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IO1 - Collaborative design of a training plan for Adult Education trainers on Mobile Robotics

E-Learning Course on Mobile Robotics for Adult Education: the fourth Industrial Revolution
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Revision History

Revision	Date	Author/Organization	Description
v 1.0	01/02/2020	All partners	Draft version of the training plan
v 1.1	01/03/2020	All partners	First version of the training plan
v 1.2	15/03/2020	**Mustafa ÇÜRÜK** / Seyhan Adult Education Center	Reviewed version after evaluation the training model designed
v 1.4	28/03/2020	**Cavidan Gülnur ÇELİĞ** / Seyhan Adult Education Center	Final version of the training plan for adult education trainers on mobile Robotics

The following organizations have contributed to the achievement of this intellectual output:

- SEYHAN ADULT EDUCATION CENTER – *Turkey*
- K MILIOS AND SIA OE – *Greece*
- MAKE IT PEDAGOGICAL – *Portugal*
- DALYA AJANS LTD. – *Turkey*
- UNIVERSITY OF CUKUROVA – *Turkey*
- CUKUROVA KAYMAKAMLIGI – *Turkey*
- MESLEKI GIRISIMCILER VE TOPLUM GONULLULERI DERNEGI – *Turkey*
- UNIVERSITY ``POLITEHNICA`` OF BUCHAREST - *Romania*

CONTENT

1. Introduction

Undertaking teaching and training activities in mobile robotics requires extensive knowledge, and competences in many engineering and science disciplines, from mechanical, electrical and electronics engineering to computer, cognitive and social sciences (Nourbakhsh et al., 2005). In a technology driven environment mobile robots will keep growing smarter and more capable of performing tasks that are currently done by people. With every new smart application, the world is learning that robotics is not about replacing people, but about helping them reach their full potential. In this scenario adult education in mobile robotics becomes a priority, thus providing trainers with engaging content and custom-designed pedagogical approaches in this area is key.

The proposed training plan addresses the need of implementing new and innovative ways to improve the teaching of mobile robotics content, to adult education learners using new pedagogical approaches and open educational resources.

The main goal of this training plan for adult education trainers on mobile robotics is to enhance training outcomes by providing trainers with feasible, easy to use and technology enriched tools.

In order to accomplish this goal, the partnership collaboratively designed a blended (face-to-face and online) training model for adult education trainers, based on mobile robotics core application areas.

We believe that our novel training plan supports strengthening specific areas of knowledge and skills that the trainers of adult learners will develop through design, creation, assembly and operating with the provided mobile robotics system.

The training plan is designed, as a six-unit interactive course, as follows: Definitions and concepts related mobile robotics; Type of mobile robotics; How to teach with mobile robotics; How to build mobile robotics; Mobile robotics for STEAM; Exploiting Mobile Robotics.

2. The actual context in different countries related to mobile robotics

From autonomous cars, mobile robot guides in urban environments, space exploration vehicles, to remote operated industrial vehicle, mobile robotics application areas have grown exponentially in the last decade. Even so, mobile robotics have yet to reach its full potential in a global environment that is actively and creatively developing based on concepts like Industry 4.0, Smart City, Artificial Intelligence, Quantum Computing and many more, which slowly are becoming mainstream.

Mobile robotics is a field, which has been playing an active role in education through a variety of activities and initiatives, starting with the basic course, project, laboratory work and going further to more innovative and engaging learning environments like blended learning in real life scenarios, national and international contests, and worldwide robotics events. All are aimed at engaging a broad age range audience in the process of designing, building and programming mobile robots. Mobile robotics education is an extremely large and diverse field, with applications in domains (*Rubio, 2019*).

Engaging adult learners with mobile robotics is a key action in the framework described by OECD (*OECD, 2019*), where robotics engineers are considered workers with “fusion skills” prepared for the new and emerging jobs. OECD also advocates that education should impart competences that are “the combination of creative, entrepreneurial and technical skills that enable workers to shift into new occupations as they emerge” (*OECD, 2019*).

