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Learning Robotics: a Review

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Abstract

Purpose of Review With the growing interest for STEM/STEAM, new robotic platforms are being created with different characteristics, extras, and options. There are so many diverse solutions that it is difficult for a teacher/student to choose the ideal one. This paper intends to provide an analysis of the most common robotic platforms existent on the market. The same is happening regarding robotic events all around the world, with objectives so distinctive, and with complexity from easy to very difficult. This paper also describes some of those events which occur in many countries.

Recent Findings As the literature is showing, there has been a visible effort from schools and educators to teach robotics from very young ages, not only because robotics is the future, but also as a tool to teach STEM/STEAM areas. But as time progresses, the options for the right platforms also evolve making difficult to choose amongst them. Some authors opt to first choose a robotic platform and carry on from there. Others choose first a development environment and then look for which robots can be programmed from it.

Summary An actual review on learning robotics is here presented, firstly showing some literature background on history and trends of robotic platforms used in education in general, the different development environments for robotics, and finishing on competitions and events. A comprehensive characterization list of robotic platforms along with robotic competitions and events is also shown.

Keywords Distribution · STEM/STEAM · Educational robotics · Robotic platforms · Mobile robotics · Autonomous robotics · K12

Introduction

Robotics in the past was considered rocket science created by scientists or high-skilled engineers. Nowadays, that is not the case anymore. The importance of learning robotics especially at early ages is visible by the amount of studies found in the literature. Although robotics started as machines that perform routine or dangerous tasks previously done by humans, it has evolved to autonomous and mobile robotics and lately is used to help improve student's knowledge and skills in science, technology, engineering, and mathematics (STEM). Arts was another area that took the opportunity to embrace robotics and thus the acronym became STEAM [1].

Kindergarten is the child's first school, and Evgenia Roussou successfully introduced computational thinking by playing with robotics at these children's level [2].

At the primary school level, a similar approach was experimented [3]. The focus was on the teacher's side providing them with a robotic kit to promote problem-solving and group work with their pupils. Teachers felt more confident and aware of teaching computational thinking concepts. Another study in primary schools was performed to introduce educational robotics (ER) by using a realistic mathematics approach [4]. Student's motivation was higher when compared with learning mathematics in a traditional way. At the K-12 level, in order to motivate students enrolling in technology areas, one school used their Project Area curricular unit to have groups of students participating in the RoboParty® event [5]. A standard robotics curriculum for K-16 students was proposed by Carlotta et al. [6] where a set of guiding

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principles for teaching robotics is drawn. These studies demonstrate the broad scope of ER in STEAM areas that can be reinforced with systematic reviews on ER for young children [7], K-12 [8, 9••], college students [10], and others [11–14]. A technical database for K-12 detailing ER characteristics of robots was also found [15••]. Many universities also organize camps (summer and others) related to learning robotics for K-12 [16, 17].

As it has been shown, from young to college ages, there is a growing effort to create and develop educational programs of robotics or to integrate it as an aid to teach STEAM areas. Learning robotics is then an activity for all ages where a robotic platform (RP) and a development environment (DE) are essential. Some DEs have included graphical simulation of different robot platforms where the learner or developer does not need to acquire the hardware to learn or practice robotics in general or a specific robot platform.

Robotic Platforms

To start learning robotics, a basic robotic platform is necessary. For that, Lego® Mindstorms with its model RCX (Robot Command eXplorer) was one of the first commercial robotic platforms available for beginners [18]. This platform allowed an easy implementation of the basic robotic primitives such as the sense-plan-act (SPA) paradigm. Nowadays, the Lego® WeDo platform is commonly used for ER in primary schools [19] and the EV3 model for advanced school projects [20]. The advantage of these Lego® platforms is the easiness of building mechanical structures. For children, it is a normal evolution from their basic brick building blocks when toddlers. For advanced school projects, a special purpose robot is fast to build requiring low mechanical skills.

