Robotics learning based on collaborative projects

Karmele López-de-Ipiña[1], Pilar M. Calvo[1], Nora Barroso[1]

[1] Systems Engineering and Automation Department
University of the Basque Country (UPV/EHU)
Polytechnical Faculty of Donostia, Europa Plaza 1, Donostia 20018, Spain
{karmele.ipina, pilarmaria.calvo, nora.barroso}@ehu.es

Abstract. Nowadays companies demand graduates able to work in multidisciplinary and collaborative projects. Hence, new educational methods are needed in order to support a more advanced society, and progress towards a higher quality of life and sustainability. The University of the Basque Country belongs to the European Higher Education Area, which was created as a result of the Bologna process to ensure the connection and quality of European national educational systems. In this framework, this paper proposes an innovative teaching methodology developed for the "Robotics" subject course that belongs to the syllabus of the B.Sc. degree in Industrial Electronics and Automation Engineering. We present an innovative methodology for Robotics learning based on collaborative projects, aimed at responding to the demands of a multidisciplinary and multilingual society.

Keywords: Robotics learning, Collaborative projects, Virtual learning, Multidisciplinary projects, Multilingual learning

1 Introduction

The University of the Basque Country (UPV/EHU) belongs to the European Higher Education Area, which was created as a result of the Bologna process to ensure the connection and quality of European national educational systems. The UPV/EHU offers a B.Sc. degree in Industrial Electronics and Automation Engineering of the UPV/EHU. Both involved fields, Electronics and Automation, have prompted a significant change in the economic development, which leads to an increasing level of automation and intelligence in the production process, with more and more complex processes and products that rely on computing and communications [1, 2]. There is a tendency for greater functionality and accuracy, based on the integration of computer components, sensors, or embedded microelectronics. Thus, there are several areas of interest related to these fields to be considered for the aforementioned degree: research, identification, analysis, or design and development of innovative projects. Multidisciplinary and collaborative projects have a particular relevance as they lead to a more advanced society with higher quality of life and more sustainable development.

In this framework future graduates will play a key role in this process throughout their professional lives. Thus the B.Sc. degree in Industrial Electronics and Automation Engineering has to provide them with knowledge related to a wide range

ISBN: 978-84-617-1860-3

of fields: development of electronic systems to improve automation of production processes; design, analysis and implementation of control systems for industrial processes in areas such as machine tool, paper industry, robotics, automotive industry, aerospace industry, bioengineering, or biomedicine; design of electronic systems applied in other areas such as medicine, agriculture, logistics, traffic management systems, production and distribution of energy, etc. In this context, this paper proposes an innovative teaching methodology developed for the "Robotics" subject course that belongs to the syllabus of the B.Sc. degree in Industrial Electronics and Automation Engineering of UPV/EHU [3].

The paper is organized as follows: Section 2 presents the materials, the methodology of the experiments is explained in Section 3, Section 4 shows the experimental results, and finally, conclusions are drawn in Section 5.

2 Materials

2.1 "Robotics" subject course

The "Robotics" subject course belongs to the syllabus of the third year of the B.Sc. degree in Industrial Electronics and Automation Engineering of UPV/EHU. Its skills integrate many of the previously described objectives. This subject course aims at providing students with the knowledge and foundations necessary to address the design and implementation of robots for industrial environments. This subject course integrates much of the knowledge acquired during the previous years of the B.Sc. degree, and addresses a field that continuously evolves over time at a fast pace. Robotics is the branch of technology devoted to the design, implementation, structural arrangement, operation, and application of robots, which are machines used to perform jobs automatically. The first robots reached the industry more than six decades ago, and nowadays there are at least six fields of research within advanced Robotics: linking the robot with its environment; behavioral; cognitive or developmental; epigenetics, evolutionary, and bio-robotics. It is a wide interdisciplinary field of study that relies on electronics, mechanical engineering, electrical engineering, and computer science, as well as on other sciences such as physics, anatomy, psychology, biology, zoology, ethology, artificial intelligence, or control engineering. Its purpose is to create intelligent and autonomous robots which in the future will behave, evolve, and act like human beings [3].