Adult education trainers must therefore adapt established teaching methods, instructional strategies, learning objectives, evaluation methods and much more, to their specific target groups’ needs, all within the continuously developing environment of mobile robotics.

In this regard, we must set the scene of what a mobile robot is and what are the available educational resources before proposing the collaborative approach of our training plan for adult education trainers on Mobile Robotics.

A mobile robot is a complex system comprised of mechatronics and software modules. The mechatronic module has four main groups of elements: sensors, actuators, controllers and mechanical components (*Crnokić, 2017*). The software module usually involves programming, which includes learning how to write commands and scripts that control the robot using encompassing code generation / code writing, debugging, documenting, and commenting (*Nourbakhsh et al. 2003*).

Mobile robotics is indeed a multidisciplinary area, consisting of four main interest fields: locomotion, perception, cognition, navigation (*Siegwart, 2004*). Locomotion relies on fundamental knowledge of mechanism and kinematics, dynamics, and control theory. Perception problems require knowledge and skills in the areas of signal analysis and specialized fields (computer vision, sensor technologies etc.). Cognition is regarded as a complex process through which a set of input data received from sensors is analyzed and actions are performed with the final scope of achieving the mobile robots' objectives. Navigation involves the implementation of planning algorithms, information theory and artificial intelligence (*Rubio, 2019*).

There is a wide range of mobile robotics training environments, educational courses, and interactive tools freely available, which are designed for and accessed by a broad age range audience (*Crnokić, 2017*). Either organized in formal settings like post-secondary degree programs, or in interactive fusion learning environments, mobile robotics initiatives are targeted at developing cross competencies in their target groups.

Stand-alone mobile robots and mobile robot kits

German company Festo Didactic from Denkendorf has developed and implemented Robotino®, a mobile robot platform designed for research and training in the education field *(Festo Didactic, 2020; Crnokić et al. 2017*). With a flexible adaptable design and a modular structure Festo developed Robotino® to perform and teach predesigned projects, but also to allow trainers to develop their own applications, thus facilitating an engaged learning experience (*Prsic et al. 2018*).

Fischertecnhik is a German company, which amongst other, offers training and education in robotics systems. From its mobile robotics projects, the most

comprehensive system is the *ROBO TX Training Lab*, teaching from independent design and robotic system stacking, to the complex programming of the mobile robot (*Fischertechnik, 2017*).

Danish company LEGO delivers educational robotic systems for all levels of education. Its most complex educational mobile robot systems are *Lego Mindstorms EV3* (*Lego Group, 2018*) and *LEGO WeDo* (*Lego Group, 2009*), which are designed as kits with online support, offering interactive ways to learn about robotics and teach the principles of programming, physical science, and mathematics. The company is also the founder of two international mobile robotics events, LEGO Education-supported FIRST® LEGO League and World Robot Olympiad. The events are targeted at teaching and developing knowledge, life skills, and increased self-confidence real life scenarios, participants experiencing how to work like real scientists and engineers in mobile robotics.

Korean company ROBOTIS launched in late 2017 an anthropomorphic mobile robot *Darwin-OP2* (Dynamic Anthropomorphic Robot with Intelligence–Open Platform) intended for education and research activities (*Robotis, 2020*). It was designed as a collaborative research and development project between Robotis, National Science Foundation, Virginia Polytechnic Institute and State University, Purdue University and Penn school of Engineering. Darwin-OP2 is a miniature humanoid robot platform with advanced computational power, sophisticated sensors, high payload capacity and dynamic motion ability to enable many state-of-the-art research, education and outreach activities.

E-Learning and cloud-based platforms in robotics

Robotics open platforms are usually developed through private sector funding and international projects financial resources. Regardless of their background they all offer extensive knowledge repositories and professional technical support, thus being an important resource to any active learner. We briefly look into the main web-based platforms which cater the mobile robotics sector.