With the growing market of Lego® Mindstorms, the need for custom build simple robot platforms using cheap commercially available components moved authors to produce their own solutions for ER. At high school and college levels, Krzysztof Mianowski proposed the construction of an arm manipulator made of composite materials, servo-motors, and PIC controllers [21]. Many authors during this decade built their own robot platform with low-cost components for ER [22, 23]. It was also the decade where some ready-made robotic kits became commercially available such as the Bot'n Roll [24] and QFIX [25], amongst others. The advent of the ready-to-use microcontroller platform such as Arduino [26] defined the trends of robotic kits for the following decade (e.g., Andruino-A1 [27]). Everywhere, Arduino-based robotic kit platforms started to blossom until today. This microcontroller platform allowed basic SPA principles to be implemented, with the application of multiple sensors and actuators and basic process control. For more elaborated and advanced solutions, another platform was added based on a small single-board computer: the Raspberry Pi [28]. This add-on board allowed a great increase in processing capability to simple robots at a very low cost [29]. It also allowed the use of complex sensors (artificial vision) and also integrated wireless communications such as Wi-Fi IEEE802.11 and Bluetooth. ER now can sense (with simple or complex sensors), plan (with advanced control algorithms), act (with advanced motion controllers), and communicate (with latest wireless technologies), thus becoming a SPAC system. Communication allows collaborative tasks between robots as well as remote monitor and sensing for the developer.

Three other ER platforms should be mentioned in this review: BIOLOID [30] and DARwIn-OP [31] from ROBOTIS and NAO from SoftBank Robotics. These three platforms are not at the low-cost level, but they are still very important for ER. BIOLOID is an ER platform created to teach the principles of robot joints, kinetics, and inverse kinematics. It is an essential platform for learning robotics where understanding of links/joints or legged motion in different shapes and forms is necessary. Whereas BIOLOID can be assembled to achieve any legged robotic form (humanoid, spider, lizard, etc.), Darwin-OP has a fixed humanoid form walking on legs, and it is the acronym of Dynamic Anthropomorphic Robot with Intelligence–Open Platform. It is being used for humanoid autonomous motion robotic research, fully featured with computing processing and camera. NAO and Pepper are more advanced humanoid robots, also walking on legs or wheels and having two arms with end grips. These platforms have stereo cameras, microphones, tactile sensors, sonar rangefinder, inertial sensors, and distance infrared sensors with wireless communications. Its vast use in research is known from robotic soccer [32], artificial intelligence [33], autism spectrum disorder [34•], etc.

Learning robotics with actual robot platforms is accessible to everyone and powerful as never been before. The motivational driver is now on the side of the DE, i.e., the software framework part.

Development Environments

A good DE is what makes the motivation for learning robotics easier. Some are graphical programming or block based (BB) and other text based (TB). Some also allow simulation. When Lego® Mindstorms was first launched, they introduced a DE that was based on BB called Robotics Invention System on the commercial version and Robolab on the educational version. The latter was based on National Instruments LabView. Many more DEs exist for this robotic platform both BB and TB. A comparison between them concluded that for beginners, a BB DE is better suited due to being more robust and supportive whereas for advanced learners, a TB DE is more powerful

[35]. That difference has been dissipated lately as actual BB DEs have greatly improved. Comparison studies found little difference in the learning outcomes for both types [36•] although there is still the stigma that BB is for novices and TB for advanced users.

BB DEs such as Scratch, Alice, and Snap! are conquering the market for novice programmers but still need some middleware to interface with robotic platforms [37]. Companies are producing their robotic platforms by adopting Scratch as their BB DE [38]. For TB DEs, C/C++, Java, Python, and Matlab are the common languages supported by the majority of the robotic platforms with their own software framework. RobotC was one of the first cross-platform DE for robotics that started with the Lego® RCX [39] and carried on to later models. It also supports robots from VEX robotics. Arduino IDE is the choice for Arduino-based robot platforms [40•]. It is written in Java and based in Processing. It has the support of a vast community of developers for improving and evolving the Arduino library.

Google Blockly [41] and Open Roberta from Fraunhofer Institute [42] are BB/TB DEs where blocks and text code are put side by side. Users create their block programming, and the DE converts it to text code on the fly, helping youngsters to easily move from BB to TB. They are both open source and are used in many robotic platforms.

Some DEs do not use computers at all for programming. They were developed for kindergarten ages as a board game and are based on using physical pieces (wood, plastic, etc.) with symbols that correspond to robot actions. Examples are found in Table 1.

