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ENXENO: LEGO© Robots from University Lab to K-12 Classroom

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Introduction

At different levels, we can state that education has experienced deep changes in the last two decades powered by the demands of different agents and factors. These changes have been materialized in the development of new learning and teaching methods that try to improve teacher-students interactions, or the way of presenting the large available amounts of existing information in a comprehensive, structured and efficient form.

Regardless of the selected approaches, these targets entail the development of innovative material aligned with new teaching methodologies, which will be a short-term demand in the new study plans. A well-known case is that of the European universities that must incorporate the European Higher Education Area (EHEA) requirements [1–3], which focus more on issues, such as infrastructures rather than creating laws that regulate methodologies. Furthermore, the general lack of methodology definitions and regulations also affects other levels of education as K-12.

An important gap can appear between both levels of education (K-12 and university) due to the divergence of the background educational plans. At this point, the university appears as the main agent to transmit contents in addition to active learning based experiences, in the form of extra-curricular activities, which deploy edutainment to other education levels.

Instructors from all educational levels should experiment with the many options offered in the quest of a winning teaching/learning formula. From this quest, the need for new methods that will allow a reasonable access to the material and software resources should not be excluded. Equal access to educational material is central to providing a homogeneous background to students from all socio-economic strata, various minorities and educational environments. Limited access to resources can seem unfair from the social point of view.

A usual objective of different methodologies is to attract and maintain student interest during class while keeping in mind the cognitive dimension of the experience. The learning-through-play theory appears as an acceptable mode of reaching this objective. It is a fashionable and amazing learning methodology but it also represents a challenge for educators that try to implement those in their classrooms, especially in primary and secondary levels. Traditional methodologies are more extended in the field of education in general than innovative means, and sometimes the play-theory finds reticence among educators who think that these play-based methodologies are only comprised of a “fun” factor [4].

ENXEÑO, that in Galician language means inventiveness/talent, is a project developed with the aim of introducing robotics topics in K-12 levels as a creative manner of approaching science and technology in pre-university grades.

This project, which was developed between 2008 and 2010, was funded by the Regional Government of Galicia and the GRADIANT Tech Institute, both located in the Northwestern Spain, namely Galicia. At present, three annual editions have taken place; it is kept in mind to continue with future editions.

From the university point of view, another significant aspect to consider is whether robots offer a good means to attract prospective engineering students to pursue Higher Education [3]. Competition among different universities, which is due to a population decrease factor, options offered by new degrees and the demands from the industry, turn extra workshops into valuable educational tools and a noteworthy added value to retain students. This has been also an objective for the ENXEÑO workshop.

Another equally important aspect to consider, along the development of this kind of learning methodology, is how to evaluate acquisition of knowledge. It is essential to collect information in the cognitive and in the affective dimensions. This information has to be analyzed to evaluate a classical trade-off: satisfaction level and effective cognitive learning.

For this reason, we have elaborated an assessment method to evaluate the results of the workshop. We have tried to identify pros and cons of the applied methodology as well as weaknesses and strengths of the experience (Fig. 1).

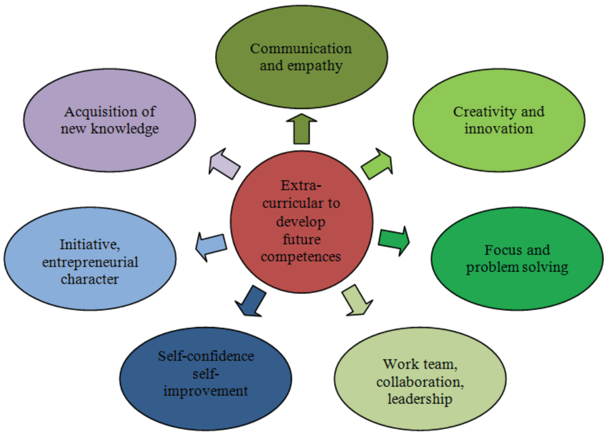


Fig. 1. Benefits from extra-curricular activities

Thus, the purpose of this paper is first to introduce a general scope of existing teaching methods that can be successfully applied. Within the analysis of the state of the art, we discuss the appealing option represented by the through play case. Then, we describe the choice selected for our experience. After that, we detail the implemented practices. We also introduce the assessment of the experience and its main outcomes. Finally, educational challenges for future editions are highlighted. Conclusions close this chapter with an overall evaluation.

