could portray the real situation of this area of knowledge, we carried out a study about works that involve ubiquitous technologies applied to learning processes. Seeking to deepen and further specify this research, we detail our analysis a little more, aiming to understand the current reality of ubiquitous solutions specifically for the PBL process. At this point, we focus on the characteristics of reflection, cooperation, motivation and just-in-time support, defined in the literature as determinants for the success of the learning process [8].

Returning to the points already exposed in the discussions, we conclude that the study area still lacks solutions that fully contemplate the characteristics defined by [8], considering that the ubiquitous technologies presented do not yet contemplate the PBL process at points such as : (a) it does not contribute to the instigation of students' reflection, cooperation between them and their motivation; (b) not to aggregate the possibilities that the daily life (time and space) of the student can bring to his educational process; and (c) not use intelligent inference of the system, which can be considered automatic, from the detection, via ubiquitous sensing, of the student's environment.

In this scenario, the development of a Ubiquitous Technology for the PBL process can contribute to the Active Learning area, given the importance of the uncovered points presented in the PBL challenges of this work and its ability to provide incentives together and/or customized in order to increase students' motivation, making them proactive regarding cooperation and reflection in their learning process.

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