Many other DEs are proprietary and made specifically for use with robot platforms of their own maker, especially for industrial robots (ABB, Fanuc, Kuka, etc.).

Robot Operating System (ROS) is an open-source software framework and library managed by Willow Garage, and it can be integrated on a DE [43]. It creates an ecosystem that allows writing robotics software to be used on different robot platforms. This framework is under the continuous development of the robotics community with the support of a very large number of robot platforms. Robot makers create their own packages to include in the ROS library. This allows users to easily integrate these robots when developing a robotic solution.

Simulation (2D and 3D) is nowadays essential and necessary. Not only because it is fundamental for industrial robotics, but also because it is now an entry point for those starting to learn robotics. For a good integration with the ROS ecosystem, Gazebo and Morse are two 3D simulators that provide a realistic visual performance of the robot that is being programmed. In the case of multi-robot programming, it is important to validate robot positions, constraints, and collaborative behavior that could jeopardize the equipment in a real scenario [44]. With simulation, these factors can be analyzed in real-time and the robots reprogrammed to suit the needs. These are simulators for advanced users only.

For beginners, V-REP [45] and Webots [46] are more user-friendly packages where many robot platforms are included as standard to allow users to develop and simulate their code to reach 3D environments. If the platform is not available with the package, it can be created by the user defining all the hardware 3D model structure, sensors, and actuators. Creating a new platform on the simulator is not for beginners but advanced users can do it to simulate their own robot creation. All these simulators have a physics engine, and therefore, gravity, friction, materials, collisions, and others can be integrated into the simulation.

DEs have now achieved their maturity in order to comply with the demands of all types of users, skilled and unskilled ones. But in many cases, what drives new users to enroll in the robotics learning path is what drives humans to overcome challenges: competitions.

Robotic Competitions and Events

There is nothing like a good robotic competition to motivate humans in solving new challenges. A path to follow to start participating in competitions was already suggested [47] where a description of some competitions with increasing difficulty is presented.

Micromouse [48] is perhaps one of the oldest robotics competitions known or reported. Since the time of the Egyptians, solving mazes was always considered a challenge and in this competition, a small robot has to solve it autonomously by moving around the maze. It is based on a grid of 16 × 16 cells where walls are set randomly on each cell to produce a maze. This event is held worldwide. The challenge is not solving the maze but how fast the robot can do it. A first run is made for path discovery and optimization. It is on the second run when the robot already computed the optimal path that record times are achieved.

First Lego® League [49] was the first robotic competition designed for those starting in robotics at very young ages (9–14 years old). Different challenges were created every year to be solved by the participants that created their own robots made of a Lego® robotic platform.

Soccer or football is one of the sports that people are interested in worldwide. With that in mind, the RoboCup Federation [50] was created with the defined goal of promoting the research and development of AI and autonomous robots that could defeat in 2050 the human world champions. This promotion was based on a competition that is being held worldwide in different countries every year. The competition is divided into leagues, and its number has increased since