Background

The participants consisted of K-12 students from schools located in the surroundings of the University of Vigo (Spain). After the success of the first edition in 2008, with more of 100 students from 10 different schools, the successive editions have extended the participating audience to cities that are farther away from Vigo, but still within the Galician region. Up to present, a total of 413 students from 29 schools have participated in this initiative and a huge impact was achieved in the mass media, as well as in the regional educational system.

The students who participated in this experience are from what is known as E.S.O. or Compulsory Secondary Education in Spain, which encompasses four grades with students in a range age of 12-16 years, and which corresponds to grades 6-10 in the K-12 system. A large percentage of school dropout and failure is stated due to lack of motivation as a main factor. The Spanish index of school failure is around 29% whereas the European average is of about 20%. At the university level, a 50% dropout occurs. It is clear that changes must be introduced to overcome the problem. Introducing new learning/teaching methodologies can help to reduce the numbers of failure/dropout, which find the most extended explanation in the lack of motivation and lack of perspective on the future.

The project’s start point was based on the idea of approaching the university to the community; more specifically it was aimed to offer a scope of the Electrical and Computer Engineering degree to prospective students. The experience is deemed suitable to make known basic concepts of robotics, sensors, mathematics and programming languages to non-university students. Specially, the workshop tried to help students to discover a technological side of them by showing that technology is not an impenetrable field in an enjoyable manner; additionally, the workshop also tried to offer a future perspective.

The social and working environment the twenty-first century young people will join requires active, flexible, creative, and teamwork-oriented individuals capable of providing innovative solutions to the challenges of today. Between this ideal requirement and the present reality, some steps must be walked in the direction of more attractive and efficient methodologies, which consider other ways of doing things. In spite of the fact that those alternative methodologies have been postulated for several decades, they still find reticence to be applied in a practical way. In the following sections we describe the main features of active methods; one of them has been selected as basis for the ENXEÑO project.

Learning through play

As observed in, play is a powerful tool for learning that becomes fundamental for both adults and children development; play allows part of the evolving human experience once it provides a way in which we learn by offering the opportunity to practice and explore in a safe environment teaching essential skills. This methodology has been widely applied in the computational and engineering teaching fields [5–8] showing a large level of satisfaction, and becoming also largely effective at the cognitive level.

This technique is not free of risks, though [4]. The main weakness to keep in mind is that students need to know “the rules of the game” *a priori*. The background knowledge level plays an important role in the success of this kind of experiences. It is not possible to play a game if the rules are not well understood. If this happens, the loss of motivation produced on the students can be important and could result in the failure of the practice. This causes discouragement on the instructors. Students must learn the fundamental concepts and the necessary skills prior to apply them effectively in a game-based experience.

As the above case, the game-based or through play methodology can be implemented developing field practices or PC based simulations. The first ones involve a large implication of the teacher during the realization. The second kind entails a large time out of class to develop the proper platform.

The play appears as a methodology named 4C since it relates 4 important teaching aspects:

1. Connection with the student and sparking her/his interest;
2. Construction as a work method;
3. Contemplating to learn from completed work;
4. Continuously incentivizing new objectives.