2.2 Hardware and Software

The "Robotics" subject course addressed in this paper is based on Lego Mindstorms robots, an educational tool, originally conceived for children, manufactured by the Lego Group Company in collaboration with the MIT (Massachusetts Institute of Technology). These robots integrate basic elements of

ISBN: 978-84-617-1860-3

robotics theory, such as joining elements, or interactive programming of actions. Lego Mindstorms robots may be used to build models of robotic systems, involving both software and controlled electromechanical elements. The base set provides the basic elements (sensors, servo motors, and mechanical elements) to build and program simple robotic solutions. There are also available Arduino boards and ROS packages, plus a suite for industrial robotics simulation. In our subject course, students program the Lego Mindstorms robots in NXC (Not eXactly C), which is a subset of the C language adapted to work in the Lego Mindstorms, with real-time concurrent programming. We use the Bricx Command Center (BCC), an integrated development environment (IDE) for programming Lego Mindstorms robots in Microsoft Windows operating systems [4-8].

2.3 Innovation group, ELEKIN

The lecturers of the "Robotics" subject course belong to the ELEKIN (Engineering for Society) innovation group [9]. This group consists of 15 members from different disciplines within the university, and from other organizations (research centers, companies). Therefore, it is a multidisciplinary group with regard to age, gender, discipline, and teaching experience. The multidisciplinary nature of the group will strengthen the present innovative teaching project. In this group 50% are women, ten members are bilingual (Spanish-Basque), and three members have the required certification to lecture in English. There are ten members that belong to UPV/EHU, within four departments: Systems Engineering and Automation, Mechanical Engineering, Industrial Engineering, and Applied Mathematics, along the three Campus branches of UPV / EHU [9].

2.4 Virtual platforms and online tutoring

In the teaching process, we use the virtual classroom service of UPV / EHU. This service is called eGela, and it is based on the Moodle platform. The eGELA service has user friendly navigation and file management systems. This service will be use for virtual tutoring. Multimedia material is also provided through this service [10].

3 Methods

3.1 Objectives

The objectives that we expect to achieve with the new methodology are:

• Community project: The students have to develop a single project involving all the classroom. The "Robotics" subject course of UPV / EHU has a common goal in each Campus branch, but can be implemented in different ways, depending on the definition of the projects in each classroom.
• The knowledge acquired in lectures has to be settled and strengthened during the project.

• Additionally to the main goals, each phase of the design of the project must meet the following requirements: sustainability, cooperation, equality, low-cost, and green-tech.

• Students have to learn how to organize and develop a multidisciplinary community project: how to define specifications, how to test system performance, how to solve problems arisen in practical implementation, or troubleshooting to meet the initial requirements.

• Students must be able to design an appropriate work plan in order to reach milestones and meet integration deadlines.

• Students have to learn how to autonomously solve problems and eventualities that arise in the project, considering several possible solutions, and choosing the most appropriate option.

• Subgroup definition: the project will be carried out in subgroups of five students. One of the students will be the coordinator of the subgroup. Students can exchange roles during the phases of the project, so that the role of the coordinator is not always held by the same student.

• Within each subgroup, students have to design the hardware and software of a robot that implements several concurrent tasks defined in the project specifications.

• Students have to learn how to handle and manage sensors.

• The designed robots have to show some human attributes such as the capability of emotional response as a reaction to the information provided by the sensors.

3.2 Competences

The skills and competences that students should acquire through the proposed group work are [3]:

• Introduction to Robotics and its basic principles. In order to achieve this, students have to take into account the kinematic, dynamic, and morphology needed to achieve the main objective (the global project), and each subproject.

• Remember and apply in practice the knowledge of the lectures of Robotics theory and other subject courses of the B.Sc. degree, for example: programming in C, sensors, or communication protocols such as Bluetooth.

• Learn to work in groups by assigning to students different tasks such as: software programming, hardware assembly, documentation, or project coordination.

• Be able to develop a work plan (by means of Gantt charts), and reach the objectives of the project within a deadline.