Table 1 Characterization list of robotic platforms

Robot	Brand	Started	Ages	Loc.	Sensors	Actuators	Programming	Interface	Comms.	Build	Mod.	Price
Alpha 1 Pro	UBTech	2016	13+	LH	3 axis gyroscope, IR	16 servos, Speaker, LEDs	3D visual software simulation, pose + record + play	App (Win, iOS, Android)	B	A		$450
Antbo	DFRobot	2017	6+	LI	IR (obstacles), light, analog sound, accelerometer, digital touch	3 servos, LEDs	Arduino, Scratch, Wendo, Antbo App	Remote control (smartphone), voice, line follow	B	B		$120
BEE-BOT	Terrapin	2015	4+	W	Push buttons	2 motors, LEDs	Push buttons on the robot, Bee-Bot App (no link to ROBOT)	7 button on the robot	No com.	A		$90
Bioloid	Robotis	2016	12+	LH	3 axis gyroscope, IR (distance), microfone	18 servos, Speaker	RoboPlus (Motion, Task, Manager) (Win, iOS, Android)	Remote control, App	B, Z	B	Yes	$1200
BOTLEY	Learning Resources	2017	5+	W	IR (obstacles)	2 motors, LED, speakers	Push buttons, cards	Code (buttons), remote control, line following	I	A		$60
botnroll OMNI	botnroll	2011	14+	WM	IR, push buttons, analog + digital inputs	3 omni wheels, LCD, LEDs, buzzer, digital outputs	Arduino IDE, Open Roberta	USB port	Be, Ze	A	Yes	€590
botnroll One A	botnroll	2014	11+	W	IR, push buttons, analog + digital inputs	2 motors, LCD, LEDs, buzzer, digital outputs	Arduino IDE, Open Roberta	USB Port	Be, Ze	B+,A	Yes	€175
Boxer	Spin Master	2018	6+	W	2 IR (front), IR (bottom bar code reader)	2 motors, LCD (eyes + mood), speaker	Cards, App	Remote control, Boxer App	I, S	A		$80
BYOR	BYOR	2019	8+	W	Distance, sound, rotary knob, light	LED, servos, stepper motor, speaker	Uses Micro:bit		No com.	B		€150
Coder Mip	WowWee	2015	8+	WS	IMU, IR, gesture sensor, sound	2 motors, speaker, LEDs	Coder MiP's App	App	B	A		$100
Codebook	MakeBlock	2019	5+	WS	Phone accelerometer, voice commands, gyroscope, magnetic dock	LED panel, dual encoder motor, 2 stereo speaker, RGB LED	Codeybot App, mBlockly App	App, blockly	W	A		$270
Codey Rocky	MakeBlock	2017	6–12	T	Gyroscope, IR, light sensor, voice, push buttons	2 motors, speakers, LEDs, IR (TV)	mBlock (Win, iOS, Android), Python	Remote control, App	W, Be	A		$160
Cozmo	anki	2016	8–14	T	Camera, gyroscope, IR (bottom), light, voice	2 motors, speaker, LCD, head axle	Sandbox App, Constructor App, Python	App	W	A		$180
Cubelets	Modular Robotics	2019	4+	W	Light, distance	2 drives, LED, rotative device	Cubelets App, Cubelets Blockly, Cubelets Flash (C Language)	Remote control with your hand	B	B	Yes	$250
Cubetto	Primo Toys	2016	3–6	W	None	2 motors	Instructions are physical parts	Physical parts	B	A		€220

Table 1 (continued)

