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A Ubiquitous Learning Approach on Robotics

Fernanda P. Mota[1], Rebeca B. Kalbermatter[2,3], Lizandro de S. Oliveira[1], José Lima[2,3]
[1]*Catholic University of Pelotas (UCPel), Brasil*
[2]*Research Centre in Digitalization and Intelligent Robotics (CeDRI), Instituto Politécnico de Bragança*
Bragança, Portugal
[3]*Laboratório para a Sustentabilidade e Tecnologia em Regiões de Montanha (SusTEC),*
Instituto Politécnico de Bragança, Portugal
Bragança, Portugal
corresponding author: fernanda.mota@ucpel.edu.br

***Abstract*—Ubiquitous learning refers to the integration of learning processes with everyday environments and activities using technology. By leveraging ubiquitous learning principles in the field of robotics, we can foster an immersive and interactive learning environment that promotes continuous learning and knowledge acquisition. This paper presents an in-depth exploration of a ubiquitous learning approach for robotics with the aim to enhance the educational experiences and capabilities of robotic systems. Furthermore, it explores the potential benefits and challenges of ubiquitous learning in the field of robotics, such as increased adaptability, personalized learning experiences, and the development of lifelong learning skills. The results indicate that a ubiquitous learning approach can significantly enhance the learning capabilities of students.**

***Index Terms*—Ubiquitous learning, Educational experiences, Learning environments, STEM.**

I. Introduction

The notion of building and testing is routine, essential, and valuable in industry and scientific research, so it must also be involved in educational processes [1]. The construction of prototypes allows the maturation of ideas, creativity, and initiative, which are a process that naturally lead to the awakening of different interests and the desire for more advanced knowledge in the pursuit of STEM areas that nowadays assume enormous importance and therefore they must be addressed. With each prototype built, a great reinforcement of knowledge is added to the student, including a critical notion of what to do and what not to do, significantly expanding the practical experience [2].

Involvement in the physical process allows the student to acquire self-confidence, which awakens interest in knowledge; thus, in the learning process, the teacher plays a fundamental role in this process, encouraging and illuminating new ways of seeking knowledge and their practical experimental implementations [3]. This paper presents a qualitative study of robotics in the Computer Engineering course. The idea is to take advantage of the class that can be multidisciplinary and allows the integration of different and interdependent knowledge in a project that performs comprehensive multidisciplinary cognitive training and is still motivating and challenging.

The main objective of this paper is to show how the Computer Engineering student understands the concepts and applications of robotics. The research is a preliminary study with a student participating in the robotics class, where we analyze the student's initial understanding of the discipline's concepts. After this analysis, we made class to help the student to understand the application of concepts in practical activities; for this, in each class, the student has access to pre-class material, in which he/she can prepare himself/herself to understand the concepts involved in the class and, when going to the classroom, he/she already has knowledge.

The structure of this article is as follows: Section II presents the theoretical bases of this work, addressing the concepts of Ubiquitous Learning, Robotics on Education, flipped classroom model, and Problem-Based Learning. Section III describes the adopted methodology. Section IV presents the main results of this research. In Section V, the discussions on the results found are addressed. Finally, Section VI presents the conclusions and indications for future work.

II. Theoretical Review

Ubiquitous learning can be referred to as the continuous and seamless acquisition of knowledge and skills in various learning environments enabled by pervasive technologies [4]. According to Weisser [5], ubiquitous computing and technology can define u-learning, characterized by Peña-Ayala [6] as the environment where applications support learning activities to improve student achievements anytime, anywhere, and in anyway.

In recent years, robotics fields have seen significant advancements, and ubiquitous learning integration approaches has emerged as a promising paradigm [7]. Robotics have been applied in multiple areas of higher education for various purposes, two of which can be highlighted to improve academic performance and facilitate learning. Higher education educators are particularly interested in technological learning environments since they offer new learning opportunities [8]. Obscure learning environments have been extensively investigated and applied in various fields, and this increase in u-learning research reveals that this new approach can provide interoperable, pervasive, and interactive environments to integrate, connect, and share learning resources [9], [10]. Ubiquitous learning is an emerging learning method that must be scrutinized when applied to learning. The main objective of recent research is to evaluate if this system helps students achieve meaningful learning to ensure the application of this new approach is valuable in education [11].

