1. **Laboratories and e-learning**

*In control systems and automation*, Besada-Portas et al. [1] describe a remote technology to reduce the costs of the hardware setup for control experiments. The technology is composed by a Raspberry Pi that runs with an open and scalable system known as REX Control System. [Čech et al.](#page24)[2] describe the virtual laboratories *ContLab*, which are dedicated to feedback and feedforward vibration control, and damping. The system was developed with the REX Control System that automatically generates the code in Java language for the different controllers. Bermúdez-Ortega et al. [3] present a Remote Laboratory (RL) for automatic control education that employs Easy JavaScript Simulations (EJsS), Node.js, and Raspberry Pis. The Raspberry Pi is used as a server and controller application for the plant (vertical mono-rotor). The students and teachers can parametrize and observe the behavior of the PID controller, and the control plant. Reck and Sreenivas [4] developed a kit for a course of control systems (GE320). The authors mentioned several experiments with the kit that has the purpose to improve the learning of the students in the topics of system identification, system frequency response, stability, PID controllers, among others. Sobota et al. [5]expose some (HIL) simulations and experiments for control systems education. The students are exposed to problems in control engineering independently of the used hardware, allowing them a better understanding of the concepts and theories in this area.

*In robotics and mechatronics*, James et al. [6] propose an infrastructure to support the development of skills in the students through a remote laboratory in the cloud called Cloud E-learning for Mechatronics (CLEM). The authors made a preliminary survey to 80 potential trainers to know the feasibility of the laboratory and perception of the learning materials deployed in it.

*In communication networks*, a study to observe the feasibility of the Raspberry Pi for a laboratory is expose by Kyuchukova et al. [7]. The proposal explores the possibility to replace the console servers that result expensive by low-cost SBCs devices. The authors proposed an architecture for communications network using the Raspberry Pi as a console server.

*In smart grids*, Schvarcbacher and Rossi [8] expose an alternative of laboratory because of the high cost of the devices and equipment. The authors point-out two scenarios of testbed; the first one is associated with the sunlight level in a solar panel and the second one regarding to predict the power consumption of a load. Authors using the Raspberry Pi and a framework named *Mozaïk* which executes data synchronization between individual simulation entities. Likewise, Zambrano et al. [9] describe the platform *GridTeractions* that was designed with LabView and Java for distribution systems in electrical engineering. The article illustrates the details of the implementation and testing of the platform.

*As improvements and services for remote and virtual laboratories*, Rivera et al. [10] describe a Smart Adaptive Remote Laboratory (SARL). SARLs allow adapting their contents in function of the learning process that one student has in a course with the configuration of the teacher. The proposed laboratory is aligned with the IEEE standard P1876 (Networked Smart Learning Objects for Online Laboratories). The authors used several Raspberry Pis to allow the students to access and control remotely the GPIOs of them. Likewise, a utility called Experiment Dispatcher to simplify the development and deployment of online laboratories is presented by Zutin and Kreiter [11]. The framework provides an online laboratory server infrastructure service to be accessed by the laboratory developers. The service reduces the technical requirements of the laboratory that could be accessed by a low-cost device like the Raspberry Pi in any network. The service interacts with the user, employing a simple web service through the HTTP protocol and it is fully compatible with the Smart Device specification from *Go-Lab* (<https://www.golabz.eu/>) [12].

1. **Computing Education**

*A proposal to teach bioinformatics* to students of Biology is addressed by Barker et al. [13]. The approach includes teaching material in Linux, Raspberry Pi, genomes, bioinformatics data, and BLAST databases. The authors indicate that the usage of Raspberry Pi simplifies the problems of compatibility between Windows and Linux machines, allowing the student to interact directly with bioinformatics in a low-cost way and replacing the cost of licensing for specialized application servers.

*As approaches to integrate robotics and programming*, Wirth and McCuaig [14] describe a methodology carried-out with 700 students of the course of programming introduction (CIS\*1500). The course is accompanied by the Raspberry Pi that provided portability to the students to develop and implement the assignments and tasks in the course. The students indicated that the usage of Raspberry Pis in the classroom is a good idea to enjoy programming and learn more about it. A holistic alternative to integrate robotics into the curriculum of computer science is exposed by Boender et al. [15]. As programming language for the approach was chosen Racket because it provides a complete interaction between programming concepts and hardware devices. An open-source robotic platform known as MIRTO (Middlesex Robotic plaTfOrm) was developed and it is composed by a Raspberry Pi and Arduino microcontrollers, allowing the students to put in practice the learned programming concepts. Doran and Clark [16] describe an approach to enhance the curriculum of computer science through robotics. The approach uses robots Lego NXT that were modified including new applications with LiDAR, ultrasonic sensors, RFID readers, and wireless XBee communications. These elements are interfaced with Arduino microcontrollers and Raspberry Pis and were included to challenge the students. The authors highlight some projects that gather machine learning and artificial intelligence in which the students learn programming concepts in the CS1 course.