DASH & DOT	Wonder Workshop	2015	6+	W	3 microphones, 3 proximity, IR, push buttons	2 motors, LED, speakers	Go App, Wonder App, Blockly App, Path for Dash and Bot App, WonderPy	App	B	A		$150
DOC Educational Robot	Clementoni	2016	5+	W	Push buttons	2 motors, LEDs, speaker (talks)	Push buttons on the robot	Push buttons on the robot	No com.	A		€80
Jimu Robot Astrobot	UBTech	2016	8+	L	IR	5 servo motors, 2 LED, speaker	Jimu App (Block style), Pose+Record+Play	App (remote control and program)	B	B	Yes	$170
Kibo 18	Tufts University	2014	4–7	W	Sound, light, IR (distance)	3 motors, LED, speaker	Wooden blocks as instructions	Wooden blocks as instructions, Robo has a Bar code reader	No com.	A	Yes	$400
KUBO	KUBO Robotics	2015	4–10	W	RFID (to read instructions)	2 motors, LED	Plastic blocks as instructions (RFID)	Plastic instructions	No com.	A		$280
LEGO EV3	LEGO	2013	10+	W,L,T	Color, touch, IR	3 servo motors	LEGO Mindstorms software, C, RobotC, MakeCode, EV3Python, Scratch, OpenRoberta, EV3Basic, LabVIEW	App (Win, iOS, Android) / Remote Control	B, U, W	B	Yes	$350
Mabot	Bell Robot	2018	6+	W,L	Color, IR, IMU, touch	1 control ball, 4 driving ball, gripper	Mabot Go App, Mabot IDE App	App	B	B	Yes	$200
Marty	Robotical	2016	8+	L	Bump, tilt, acceleration, force	9 motors	Scratch, Python, Java	App (iOS, Android)	W	B		€125
MatataLab	MatataLab Co.	2018	4–9	W	Ultra-sound, IR	2 motors, speaker	Tower sees (camera) physical commands (blocks) / MatataCode App	White board with tower, App	B	A		$200
Mbot	MakeBlock	2015	8+	W	Ultra-sound, light, line follower	2 motors, RGB LED	mBlock Blocky, MakeBlock App	Line following, obstacle avoidance, remote control	B	A		€100
Meccanoid 2.0	Meccano	2016	8+	W	Voice recognition	8 Motors, LEDs	Pose+Record+Play, Meccanoid - Build Your Robot! App, mimic human, C++	App, voice control, buttons	B	B	Yes	£300
Micro:bit	BBC	2016	9-11	n.a.	3-AXIS digital accelerometer, compass, 3D magnetometer, push buttons, input ports	5 × 5 LEDs, output ports	MakeCode (blocks and JavaScript), micro:bit, Micro Python, Matlab, C/C++, Pascal	App (Win, iOS, Android, Linux), Raspberry PI, Arduino	B, U	B	Yes	£14
MOSS Zombonitron 1600	Modular Robotics	2014	8+	W,O	Light, IR (proximity)	2 motors, 2 corners	Cubelets Blockly App	Made up of functional cubes, linked by small spheres	B	B	Yes	$200
mTiny Coding Kit	MakeBlock	2019	4+	W	OID sensor, 6 axis motion sensor	2 encoder motor, speaker, 2 LCD eyes, 8 RGB LED	Physical commands (blocks), tap to code interaction	Joystick control, tap to code interaction	W	A		€160
NAO	Softbank	2008	7+	LH	Camera, sound, gyroscope, motion, sonar, touch	25 DOF, LEDS, speakers	NAO controller, NAO remote controller, NAO Spy, C/C++, Python, Java, Pose+Record+Play	App, Pose+Record+Play	U	A		$9000
Ozobot	Ozobot	2014	9+	W	IR (proximity), optical sensors	Push buttons, speaker, LEDs	OzoBlockly (online), JavaScript, screen-free with the stroke of a color code marker	App (Win, iOS, Android)	B, C	A		$96
Pi2Go	4tronix	2014	9+	W		2 motors			U, B, W	B+		$50

Table 1 (continued)

					Sonar, IR (obstacles), IR (line following)		Raspberry Pi 4 (Scratch, Python or any other that runs on Raspberry Pi)	USB, Bluetooth, Wi-Fi				
ROBO TX Explorer	Fischertechnik	2011	10+	T	IR (distance), Light, color, temperature, 4 counters, line follower	2 motors (with encoders)	Robo Pro software (Windows)	Robo Pro software	B	B	Yes	$380
RoboMaker Pro	Clementoni	2018	10+	W,L,T	IR, touch	3 Motors, Speaker	RoboMaker App	App (Win, iOS, Android)	B	B	Yes	€65
Roborobo	Roborobo	2015	9+	W,L	2 IR, 2 touch	2 motors, 2 LEDs, 1 buzzer	Smart Rogic App (iOS, Android)	App	B	B	Yes	$200
Robosapiens X	WowWee	2013	8+	LH	IR, acoustic, touch	10 DOF (legs, arms, neck), LEDs	RoboRemote-WowWee App (iOS, Android, Win), Keys on a remote control, Pose+Record+Play	Remote control, App, Pose+Record+Play	B	A		€100
RVR	Sphero	2019	8+	T	Color, light, IR	2 motors, LEDs	Sphero Edu App, OVAL (C based programming language)	App, remote control (App)	B	A		$250
Scribbler 3	Parallax, Inc.	2016	14+	W	Light, IR (obstacles), stall sensing, line following	2DC motors (with encoders), speaker, outputs ports	BlocklyProp online tool	App	U	A		$220
Sphero SPRK+	Sphero	2011	8+	S	Light, gyroscope, accelerometer, inductive charging	LEDs, 2 motors generate sphere movement	Sphero Edu App, OVAL (C based programming language)	App, remote control (App)	B	A		$130
Tacobot	RoboSpace	2019	4+	W	Ultra-sound, line follower	2 motors to move, 2 motors for arms, speaker, LEDs	Tacobot App (Win, iOS, Android), keypress programming, remote control	App, remote control (App), push buttons, voice interaction, cards	B	A	Yes	$100
Thymio	mobsya	2015	6+	W	9 IR, 5 touch, 1 IMU, 1 thermometer, 1 microphone, IR (remote control)	39 LEDs, 2 motors, 1 speaker, line follower	Thymio VPL, Blockly, Scratch, Aseba studio (Windows, Mac, Linux)	App, Remote Control	U	A		£130
Tinkerbots	Tinkerbots	2014	6+	W	Sound, distance, light, twist, push button	Grabber, motor	Tinkerbots Controls App / Pose+Record+Play	App	B	B	Yes	$150
Tobbie II	Elenco	2018	8+	LI	IR, temperature, compass, light	6 motors (legs), 1 rotational body	Scratch, Python, micro:bit, Javascript Block Editor	App (to remote control)	Bs	B		$110
VEX IQ Super kit	VEX Robotics	2015	11+	W,L,T	Bumper, ultra-sonic, light, color, gyroscope, push buttons	4 motors (with encoders), LEDs	Robot Mesh Studio (Blockly, Python, flowol), ModKit, RobotC, Python Blocky	App, remote control	B, U	B	Yes	$380
Zowi	BQ	2017	6+	LH	Ultra-sound	4 servo motors	Zowi App (Android), Bitbloq App (online tool), Statechart Tools, Compatible with Arduino, replay very simple movements	App, remote control, pose + record + play	No com.	A		€80