3.3 Methodology and innovation

As aforementioned, the ELEKIN educational innovation group is multidisciplinary as the staff belongs to different departments within different areas of technical expertise. This ensures an appropriate development of the educational project and the new methodology. Apart from the lectures, the involved lecturers provide support by means of virtual teaching, providing virtual materials, and/or virtual tutoring. The proposed methodology can be adapted to any number of students. This new

ISBN: 978-84-617-1860-3

methodology is based on the well known "Problem Based Learning and Project Based Learning" [11-20]:

- The learning process will be supported by Project Based Learning: small projects will be integrated into a global project.
- The selected community project can be adapted to a Campus branch, to an educational center, to each group of students, to each language (Basque, Spanish, or English) and to each specific environment. Then, the global project is divided into small subprojects to be carried out by subgroups of five students in order to effectively achieve particular and community goals.
- Students will improve their communication skills, teamwork skills, and entrepreneurship, since they will have to autonomously work with a great proactive attitude. They will work with new lecturers and students, in order to carry out the work assigned to each subgroup, and the collaborative work in the final proposal.
- Self-learning will be encouraged through the Virtual Classroom, Wiki, portfolio, and blog.
- Students will improve their Curriculum by applying in practice many of the disciplines of the B.Sc. degree.
- The collaborative projects will promote the development of transferable skills, for example: communication, gender, ethics, emotional intelligence, teamwork, entrepreneurship, or sustainability.
- The collaborative projects will promote collaboration between subgroups, Centers, or different language environments.

So the foundations on which this proposal is based are:

- Use of active learning methodologies and continuous evaluation to promote self-learning and learning throughout life.
- The implementation of the European Higher Education Area requires to set up new methodologies in order to further involve students in the learning process.
- Methodologies to work in groups based on the classic Problem Based Learning method and Project Based Learning method.
- Use of low-cost materials such as Lego Mindstorms robots.
- Multidisciplinary and multilingual teaching and tutoring.
- Interactive assessment and self-evaluation.
- Virtual teaching methods such as virtual tutorials or video conferences, by means of Skype or the Moodle platform.
- New low-cost methodologies, sustainable, and GreenTech.
- Inter-department collaboration, multi-campus, inside the university and with external agents.
- In order to carry out the collaborative work, it is essential to define a problem very close to students, to help in the acquisition of the competences of previous subject courses. The global project and subprojects will take into account most of the subjects of the B.Sc. degree.
- Students will interact and help each other by means of virtual question-answer interaction forums.

Table 1. Definition of the subprojects of the global project: "Liquid managing industrial chain"

Subproject name	Task definition	Communi. type
Coordinator	Send commands. Manage alarms. Read color-labels	Master A
Supporting robot	Support the coordinator: manage alarms and clean spilled liquids	Slave A3
Bottle store	Place bottles in the conveyor belt and manage the store	Slave-A1
Conveyor belt	Transport bottles depending on their color	Slave A2
Dangerous liquid	Manage dangerous liquid and commands. Generate alarm.	Master B
Beer	Manage beer and commands	Slave B1
Water	Manage water and commands	Slave B2
Oil	Manage oil water and commands	Slave B3

4 Results

The analyzed classroom consists of 40 students, and eight subgroups of students were created in order to carry out each subproject. The first stages were developed in the virtual classroom service eGELA. Firstly, in the task "Proposals Forum" students suggested 24 collaborative project proposals. Secondly, in the "Selection of collaborative project" task, students voted in order to choose the global project. Then, the lecturer selected the most voted proposal and developed the requirements of the collaborative project. Finally, the global project was divided into eight subprojects, one for each subgroup of students.

This classroom selected the "Liquid managing industrial chain" collaborative-project proposal. The project consisted in managing different liquids in an industrial chain: water, oil, beer, and a dangerous liquid. Fig. 1 shows a photograph of the global project. The collaborative robots had to classify the bottles of a store in different boxes depending on the liquid type. A color label over the bottles was used to distinguish the liquid inside the bottle.