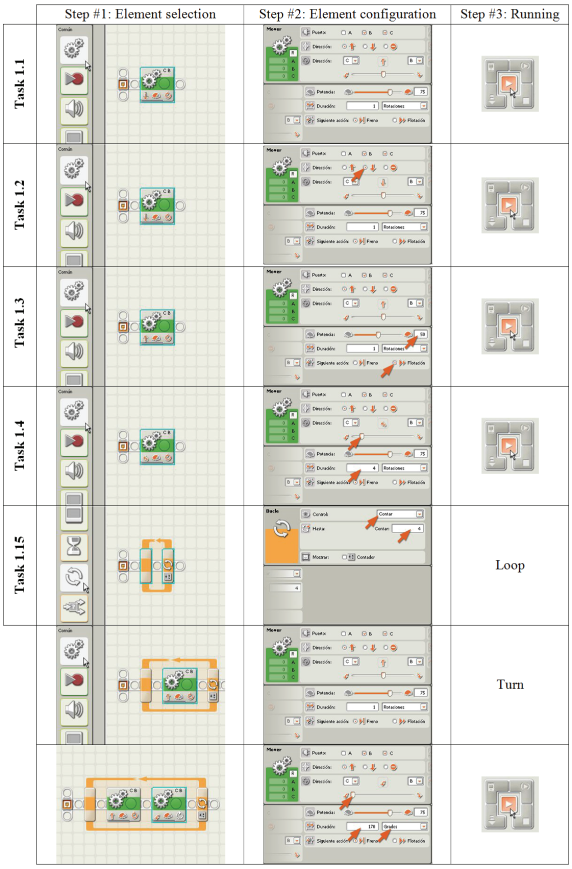


Fig. 2. Programming practice 1 tasks

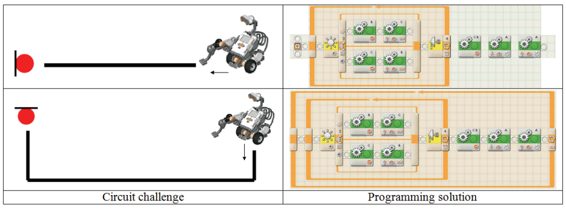


Fig. 3. Programming practice 7 tasks: guided part

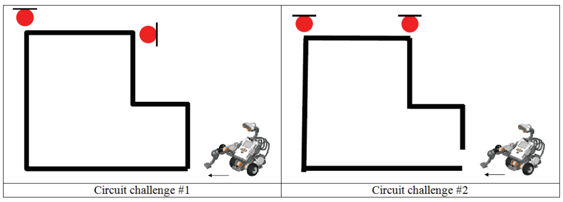
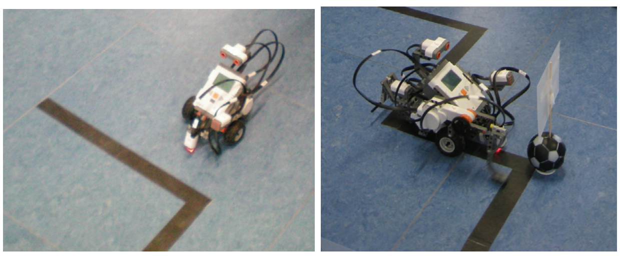


Fig. 4. Programming practice 7 tasks: challenge part



a) b)

Fig. 5. The robot moves towards the black line on the ground and shoots the ball out of the black line

The through-play methodology developed under the 4C principles provides important benefits to the student. The through-play experience can not only be developed in the school environment, but also planned as extra school activities so that many require future competences can be developed under other conditions. In Fig. 1 we illustrate this idea and the benefits derived from the use of extra-curricular time as a space to deploy events oriented to potentiate future competences in the student.

Methodology, practices and beyond

Learning by doing or through playing experiences based on hardware activities imply the use of material that, sometimes, is not covered by the general purpose instrumentation [1, 4].

The acquisition of specific educational material is largely costly and not usually affordable. However many solutions exist in form of development kits available for the industry and perfectly valid for academic purposes.

A program of practices was designed containing 7 different experiments with an increasing complexity level. The students were teamed up in groups and volunteer monitors from the academia (professors, assistants, students …) supervised their work and tutored the students throughout the developing stages of the experiment. A full-description guide was elaborated containing step-by-step instructions, with colorful pictures, schematics and diagrams needed to accomplish each experiment. Two laboratories of the Electrical and Engineering Computer School at the University of Vigo were used to develop the project.

Each group of students was provided with a LEGO© Mindstorm robot kit with 5 sensors, a laptop with installed LEGO visual programming language, and a guide. Two different kinds of practices were designed regarding the concepts of linear tracking and sensors operation shown in the theory. The set of practices were based on a commercial kit of robots (LEGO Mindstorms®). The kit consisted of various accessories: an indexer, motors, and infrared sensors. Commercial software was also included in the kit to program the robot's operation main parameters, such as movement direction, speed, sensor thresholds and execution time. Such a toy is obviously an evolution of those directed to five-year old children, and is in fact oriented to people younger than our University students.

A tutor was assigned to each group and a supervisor was present in each one of the two lab-classrooms. The students allocated in each lab-class usually came from the same school and classroom, and the corresponding tutor was present.

Prior to the development of the experiment, students were introduced to the project and some previous concepts such as "What is a robot?", "What is a sensor?" and so on in their respective schools.

The students were organized in groups of up to five members, and a set of tasks were proposed to each group. The final objective of the practice was to mount a wheel engineered robot, with the aim of tracking a line on the floor.

During the proposed tasks, the students had to construct a wheeled robot that was able to move forward and backward, to turn left and right, to stop and go... That stage involved all the team and tried to develop students' perceptive functions in a task that is not common for either K-12 students or electrical engineering undergraduates in general. Tasks corresponding to Practice 1 are illustrated in Fig. 2 as plotted in the student's manual.