the beginning. RoboCup has broadened its scope from Soccer only leagues to Rescue, Home, Logistics, Work, and Junior Leagues [51]. Apart from the Junior League, participants are usually college or post-graduate students that create teams with their professors or supervisors in order to participate in the event. In order to qualify for the annual event, teams participate in regional/country RoboCup Opens with the approval of the RoboCup Federation. Like in RoboCup, some robotic events also have associated with it a scientific conference such as FIRA and RoboMaster with its proceedings published.

The presented competitions have no prize money. On the other hand, the DARPA Challenges are high-prized competitions with irregular time spaced editions. First editions had the objective of promoting the autonomous driving of road vehicles [52]. It then went to promote humanoid robots able to execute complex tasks in difficult environments [53]. The latest edition promoted the development of adaptive vehicles for military purposes [54].

RoboParty is an educational robotic event, where more than one hundred teams of four people, during three non-stop days, learn by experience how to build the Bot'n Roll robotic platform (mechanics, soldering the electronic components, and assembling the parts) [55]. Workshop tutorials teach participants how to build the electronics, assemble the mechanics, and program the robot using Arduino DE. Three known challenges are then tried to test their robot and the developed algorithms. Participants can assess their robot and software performances and compare them with the results of other teams.

It is a learning cycle, and the essence of this pedagogical robotic event, where participants keep their robot after the event, is to further their robotic studies. With more than a decade of annual events in the same place, it was also realized in different countries as well as in some editions of the RoboCup competition. Figure 1 shows an image of the Bot'n Roll robotic platform specifically developed for RoboParty and a group picture of the participants of the event.

RoboParty has been changing student academic performance with relevant impact like the huge increase in the number of robotics clubs in the last 10 years (according to the ministry of education); some teachers even use the RoboParty lessons at their schools, and more students are registering into electronics/informatics university degrees (increasing the university entrance average grade).

This review has shown the general outlook of the literature focusing on the major aspects of each part: (a) educational robotics at different age ranges, (b) robotic platforms, (c) development environments, (d) robotics competitions and events. Next, detailed and classified lists of robotic platforms and robotics competitions and events are presented.

Characterization Lists

Due to the amount of data gathered, the following lists presented in Tables 1 and 2 had to be synthesized. For Table 1, column Locomotion (Loc.) uses the following acronyms: Legs (L), Wheels (W), Tracks (T), Spherical (S), Others (O), Legs (Humanoid type) (LH), Legs (Insect type) (LI), Wheels/Self-Balance (WS), Not Applicable (n.a.). For column Communications (Comms.): Bluetooth (B), USB (U), Wi-Fi (W), Zigbee (Z), Infra-Red (I), Ultrasound (S), Bluetooth via micro:bit (Bs), Bluetooth Extra (Be), Zigbee Extra (Ze). For column Build: Assembled (A), to build (B), to build (electronics plus mechanics) (B+). Column Modularity is represented by its short version (Mod.). It is important to point out that the Robot Name has a link to a YouTube video, and the Brand name has a link to the Robot Description web page. For Table 2, column Type: Competition (C), Demonstration (D), Educational (E). For column Robots: Remote Controlled