The ubiquitous learning environment can be an ally to emphasize learner-centeredness, context-awareness, and the integration of real-world tasks to foster active engagement and knowledge transfer. U-learning combines mobile and pervasive technologies, such as sensors, wearable, and smart devices, to create an immersive and personalized learning experience. Thus, Ubiquitous Learning, in the context of robotics, can be addressed into three topics to be debated, namely:

- Integration of Robotics and Ubiquitous Learning: Explores the integration of ubiquitous learning with robotics, where robots act as interactive agents, facilitating learning experiences. U-learning provides an ideal platform to enhance robot-human interaction, adaptive learning, and personalized instruction. The potential benefits of integrating robots into educational settings, training programs, and skill acquisition domains are discussed.
- Ubiquitous Learning Technologies for Robotics: Enabling the technologies to be used in u-learning in the context of robotics. This includes the use of sensors, IoT devices (Internet of Things), augmented reality, virtual reality, wearable devices, and cloud computing. These technologies provide the foundation for ubiquitous learning experiences by enabling data collection, context awareness, real-time feedback, and collaborative learning.

Problem-Based Learning (PBL) is another methodology that can help in the robotics learning process. Ubiquitous Learning Approach in Robotics has gained significant attention due to its potential to enhance student engagement and motivation while improving learning experiences and outcomes. Within this framework, two essential pedagogical methodologies emerge as effective strategies: the flipped classroom model and project-based learning. Both approaches emphasize hands-on activities, collaborative problem-solving, and active student participation, leading to enhanced motivation and a deeper understanding of robotics concepts.

PBL is an innovative learning method, as opposed to didactic models of teaching based on so-called traditional perspectives, in which the teacher is the processing center of transmitting knowledge to students who only receive and memorize knowledge transmitted [12]. Problem-Based Learning is a learning method that has gained space in numerous educational institutions of higher education and basic education in various disciplines [12].

In the conception of Barrows [13], PBL represents a learning method based on the use of problems as a starting of new knowledge acquisition and integration. In essence, it promotes student-centered learning, with teachers being mere facilitators of the knowledge-production process. In this process, problems are a learning stimulus for the skills development of resolution. PBL emphasizes comprehension more than memorization; but considers memorization is also necessary because the better the understanding of a given subject, the easier it will be to memorize and, consequently, learn.

The Flipped classroom model changes the traditional teaching paradigm, where students engage with instructional content outside of the classroom, usually using pre-recorded lectures, online modules, or readings. Classroom time is then dedicated to collaborative activities, discussions, and hands-on experiences. On the other hand, Project-based learning (PBL) is an approach that encourages students to work on real-world once hands-on projects are relevant to their enthusiasm. PBL in robotics involves designing, building, and programming robots to solve complex problems or address specific challenges. By engaging in PBL, students develop critical thinking, problem-solving, and teamwork skills while they apply theoretical concepts to practical activities.

The flipped classroom is just one way for teachers to adopt the active methodology. Although it is a method that has attracted more and more followers, it is a practice that requires, on the part of the teacher and the students, a different dynamic in their studies [14]. The flipped classroom is a pedagogical model created in 2007 by North American chemistry teachers Jonathan Bergmann and Aaron Sams, who are considered the pioneers of the model in high school [15].

The Flipping Classroom establishes a framework that offers students a personalized education tailored to their individual needs. When talking about flipped classrooms, it must be considered that when the teacher opts for this methodology, it is up to him/her to practice "making it happen", since the central idea of such practices is to shift attention from the teacher to the learner. and their respective learning. The class revolves around the students, not the teacher, who is present solely to provide expert feedback [14].

III. Methodology

The purpose of this paper is the preliminary analysis of learning process of robotic class. The class has just one student participating in the robotic class of the Catholic University of Pelotas, UCPel, where we analyze the student's initial understanding of the subject's concepts. A student is a man with a 26-year-old enrolled in the robotics discipline of the 8th semester of the face-to-face Computer Engineering course.

The discipline took place in the first half of 2023, from March to June 2023. During this period, the student had access to audiovisual and textual materials on the following subjects related to robotics: Introduction to robotics, history of robotics, the structure of the manipulator robot, control of manipulator robots, types of sensors, functions of sensors, types of actuators, functions of actuators, types of programming language, levels of control, exercise with the robotic simulator webots, Robotic Systems: Architectures of Robotic Systems, Components and Subsystems, Sensors, Actuators, Microcontrollers, Human-Machine Interfaces, Embedded Systems, Motors, and Sensors, Computer Vision, Robot Control, Artificial Intelligence in Robotics, Mobile Robotics, Collaborative Robotics, and Robotics in Space Exploration.