Arduino Project Hub (https://create.arduino.cc/projecthub) is a cloud-based platform offering a variety of open source robotics projects, including mobile robotics. Arduino in

partnership with UNDP, ARM, NVIDIA, AVNET, NXP and The Things Industries, developed the Hub as a customized web-based platform offering a variety of resources on mobile Robotics. The main advantage of this web platform is that it provides a large repository of interactive open source robotics projects. It also functions as research community allowing real time feedback features and personal project uploads. It is addressed to robotics enthusiasts of all ages.

Electronics Hub (https://www.electronicshub.org/) is an open interactive platform with resources like projects, tutorials, reviews, kits and much more for mechatronics and robotics applications. Targeted mainly at professional communities, the Electronics Hub also caters beginners in the area of robotics with its' DIY projects, tutorials and starter kits. Set as a community type platform the hub is a highly responsive environment, putting in touch professionals from a variety of domains.

The Future AI and Robotics for Space (FAIR-SPACE) Hub (https://www.fairspacehub.org/) is a UK national centre of research excellence in space robotics and AI. FAIR-SPACE Hub is a highly specialized creative web platform which brings together leading experts from academia, industry and governments, aiming at pushing the boundary of AI robotics for future space utilization and exploration. Led by the University of Surrey with over 30 international partners, the FAIR-SPACE Hub consortium offers a unique combination of expertise and capabilities to address key challenges in space robotics and autonomous systems.

DIH-HERO (Digital Innovation Hubs in Healthcare Robotics) (https://dih-hero.eu/) is an independent online platform which connects Digital Innovation Hubs across Europe to create a sustaining network for all those who are active in the healthcare robotics sector. The project consortium consists of 17 core partners spread across 11 pan-European countries. The Hubs' primary objective is to accelerate innovation in robotics for healthcare.

RoboHub (https://robohub.org/) is an online communication platform that brings together experts in robotics research, start-ups, business, and education from across the globe. Aiming at connecting the robotics community to the rest of the world, RoboHub offers an extensive learning and knowledge. The learning repository is divided

in 16 domains, such as: R&I, Education & DIY, Automotive, Space, Aerial, Mapping & Surveillance etc.

International events on mobile robotics

Mobile robotics events are addressed to young people and adults alike. While there are some competitions with age related restrictions for participants, all mobile robotics competitions which primarily target young participants, require the supervision of adult mentors with trained skills in mechatronics and robotics, extensive programming, advanced mathematics and much more. Without considering it to be exhaustive, below we present a series of worldwide events in mobile robotics, giving just a glimpse of this effervescent field.

RoboCup (https://www.robocup.org/) is an international event and it is intended by its developers as a vehicle to promote robotics and AI research, by offering a publicly appealing, but research intensive challenge through interactive team-based science and engineering activities. The event caters a wide range of audiences with its' five-league structure (RoboCupSoccer, RoboCupRescue, RoboCup@Home, RoboCupIndustrial and RoboCupJunior) and a complementary symposium for research papers (RoboCup Symposium).

Japanese Biped Robot Association organizes the annual ROBO-ONE (https://www.robo-one.com/en/) international convention focused on martial arts with bipedal walking robots. Open to audiences of all ages the convention has five mobile robotics tournaments and a conference. Within the conference, the organizers held robot technology courses for beginners and advanced users who participate in the annual convention tournaments.

FIRST (https://www.firstinspires.org/) is a global robotic community which implements four K-12 STEM mobile robotic programs: FIRST Robotics Competition, FIRST Tech Challenge, FIRST LEGO League, FIRST LEGO League Jr.. They are developed and implemented with the aim of inspiring audiences to be science and technology leaders and innovators.