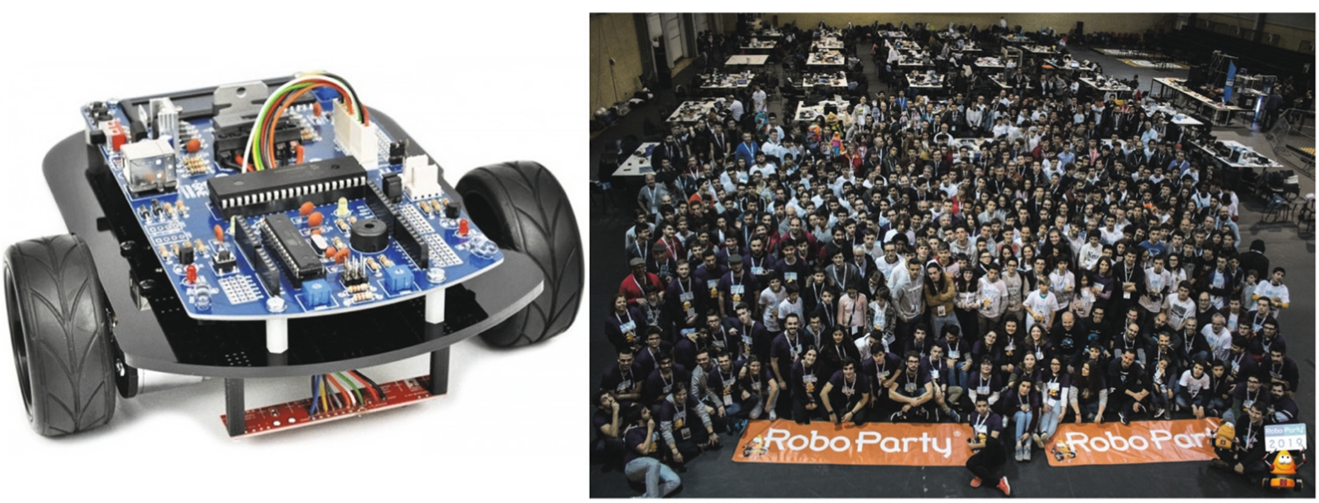

Fig. 1 Left: Bot'n Roll One A educational robotic platform. Right: RoboParty educational event group picture