The methodology consists of three parts, as shown in Fig. 1: i) diagnostic evaluation - consists of an initial analysis of the student's understanding of the topics that will be addressed

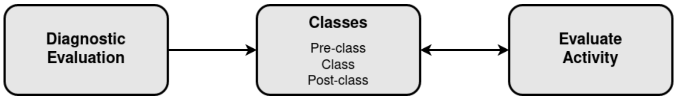

Fig. 1. Methodology Design

during the course. ii) classes - carried out in three stages: *pre-class*, in which the student has access to material for an initial understanding of the concept that will be addressed in class. The student have access to preclass material, in which he/she can prepare himself/herself for the understanding of the concepts involved in the class and when going to the classroom he/she already have prior knowledge and doubts that can be solved during the class; *class*, in which the topic will be addressed in person for approximately one hour, with exercises and didactic material; and *post-class*, which consists of material to exercise and internalize what was covered during the class. After the class, activities are also sent to assess the student's understanding throughout the learning process. iii) evaluative activity - consists of an evaluation through a practical activity or exercise to identify possible student difficulties when approaching topics related to robotics.

IV. Results

In the pre-class, audiovisual materials were used for the initial understanding of concepts, as shown in Figure 2, which served as a basis for discussions on the central theme of the class. In addition, it can be seen that the material helped to begin the initial contact with the concept, promoting curiosity and doubts about the topic to be addressed. In the class, an approach was used that is based on the pre-class and the presentation of the initial concepts and subsequent discussion with the student about the implications of the concepts in practice, such as sensor changes and their influence on the robot's activity, as well as real applications in the industry as control of manipulator robots in activities of the automobile industry. In the postclass, it can be noticed that the student can practice the learning processes discussed during the class, such as making connections between the audiovisual material observed in the preclass, concepts analyzed in class, and practical exercises carried out after class.

The exercises were performed in an open source and cross-platform desktop application used to simulate robots, which is called Webots. Webots [17] provides a complete development environment for modeling, programming, and simulating robots, as seen in Figure 3. Webots includes a collection of freely modifiable models of robots, sensors, actuators and objects. Webots uses a fork of ODE (Open Dynamics Engine) to detect collisions and simulate rigid body dynamics. The ODE library allows one to accurately simulate the physical properties of objects such as velocity, inertia, and friction [17]. Webots include sensors and actuators often used in robotic experiments, for example, lasers, radars, proximity sensors, light sensors, touch sensors, GPS, accelerometers, etc. Robot controller programs can be written outside of Webots in C, C++, Python, ROS, Java, and MATLAB using a simple API.

Fig. 2. Pre-Class Example. Source: [16]

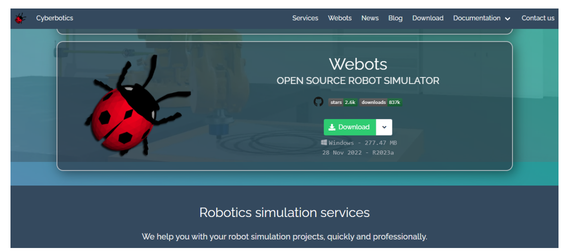

Fig. 3. Webots Example. Source: Webots [17]

Three practical activities were carried out: i) Simulation environment with two pre-programmed robots: in this activity, the student had an initial contact with the simulator, in which the student configured the variables in the environment and inserted static elements such as trees and objects from a garden, as well as a vacuum cleaner robot and a quadruped robot with a camera and movements predefined by the simulator, as can be seen in Figure 4. ii) Robot with legs: in this challenge an insect-shaped robot was developed and made from a combination of linear motor devices, LinearMotor, in which objects were inserted in the environment, and the robot code was changed so that it could move in the environment, as shown in Figure 5. iii) Robot soccer game: in which two teams of simple robots play soccer. A Supervisor controller is used as the arbiter; it counts goals and displays the current score and remaining time in 3D view. This example shows how a Supervisor controller can be used to read and change the position of objects, as seen in Figure 6.

V. Discussion

In this work, we used the concept of Ubiquitous Learning by providing materials that preceded the face-to-face classes to stimulate the student's curiosity to search for other contents and topics related to the subject that would be addressed in class. Regarding the concept of PBL, the methodology was approached through challenges that were sent to the student after the face-to-face classes, in which the student could build

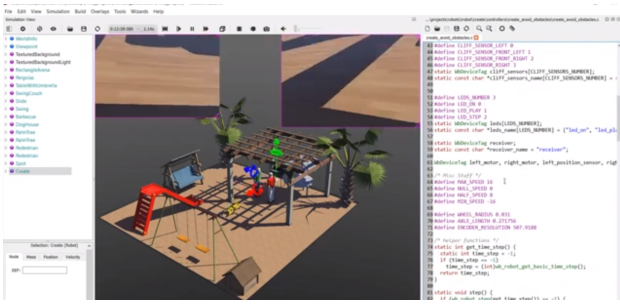

Fig. 4. First challenge in Webots simulator.