*In image processing*, Morison et al. [17] expose an experience using a Beagleboard-xM board for a course of machine vision and image processing, which is offered to the students of Computer and Electronics Systems in the final year of their career. An object tracking with OpenCV was proposed as a final project. The students’ feedback from the laboratory work was positive and the students found the project challenging but enjoyed the educational experience according to the authors.

*In parallel computing*, Doucet and Zhang [18] present a cluster using Raspberry Pis. The initiative was promoted by a student and the teachers given the lack of resources to learn parallel programming. Students were funded to acquire the components employed in each cluster, learning about the required concepts. A benchmark testing was performed between a single Raspberry Pi and the developed cluster comparing the results for the calculation of the PI value. Matthews et al. [19] propose a course for parallel and distributed computing with Raspberry Pi. The authors pose several features of the Raspberry Pi such as standardization, ease of setup and maintenance, affordability, and immediacy. The teaching modules for the courses encompass parallel fundamentals, parallel decomposition, communication, coordination, parallel algorithms, and architectures that are available at the site *csinparallel.org*. The experience of the course indicates that the usage of SBCs is a highly motivating way to introduce undergraduate students on parallel and distributed computing. Levandowski et al. [20] present a methodology to learn parallel programming with the Operating System (Xinu) developed by Purdue University. The Xinu’s core files were replaced to prepare the students in the steps for the set-up of multicore assembly. Then, Xinu is run remotely through the Raspberry Pi and the students made different tasks with hardware interaction. The authors state that the prior work on parallel computing was focused on theoretical aspects and high-level packages instead of the understanding of the low-level programming needed in parallel programming. Younis et al. [21] indicate a proposal that employs the educational methodology of PBL to impact student learning in the course of (Cs3120-computer organization and programming) which is focused on parallel programming using the raspberry pi and OpenMP. To measure the impact of the proposal both a pre-test and a post-test were performed to 124 students. Results show a medium improvement of personal learning in programming and soft- skills with a positive reception of the methodology by the students.

*As proposals to learn MySQL and assembly language*, Bruce et al. [22] show how the Raspberry Pi is being used in some courses of computer science (Internet of Things, Embedded Systems and Database Management Systems). In the last course, students install a MQSL server in the Raspberry Pi, configuring the permissions, and put their databases in a network with PHP and JavaScript. In this case, the RPi facilitates the interaction between computing and real applications. Kawash et al. [23] describe a methodology for teaching Assembly Language to students of computer science in the subject of Computing Machinery II (CPSC 359). The approach uses a Raspberry Pi and a Super Nintendo Entertainment System (SNES) controller as devices for the students interact with software and hardware. The course is focused on computer interaction with input-outputs of the Raspberry Pi, Video programming, advanced ARM assembly programming, interrupts, and exceptions. 337 students took the methodology during the periods (2013-2015) and 198 students answered a final survey in a Likert Scale. 82.32% of the students indicate that the Raspberry Pi helps to enhance their learning process and motivation in the course.

*Lastly, as a proposal to learn digital literacy*, Vasilchenko et al. [24] illustrate an alternative to teach media literacy to 34 students of computer science. Students were encouraged to record several tutorials in videos about topics regarding programming and Raspberry Pi in a collaborative way with the tool *Bootlegger*. 102 tutorials were submitted by the students. The tutorials were evaluated, and the authors posed that the methodology was positive despite the bugs and in stability of the video tool.

1. **Robotics**

*In design and construction of robots*, Gonzalez-Nalda et al. [25] expose a learning experience in an elective course in which students designed and developed a remote control system based on Android to handle an educational robot, combining the concepts learned in previous courses such as programming, operating systems, and network data. Bewley et al. [26] present a new educational program in robotics for professional students based on the development of three versatile vehicles with the SBC BeagleBone. The course covers topics in control theory, robotics, and operational amplifiers. This approach is also described by [Krauss](#page25) [27] that exposes the learning experience of the students in the construction of small low-cost autonomous vehicles.

*In the perspective of low-cost and accessible robots*, Kumar et al. [28] indicate an architecture for remote labs with Free and Open-Source Software (FOSS). Eight experiments were proposed in the line of *bio-inspired* robotics. A comparison with a proprietary architecture composed by a LabVIEW server and the new one with FOSS is described in the article with their implications. Brand et al. [29] expose an introductory robotic course with a robotic platform to teach drones called *PiDrone*. In the course, students built and tested several autonomous drones with the help of a camera and distance sensors. Hernández et al. [30] present a didactic experience in the implementation of a robot that has been elaborated with a Raspberry Pi. The proposal describes how topics as microcontrollers, mechanical design, and communications interfaces can be integrated as pedagogical elements in the courses of programming. It is worth mentioning that during the last years, these kits and low-cost robots have fostered learning and creative thinking in the students [31].