Table 2 Characterization list of Robotic Competitions and Events

Name	Type	Robots	Started	Peri.	Level	Leagues	Location	Intern.	# Participants	Branded
ABU Robocon	C	RC, A	2002	A	Medium	1	ASIA (Tokyo, Bangkok, Seoul, Beijing, Kuala Lumpur, Hanoi, Pune, Tokyo, Cairo, Bangkok, Kowloon, Da Nang, Pune, Yogyakarta, Bangkok, Tokyo, Ninh Bình, Ulaanbaatar)	Yes	> 50 teams	No
All Japan Robot Sumo	C	RC, A	1990	A	Medium	1	Japan	Yes		No
BEST robotics	C	A	1993	A	Middle and high school	1	USA	No	>800 teams	No
DuckieTown	C	A	2016	R	Medium	1	Worldwide	Yes		Duckietown
Eurobot	C	A	1998	A	Medium	1 (plus 1 for juniors)	Mostly in La Ferté-Bernard (France) but also in Yverdon-les-Bains (2005), Catania (2006), Heidelberg (2008), Rapperswil (2010), Astrakan (2011), Dresden (2014), Yverdon-les-Bains (2015), Le Kremlin-Bicêtre (2016), La Roche-sur-Yon (2017, 2018, 2019)	Yes	>200 teams	No
European Land-Robot Trial	D	RC, A	2006	B	Advanced	1	EUROPE (Hammelburg (2006), Monte Ceneri (2007), Hammelburg (2008), Oulu (2009), Hammelburg (2010), Leuven (2011), Thun (2012), Berchtesgaden (2013), Warsaw (2014), Eggendorf (2016), Lens (2018))	Yes		No
FIRA	C	A	1996	A	Easy/medium/advanced	18 (distributed by Sport, Youth, Challenges, Air)	Mostly in Asia (Korea, Korea, France, Brazil, Australia, China, Korea, Austria, Korea, Singapore, Germany, USA, China, Korea, India, Taiwan, UK, Malaysia, China, Korea, China, Taiwan, Taiwan, Korea)	Yes		No
First LEGO League	C	A	2007	A	Easy	1	USA	Yes	> 40,000 teams	Lego
MicroMouse	C	A	1979	A	Medium	1	Many parallel events in many countries	Yes		No
Robo one	C	RC, A	2002	A	Medium (just off-the-shelf humanoids)	3	Mostly in Japan (but also in South Korea and USA)	Yes	240 Teams	No
RoboCup	C	A	1997	A	Medium/advanced	12 major/8 junior	Different country every edition (Nagoya, Paris, Stockholm, Adelaide, Seattle, Fukuoka, Padova, Lisbon, Osaka, Bremen, Atlanta, Suzhou, Graz, Singapore, Istanbul, Mexico, Eindhoven, João Pessoa, Hefei, Leipzig, Nagoya, Montreal, Sidney)	Yes	330–350 teams	No
RoboFest	C	A	2000	A	Easy/Medium	11	Detroit, Lawrence Tech University, USA	Yes	2500	No
RoboGames	C	RC	2004	A	Medium	56	California, USA	Yes	Guinness Record	No
RoboMaster	C	RC	2015	A	Medium (5 types: Hero, Standard, Engineer, Aerial, Sentry)	3	Different country every edition (Shenzhen, Shenzhen, Singapore, Brisbane, Montreal)	Yes	220 teams	DJI
RoboParty	E	A	2007	A	Easy/medium	3	Guimarães (Portugal), extra editions also in João Pessoa (Brazil) 2014, Leipzig (Germany) 2016, Montreal (Canada) 2018, Bramming (Denmark) 2019, Lisbon (2017, 2018, 2019)	Yes	120–150 teams	botnroll
RTC Cup	C	RC	2014	A	Easy	1	Russia	No	2500 participants	No
VEX	C	RC	2008	A	Easy	1	USA (LA, Dallas ×2, Kissimmee, Anaheim ×3, Louisville ×5)	Yes	1075 teams	VEX Robotics
World Robot Olympiad	C	A	2004	A	Easy (Just Lego - Regular, College, Open and Soccer)	4	Different country every edition (Singapore, Bangkok, Nanning, Taipei, Yokohama, Pohang, Manila, Abi Dhabi, Kuala Lumpur, Jakarta, Sochi, Doha, New Delhi, San José, Chiang Mai, Gyor)	Yes		Lego

(RC), Autonomous (A). For column Periodicity (Peri.): Annual (A), Biannual (B), On-request (R). It is important to point out that the Event name has a link to the Robotic event web page.

Conclusions

STEAM education relates these five subjects, giving as a result a multidisciplinary learning process, through the development of real projects based in real-life situations. After building a robotic platform, the participation in a robotics event is very desirable since students can compare their work with other team's solutions. And apart from learning technological and engineering subjects, they also improve some social skills.

Robotic competitions are important in the learning process of youngsters, and it is becoming more and more usual in the last few years. The development of a robot, either from scratch or starting with an off-the-shelf platform, motivates and gives practical experience, forcing students to solve unexpected problems towards the success of a final goal.

Amongst the largest robotics events, there aren't many which are purely educational, with the exception of RoboParty.

The participation in robotic events requires from the students some characteristics like being proficient in Mathematics/Physics, writing and reading, having the will to learn more robotics/programming and mathematics, having a positive learning attitude, accepting to work integrated in a team, and enjoying technical hands-on projects. They also need to work hard, take risks, be perseverant, and take responsibility. Participation in robotics competitions will give the youngster some new hard skills like algorithm thinking, electronics basics, mechanical engineering, computer engineering and programming, system engineering, and also some soft skills like teamwork, leadership, communication, project planning, and high order of thinking.

The most relevant robots have been described and compared, in order to facilitate the correct choice for teaching in the classroom or at home. A group of the most known robotic events has been also compared with help students/teachers to select the right one to participate.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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