The strategy of the experiment follows the three phases indicated in [9] for an edutainment (education through entertainment) experience:

1. Planning and building of the artifact, related to problem identification and objective definition; collection and production of ideas; and problem conceptualization. During the building and manipulation phases, a fundamental role was exercised by the perceptive and behavioral functions;
2. Behavioral programming, in which students identified problems, hypothesized and applied solution strategies;
3. Testing the execution of the artifact and deciding on the need to go back to the building phase, to the programming phase, to both, or rather to search for new ideas.

Once the artifact was built, the next stage was to force it to perform different routines. Firstly, some simple movements were programmed in the indexer to control the activity of the robot. The students looked for the best way to reach the required solution, performing an activity that they are not familiarized with: managing programming devices. A PC connected via USB to the indexer and a programming language, which was designed following an intuitive graphic procedure specifically aimed to control the robot, were the two tools needed to carry out the tasks.

After the previous stage, the students knew how to force the robot to perform different movements. At that point, important concepts appeared: the robot should perform different movements in response to different situations. In other words, it is desired that the robot senses the environment and reacts to such environment.

We began by presenting the different sensors in the kit: sound, color, infrared, switch, and, then, programming simple codes to control each of them individually. The final objective was to ask the robot to follow a black line on the floor, and to perform the test right! The robot had to move along the room, avoiding crashing into the furniture or walls while tracking the marked path. In particular, the threshold level parameter of the color sensor control block in the indexer program was used to distinguish one color from another on the floor in order to detect the presence of the path. An infrared distance sensor was used to avoid the aforementioned crashing events.

Most students decided to voluntarily extend the requirements of the practice 7, forcing the robot to perform a more complex activity: a ball is unexpectedly placed at any point along the black line and the robot, while tracking the black line, has to detect the ball and shoot it out of its path so it can follow its track. In Fig. 3 and 4 we show the tasks corresponding to the guided and extended parts of practice 7. The pictures in Fig. 5 show a robot moving towards and along the black line during the test of the program by one of the students' groups. The picture shows the robot shooting the ball far from the black line.

Some thoughts on methodology

From a pedagogical point of view, we can identify an active learning methodology with two clear branches:

1. Work subdivision learning: occurs in a horizontal plane, inside the group wherein different roles are assumed by the students as a way to organize, speed up and ensure the successful achievement of the experiments;
2. Play-based [4]: learning is provided by a play structure through the use of toy robots. The final challenge is to be the first group to complete the work in a successful way. This methodology takes place in a vertical plane along the increasing level of complexity in the designed practices.

During the execution of the practices, we detected the same three different typologies of work subdivision as reported in [9]:

1. The first one was a collaborative activity, in which each member adopted a role in the building process and all of them participated in programming the robot;
2. The second typology corresponds to an all-at-all activity: members that did not adopt a specific task in building or programming the robot;
3. The third option was a leadered work: each member adopted a role in building and programming the robot and a leader supervised the work.

Regardless of the chosen strategy, the students seemed to be very interested in reaching the objective and deeply involved in the assigned task. We then found that the use of the playing kit stimulated students to explore their own knowledge in a critical way and to share it with their group members, which means that the objective of the experience has been largely reached.

The qualitative impact on students' learning may be considered, as a consequence, completely positive, as they could work in a friendly environment while playing with a funny toy, and getting some tech knowledge and skills required, or not, for their professional career development. The quantitative impact of the experience is analyzed in the following section.

Finally, we would like to remark that, in designing play-based teaching experiences, instructors have to balance opportunities, challenges and risks. The first of them is the teacher's role during game-based learning. By definition, play-based experiences lead the teacher to a secondary role during the execution of the game. This passive role can drive the students to failure or to feelings of dissatisfaction. The same can happen to the instructor, which may lead him/her to abandoning seeking for innovative means.

Assessment of the experience

At the end of the day, a survey was completed by the students, and as a reward they received different souvenirs (T-shirts, caps …). Back at school, they had to present a work about the experience implementing a show-and-tell style. At the end of the workshop and once all the schools had participated, there was a drawing in which the robot kits were given away.

A different survey was handed out by the schools consisting of different questions in order to evaluate satisfaction level, issues to be improved, the level of complexity found in the practices, among others. An additional qualitative task was performed by the monitors in order to evaluate the grade of completion of both the collaborative learning and play-theory. Research results were obtained from both surveys and qualitative observations. In both cases, the parameter of gender was taken into account. From the total of 413 participant students, a 47% were girls.