*In Artificial Intelligence with robotics*, Ferreira and Freitas [32] developed a two-month intensive workshop for undergraduate, master, and PhD degrees. The course covers topics in Robot operating system (ROS), (AI), kinematics, 3D printing, and sensors. Students got experience in problem-solving, decision making, and task completion. 84 students participated in the workshop. The proposal shows the educational results in terms of comparisons between the initial and final levels of understanding in the areas of mechatronics, control, AI, and computer-aided design. In turn, Matzka and Franke [33] apply the AI in a course with autonomous robots. Students made the programming of a control system to use the feedback from ultrasonic sensors and Wi-Fi modules. The authors emphasize the importance to integrate AI with applications in the real world that tackle the learning needs and competencies required by the students. Ma and Alborati [34] present a robotic kit, controlled, and programmed employing a Raspberry Pi. The kit is included into an educational methodology based on Artificial Intelligence (AI) and control systems to improve the learning of the students.

1. **Internet of Things (IoT)**

During the last years, IoT has gained importance in engineering and CS education by two factors: its ubiquitous nature and the requirements of the industry sector in so far as the technical abilities of the students. [Madakam](#page26) et al. [35] define IoT as “An open and comprehensive network of intelligent objects that have the capacity to auto-organize, share information, data and resources, reacting and acting in face of situations and changes in the environment”. Although this paradigm is maturing, there exists a lack of educational methodologies in this field. As a result, students in the STEM fields will not be adequately prepared to cope the challenges of the labor market demands [36].

To deal with this matter, in two studies [36, 37] He et al. propose a curricular transformation in CS that includes the features and advantages of IoT. The authors emphasize the importance of IoT for problem-solving and learning with emerging technologies that are demanded by the industry sector. The studies [22, 38–40] indicate that the SBC (Raspberry Pi) has facilitated learning in the realm of programming and sensor networks. The usage of SBCs with IoT should be included in the curricula of CS to benefit the students. Bruce et al. [22] show the educational development of three courses in CS education, one of these focused on IoT. While the course size and the teaching styles can change, the Raspberry Pi provides the students the opportunity to experiment and valid the theoretical concepts of the course.

Chaczko and Braun [38] describe the suitability to incorporate the open-source tool Node-RED to teach concepts in an IoT course. The comprehension and experimentation with IoT technologies depend on the hardware availability, low-cost, and the easiness of the tools employed by the students. With the development of simple laboratory exercises that involve hardware and software, the students acquired basic abilities in data engineering. In the same line, [Klinger](#page25) and Madritsch [39] present pocket laboratories for image processing and IoT. The methodology was offered to 60 students and their opinions regarding the laboratory and its implications are summed up in the document. [Mahmood](#page26) et al. [41] pose a framework to detect the student’s behavior in terms of attentiveness and peer interactions through facial recognition using Raspberry Pi and IoT. The framework is integrated into an e-learning platform to monitor the student’s performance with learning analytics, providing feedback to the teachers take actions to foster learning in the students.

1. **Persons with disabilities**

Although the main part of the selected studies in the SLR have been specified for persons without special educational requirements, some studies describe technological proposals or methodologies that can help with learning and teaching in the community of persons with physical and cognitive disabilities. In this line, Agatolio et al. [42] show a study about teaching robotics to educators who serve students with attention deficit, autism, or mild mental retar-dation. The methodology aims to robotics will be included in the courses as a scaffold to foster cooperative learning and social interactions in the students. Participants in the study manifest that robotics is a powerful tool that can be included in their courses to help students with learning disabilities.

Ramirez-Garibay et al. [43] present the device *MyVox* for deaf-blind persons. The system is composed of a braille screen, a Raspberry Pi, and a speaker. With the device, persons with these disabilities can interact each other. The authors indicate that the system is portable and can be used in diverse applications such as speech synthesis, braille contractions, and SMS messaging. Also, the studies in [44–46] depict systems for braille with speech recognition that arose as low-cost alternatives. Similarly, da Fontoura Haeser and [Miletto](#page24) illustrate the development of the prototype *Gambiarrádio* which is a device to transmit radio through FM radio waves that could be employed to support visual impairment students. The authors highlight that the prototype is FOSS and could serve as an inclusive tool to promote learning in students with disabilities.

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