World Robot Olympiad - WRO (https://www.wro-association.org/) is a global mobile robotics competition under four different categories, Regular, Open, WRO Football and Advanced Robotics Challenge, which is dedicated to science, technology and education. More than 75 countries have joined WRO in an effort to promote robotics in STEM education worldwide, whilst developing core competencies like creativity and problem-solving skills in a fun and engaging way for their participants. In the 2019 competition alongside the 28.000 teams which actively participated, around 35.000 adult helpers were involved in the implemented activities.

Founded by Texas Instruments, BEST Robotics (https://www.bestrobotics.org/) is a national six-week robotics competition, held in USA and designed to create interest in possible engineering careers. BEST (Boosting Engineering, Science and Technology) encourages participation of students in their project-based STEM program, helping them to develop technological literacy skills through robotics design and development.

A plethora of other mobile robotics competitions are organized worldwide (*RoboticsBiz, 2020*) all aiming at preparing future generations for the challenges of technological advancements, in an interactive hands-on learning environment.

Mobile robotics courses and other learning resources

One of the most comprehensive web-based search portals for study options is Study Portals (https://studyportals.com/). Catering all three categories of tertiary learning the services are divided in: Bachelors Portal, Masters Portal and PhD Portal.

A Study Portals Bachelors (https://www.bachelorsportal.com/) search revealed that there are 168 mobile robotics related study programs available worldwide. Although more than 65% of the programs are based un USA and UK, bachelor study programs are also available in countries like Estonia, Sweden, Israel, Malta, Denmark, South Africa, Hungary, Turkey and Malaysia. According to Study Portals Maters (https://www.mastersportal.com/) there are 125 Masters degrees options worldwide in mobile robotics and mobile robotics related areas (i.e. AI). PhD degree offers are far less than Bachelors and Masters, with only 13 programs related to mobile robotics showing up in Study Portals PhD (https://www.phdportal.com/).

NULLSPACE offers two certification programmes within its Adult Robotics Class – Certification & Professional Development in LEGO Mindstorms EV3 (https://sg.nullspacegroup.com/robotics-adult-class-certification/). Through the Nullspace Certified Trainer and Nullspace Certified Master Trainer programmes participants learn how to use the LEGO Mindstorms EV3 platform to plan, design, and deliver an engaging robotics class.

Class Central offers over 65 free online robotics courses out of which 18 are specifically targeted at mobile robotics design, development and implementation (https://www.classcentral.com/subject/robotics).

Similar to Class Central there is a wide range of open online course repositories, all aimed at enhancing skills and competences in the mobile robotics field.

Other European influential entities which activate in the robotics / mobile robotics sector (https://www.eu-robotics.net/) are: euROBOTICS, SPARC – The partnership for Robotics in Europe, European Robotics Forum, European Robotics Week, European Robotics League.

Amongst other mobile robotics learning environments, we can mention summer robotics camps, intensive certification classes and special education robotics.

One can be overwhelmed with the abundance of information available and with a lack of appropriate knowledge could opt out on the amazing opportunity to start learning and teaching in the mobile robotics extensive domain.

The extensive research done by the project consortium revealed the fact that there is a lack of comprehensive teaching guidelines in mobile robotics designed specifically for adult learners. They represent a unique target group of learners, with specific needs which must be catered with targeted teaching methods adapted to mobile robotics distinctive features.

In this regard, the consortium proposes a collaborative training plan custom-tailored for adult education trainers on mobile robotics, detailed in the next chapter.

3. Training plan structure

The target group of the training plan is comprised of, but not limited to, Teachers, Educators, STEM Advocates who are engaged in adult education.

Learning objectives were defined in accordance with Bloom's revised taxonomy for the cognitive domain, as described by Gershon M. in his work (*Gershon, 2018*): Level 1 (L1). Remembering - recall of information; Level 2 (L2). Understanding - interpret information in one's own words; Level 3 (L3). Applying - use knowledge or generalization in a new situation; Level 4 (L4). Analyzing - break down knowledge into parts and show relationships among parts; Level 5 (L5). Evaluating - make judgements on basis of given criteria; Level 6 (L6). Creating - put elements together to form a new functional whole.