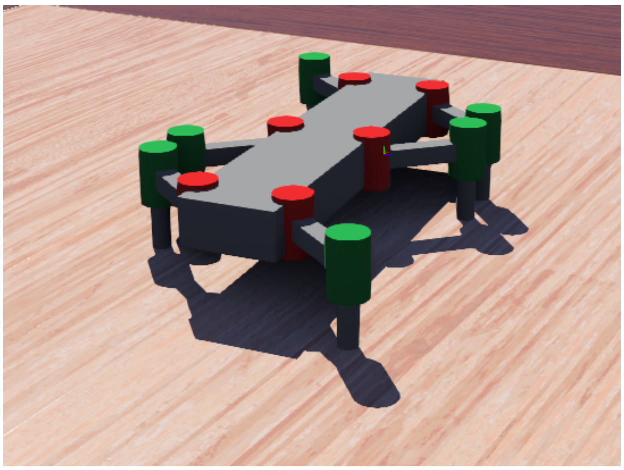

Fig. 5. Second challenge in Webots simulator.

connections between the concepts and problems of their daily life.

Activities, such as assembling robot components, programming their behaviors, and testing their functionalities, allow students to get a deep understanding of robotics principles. As remark, the combination of the flipped classroom model, project-based learning, and a hands-on approach creates a powerful learning environment that motivates students in the field of robotics. It is noticed that these approaches bring students are more likely to actively participate, explore advanced concepts, and improve their solving complex problems capability. Moreover, these approaches give students soft skills such as Teamwork and Collaboration, Time Management, Leadership and Decision Making and hard skills such as Programming and Coding, prototyping and mechatronics knowledge just to mention a few.

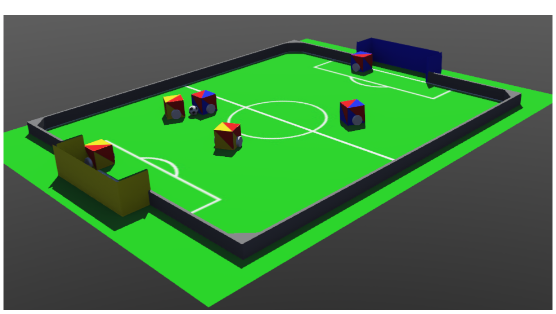

Fig. 6. Third challenge in Webots simulator.

The previously presented challenges are examples of practical activities that allow students to test several technologies in simulation, such as dynamics, programming, sensors data interpretation, actuators, and behavior. Finally, computational thinking has emerged as a crucial skill set that equips individuals with problem-solving abilities applicable to several domains, including robotics [18]. It uses computational concepts and strategies to approach complex problems. So, robotics as a multidisciplinary area, provides an ideal platform for developing computational thinking skills. In summary, the presented challenges using robotics to teach are aligned with the methodology of STEM (Science, Technology, Engineering, and Mathematics) disciplines and beyond.

Finally, regarding the flipped classroom concept, we used this classroom methodology by placing the student at the center of their learning process; we provided subsidies so that the student could seek new activities and challenges that addressed the themes related to the topic covered in class. By promoting moments in which we evaluated the student's prior knowledge, as well as classes that had pre-class, class, and post-class activities and diagnostic evaluation, it allowed us to accompany the student throughout the learning process, giving us subsidies to assess whether the topics and activities addressed were being understood and providing challenges so that the student felt motivated to continue challenging himself in his learning process.

The initial results showed evidence that the challenges related to PBL, as well as the use of the concept of Ubiquitous Learning in a flipped classroom, can provide students with enriched learning processes through moments of discussion about the application of the subjects and their relevance in their lives and academic education.

VI. Conclusions

This paper presented several examples of ubiquitous learning approach for robotics with the aim of enhancing the educational experiences and capabilities of robotic systems. Examples showed the potential benefits and challenges of ubiquitous learning in the field of robotics, such as increased adaptability, and improved teamwork and collaboration skills. Hard skills such as Programming and prototyping are also reached with the proposed applications. The results stated that using a ubiquitous learning approach can improve the learning capabilities of students while keeping them motivated. In future work, the authors intend to explore additional scenarios and approaches.

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