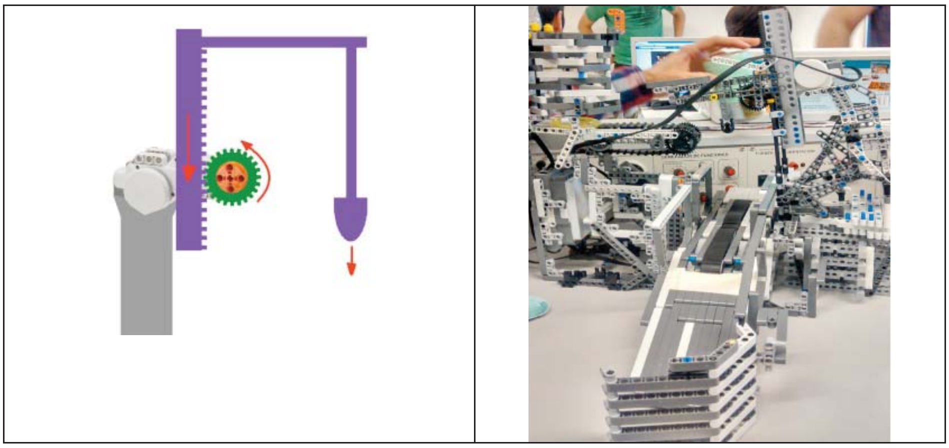

Fig. 1. Detail of the design and photograph of the global project.

 ISBN: 978-84-617-1860-3

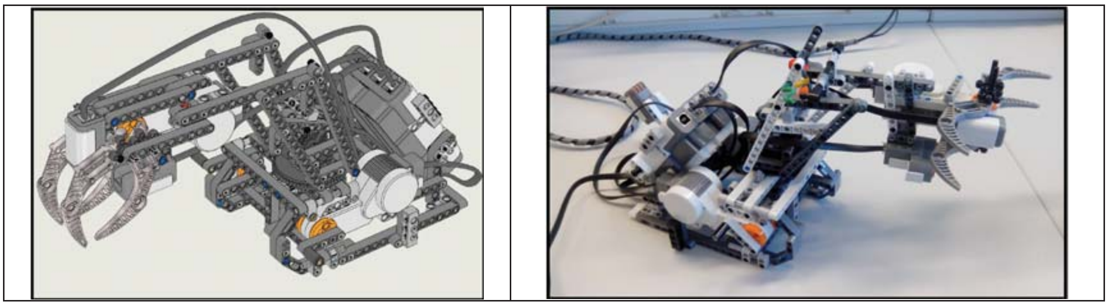

Fig. 2. Scheme and photograph of the "Bottle store" robot

Table 1 shows the defined subprojects: there was a coordinator which managed the process, a supporting robot that helped the coordinator, a robot that managed the store, a robot working as a conveyor belt, and four robots that managed the liquid bottles, one for each liquid type. Robots could communicate by means of Bluetooth using a Master-Slave protocol. The role of each robot is shown in Table 1. Fig. 2 shows the scheme and photograph of the "Bottle store" robot.

Students developed the project in six stages: analysis, design, development, integration, assessment, and documentation. The evaluation to grade students consists of: a technical report, a poster, and an oral presentation. During the analysis phase, students had to do a Gantt chart. They reviewed this chart in the final assessment in order to analyze the deviation from the initial work plan. Fig. 3 shows one example of the initial Gantt chart and the final Gantt chart. By analyzing the initial work plan and the actual final plan, students learned from mistakes how to properly estimate the assigned time to each task depending on the difficulty of the task. In general, students undervalued some tasks such as software analysis, design, and development. These tasks were not properly planned, the time initially assigned was not enough, so the deviation from the initial time estimation was very noticeable. Most of the students achieved with good results all the objectives and competences proposed in section 3. We must also highlight the high level of satisfaction, more than 80% during all the process, not only with regard to the motivation of, but also with regard to the teaching staff.