Instructional Strategy as defined by White D. and Braddy A. (2017) in their work, were associated to each course unit.

The recommended timeframe for the training plan is 14 weeks, with 4/6-hour weekly meetings. Each weekly meeting can be taught in one continuous 6-hour session or can be split into two separate weekly meetings: one for the interactive lecture (theory & interactive demonstrations) and one for the laboratory work (hands on). In total, the course will have 28 interactive lecture hours and 56 laboratory hours.

Alternatively, the trainer can choose to deliver the contents in one of the following formats: Interactive Technology Fair, Live demonstration, Invited Technology presentation, Group workshops, Seminar on good practice examples, IT Labs, Workshop on good practice examples, Product live demo.

Table 1. Training plan structure for Adult Education trainers on Mobile Robotics

Unit title	Learning Objectives (Blooms' revised taxonomy levels)	Duration [hours]	Content	Resources and materials	Training Method & Instructional Strategies	Methods of Evaluation
U01. Definitions and concepts related mobile robotics Main reference for content development: (*Rubio, 2019*)	(L1, L2) To acquire specific knowledge of basic concepts used in mobile robotics. To accurately identify and explain main mobile robotics fundamental knowledge: locomotion, perception, cognition, navigation.	4 hours – Interactive lectures	**1.1. Definition and classification of locomotion system** **1.2. Definition and classification of perception** - Sensor classification - Types of sensors (tactile, force torque, encoders, infrared, ultrasonic, sonar, active beacons, accelerometers, gyroscopes etc.) **1.3. Cognition and control strategies** - Computed torque control methods - Robust control methods - Sliding mode control methods - Adaptive methods - Neural networks methods - Fuzzy logic methods - Invariant manifold method - Zero moment point control **1.4. Navigation** - Navigation skill - Localization and mapping - Path, trajectory, and motion planning - Tracking planning - Obstacle avoidance	E-learning platform Web resources Internet connection PPTX Printed presentation notes Lesson plan Printed speaker notes	Face to face and online courses which includes lectures, presentations and videos from YouTube / Literature response Cooperative learning	Quiz based assessment Oral discussions
U02. Type of mobile robotics	(L2) To understand mobile robotic systems and the complementarity	2 hours – Interactive lecture	**2.1. Autonomous vs remote controlled mobile robotics** **2.2. Stationary (arm/manipulator)** **2.3. Land-based mobile robots** - Wheeled mobile robot (WMR)	IDEM U01 and	Face to face and online courses Webinars	Quiz based assessment

Main reference for content development: (*Siegwart et al., 2004*)	of different involved disciplines. To explain the synergy between different types of mobile robotics platforms.	8 hours – hands on laboratory work	- Walking (or legged) mobile robot - Tracked slip/skid locomotion - Hybrid **2.4. Air-based mobile robots** **2.5. Water-based mobile robots** **2.6. Other mobile robots**	Printed case study description	Tutorials / Debate Group roles Cooperative learning	
U03. How to teach with mobile robotics Main reference for content development: (*Ferrarelli et al., 2017*)	(L4, L5) To understand the capabilities of the selected mobile robotics system and how to effectively use it in an educational context. To design new mobile robotics environments in learning spaces.	4 hours – Interactive lecture 8 hours – hands on laboratory work	**3.1. Establish the input parameters of the teaching environment** - Target group description - Identification of resources (human, financial, materials) - Definition of mobile robot role - Definition of trainer role - Identification of teaching disciplines in which the mobile robot will be deployed - Prerequisites for adult learners and trainers **3.2. Identify the mobile robot that best suits the training scenario** **3.3. Define educational activities within a specific learning scenario** **3.4. Set assessment method for evaluation of the learning gain** **3.5. Test new pedagogical scenarios in focus groups** **3.6. Implement the newly developed and improved pedagogical scenario on a larger scale**	IDEM U01 and Printed Best practice scenario Printed Model plan	Face to face and online courses Webinars Tutorials Invited lectures **/** Cooperative learning Portfolio development Idea builders	Oral questions Portfolio
U04. How to build mobile robotics	(L3, L4, L5) To develop hands-on experience building and programming mobile robots to accomplish problem-	8 hours – Interactive lecture 20 hours – hands on	**4.1. Robot Programming Software** **4.2. Establish Actuators and Sensors** **4.3. Design of Robot Vision** **4.4. Design of Robot Control** **4.5. Plan of Robot Behaviors** **4.6. Control Architectures Building** **4.7. Applied Navigation Strategies**	IDEM U01 and Mobile robot kit; Basic mechanical tool kit;	Face to face and online courses Laboratories Workshops	Practical applications – perform given task with mobile robot

Main reference for content development: (*Rubio, 2019*)	based mission objectives.	laboratory work	**4.8. Robotic Map Building**	Graphical illustrations; Flow charts; Assembly files; Activity videos; Program files;	Field visits / Interactive instruction Independent study Reciprocal teaching	Quiz
U05. Mobile robotics for STEAM Main reference for content development: (*Lego Group, 2020*)	(L5, L6) To plan, design and conduct mobile robotics curriculum for use in STEM (Science, Technology, Engineering, Mathematics) learning environments.	6 hours – Interactive lecture 8 hours – hands on laboratory work	**5.1. Design a mock-up curriculum based on project-based learning** **5.2. Develop research prototype projects (RPP) and establish investigation targets (IT)** **5.2.1.** RPP: ***The way forward*** – program the robot to go forward / IT: control the distance of the robot's movements. **5.2.2.** RPP: ***Right turn*** – program the robot to turn / IT: Measure turns and control the angle of the robots' turns. **5.2.3.** RPP: ***Make it sing*** – Start and stop with the sound sensor / IT: differentiate between frequency and amplitude and learn what a sound sensor detects. **5.2.4.** RPP: ***Follow the leader*** – Use the light sensor to track a line / IT: ensure faster line tracking and master driving backwards. **5.2.5.** RPP: ***Obstacle ahead*** – detect objects with different sensors / IT: evaluate the field of view through breadth, depth and blind spots. **5.2.6.** RPP: ***Gear-Up*** – speed the robot up / IT: coordinate gears and speed by ensuring proportionality and measured speed.	IDEM U04	Face to face and online courses Case study seminars Laboratories / Interactive instruction Cognitive Organizers Strategic questioning Learning logs	Practical application – write and compile software programming for specific task Peer-assessment
U06. Exploiting Mobile Robotics	(L6)	4 hours – Interactive lecture	**6.1. Main sectors with intensive use of mobile robotics – applications** - Research & Innovation	IDEM U04	Face to face and online courses	Group pool Feedback

Main reference for content development: (*Arduino Project Hub, 2020*)	To gain familiarity in troubleshooting and debugging common issues faced by learners. To promote the use of mobile robotics in innovative pedagogical approaches by trainers and learners.	12 hours – hands on laboratory work	- Business & Finance - Health & Medicine - Politics, Law & Society - Arts & Entertainment - Education & DIY - Events - Military & Defense - Exploration & Mining - Mapping & Surveillance - Environment & Agriculture - Aerial - Automotive - Industrial Automation - Consumer & Household - Space **6.2. Healthcare mobile robot application** - Pulse and temperature scanning **6.3. Industrial automation mobile robot application** - Product bar code scanning - Gripping, transporting and placing a load **6.4. Environment & Agriculture mobile robot application** - Testing soil humidity - Delivering water at programmed time intervals 6.5. Mapping & Surveillance **mobile robot application** - Retrieving coordinates of a specific object - Motion sensor activated tasks		Field visits Live demonstrations Invited technology presentations / Interactive instruction Brainstorming Live demonstration Portfolio development	Self-assessment

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