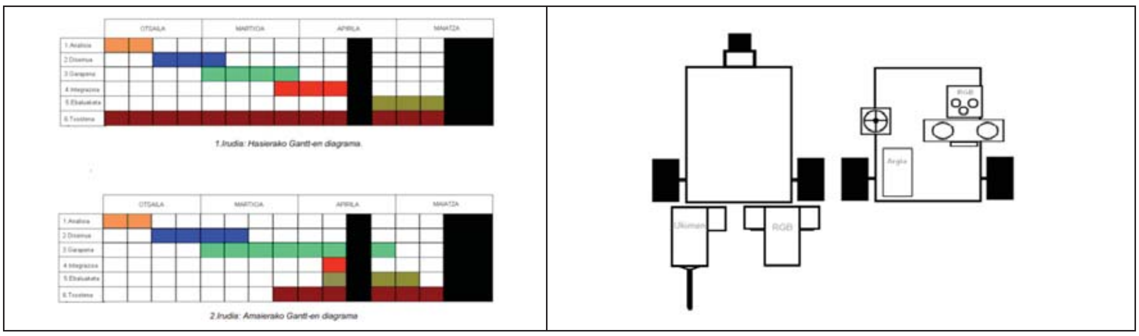

Fig. 3. Initial and final Gantt charts, and outline of a subproject

5 Conclusions

Multidisciplinary and collaborative projects have a particular relevance as they lead to a more advanced society with higher quality of life and more sustainable development. In this context we propose an innovative teaching methodology for the "Robotics" subject course of the B.Sc. degree in Industrial Electronics and Automation Engineering of the UPV/EHU. We have presented a collaborative-project based learning method as a response to the demands of a multidisciplinary and multilingual society. The results show a high level of satisfaction not only with regard to acquiring competences, but also because of the motivation of students during the learning process. In future innovation lines the defined methodology will be applied to other subject courses in the aforementioned B.Sc. degree.

References

1. Report to request the official verification of the B.Sc. degree in Industrial Electronics and Automation Engineering of UPV/EHU. www.ehu.es
2. B.Sc. degree in Industrial Electronics and Automation Engineering of UPV/EHU www.ehu.es
3. Robotics Subject Course of UPV/EHU www.ehu.es
4. Brooks, R. (1998): Prospects for Human Level Intelligence for Humanoid Robots. MIT, july, Artificial Intelligence Laboratory.
5. Benedettelli, D. (2007). "Programming LEGO NXT Robots using NXC", http://bricxcc.sourceforge.net/nbc/nxcdoc/NXC_tutorial.pdf
6. Calvo, I., Perianez, G., Butler, D., and Martin, F. (2001). "Learning with LEGO Mindstorms in Irish Primary Education", The Spring Symposium of the American Association for Artificial Intelligence (AAAI), Stanford, California USA.
7. Go´mez-de-Gabriel, J. M., Mandow, A., Ferna´ndez-Lozano, J., Garci´a-Cerezo, A. (2010). "Using LEGO NXT Mobile Robots with LabVIEW for Undergraduate Courses on Mechatronics", IEEE Transactions on Education, Available on-line: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5430870
8. Hansen, J.C. (2009). "LEGO Mindstorms NXT Power Programming: Robotics in C", Variant Press.
9. ELEKIN (Engineering for Society) innovation group. Available online: http://elekin.net
10. eGELA, learning virtual platform. https://egela.ehu.es/
11. Dario, P. (2005): Robot, ovvero tra illusioni e realtà. Media Duemila Journal, Special Issue: Robotics, July/August, pp. 22/5.
12 Mataric, M. (2002): Situated Robotics. Encyclopedia of Cognitive Science, Nature Publishers Group, Macmillian Reference Ltd.
13. Peters, L. (2000): Trends in Robotics. ERCIM News, july, n. 42. Special Issue: Robotics.
14. Pratihar, D. (2003): Evolutionary robotics – A review.ias.ac.in/sadhana/Pdf2003Dec/Pe979.pdf. Sãdhanã Journal, december, vol. 28, Part 6, pp. 999–1009.
15. Ros, E.; Pelayo, F., Prieto, A., and del Pino, B. (2002): Neuromorphic Engineering: The role of the reconfigurable hardware. Sitio Cortivis
16. Druin, A., and Hendler, J. (2000). Robots for kids: Exploring new technologies for learning. San Diego, CA: Academic Press.
17. Hung, D. (2002). Situated cognition and problem-based learning: Implications for learning and instruction with technology. Journal of Interactive Learning Research, 13(4), pp. 393-414
18. Jonassen, D. H. (1996). Computers in the classroom: Mindtools for critical thinking. Englewood Cliffs, NJ: Prentice Hall.
19. Lui, M., and Hsiao, Y. (2002). Middle school students as multimedia designers: A project-based learning approach. Journal of Interactive Learning Research, 13(4), 311-337

 ISBN: 978-84-617-1860-3

20. Penner, D. E. (2001). Cognition, computers, and synthetic science: Building knowledge and meaning through modeling. In W. G. Secada (Ed.) Review of Research in Education. pp. 1–35. Washington, DC: American Educational Research Association.

 ISBN: 978-84-617-1860-3