The students' survey consisted of six questions as shown in Table 1. It is remarkable that 96% indicated that they liked the workshop, and that 16% suggested a longer duration. The schools' survey consisted of eight questions. In Table 2, we observe the statistics for the questions in teachers' survey indicating a good consistency of the practices duration with the students' background. Out of the results we can point out the 6.84% of schools considered that the adequacy of participants' age could be improved.

In Table 3 we offer statistics from the questions corresponding to the student's survey about what they considered was either missing or could be improved. In Table 4 we show the analog case for schools. General speaking the scores achieved in the surveys show a large degree of satisfaction for both the schools and students.

From the qualitative analysis it is inferred that students were able to successfully achieve an optimal role distribution in their team and could also keep it along the development of the experience. In a large percentage, 85%, the groups did not have problems with teamwork and were adequately organized. In some groups, the distribution was changed presenting more or less issues. This point indicates a large success of the collaborative method selected.

Another point regarding the play-method implies that students should verify the achieved results. In a 90% it was necessary to insist on the need to verify the results of each performed subtask; often children moved on to the next task with virtually no verification of the target objective once they had finished both the mechanical and the programming stages.

Future directions

Despite the evident success of the experience, some weaknesses have been found a posteriori. Most of flaws identified in the development of the ENXEÑO workshop are related to the pre- and post- stages of the experience. As aforementioned, many but not all the schools prepared their students prior to the participating in the workshop; likewise, not all the schools developed activities after the experience concluded. We cannot blame schools or ourselves; however in future editions we would like to send additional material so that several introductory and follow-up activities can be developed in both stages.

Other materials can be offered in the form of a competition which could work as an extra-curricular activity so that participating students could give some continuity to the knowledge acquired in the workshop. A kind of survey can be designed for both a priori and posteriori stages so that the evolution and effect of the workshop experience on the cognitive level and always without neglecting the affective dimension can be followed in close and in-depth ways.

Another observed weak point was the fact that volunteer monitors were spread out and did not have an observation guideline, so the qualitative evaluation of the workshop was not very consistent. For future editions, they should receive a set of indications to correctly track the development of the experience.

Table 1. Results for students' survey

Did you like the workshop?	Good			Regular			Not		
	95.13%	96.26%	96%	4.87%	3.74%	4%	0.00%	0.00%	0.00%
What did you like more?	Building the robot			Programming the robot			Both		
	39%	50%	44%	42%	34%	38%	19%	16%	17%
For you, the tasks of building the robot are	Very easy			Appropriate			Very difficult		
	37%	16%	28%	60%	80%	69%	3%	4%	3%
For you, the tasks of programming the robot are	Very easy			Appropriate			Very difficult		
	35%	28%	31%	62%	70%	65%	4%	2%	3%
Do you think that the workshop duration was	Very long			Good			Very short		
	3%	2%	2%	52%	61%	56%	45%	37%	41%
Would you come back next year?	Without doubt			Probably			Not at all		
	91%	90%	90%	9%	10%	9%	0%	1%	0%

Table 2. Results for schools' survey

How did the school learn about the workshop?	e-mail information		Mass media		Parents, friends, other…	
	21	72.41%	1	3.45%	7	24.14%
How would you rate the novelty of the subject?	Not novel		Novel		Very novel	
	0	0%	5	17.24%	24	82.76%
How would you rate the interest of the subject?	Not interesting		Interesting		Very interesting	
	0	0%	2	6.89%	27	93.11%
Rate the organization of the workshop	Bad/Not well organized		Appropriate		Very well organized	
	0	0%	0	69%	0	100%
Adequacy of participants' age	Improvable		Adequate		Very adequate	
	2	6.89%	9	31.04%	18	62.07%
Rate workshop considering the duration of activity and participants' age	Improvable		Adequate		Very adequate	
	1	3.45%	7	24.14%	21	72.41%
Would your school participate again next year?	Without doubt		Probably		Not at all	
	384	90%	0	9%	29	100%

Table 3. Observations and comments from students' survey

Observations and comments		
Accommodating more students	6	20.69%
More explanation of the programs	1	3.44%
Admitting older students	5	17.24%
Longer duration	1	3.44%
Admitting younger students	1	3.44%
None	14	48.27%
Introduction to Electrical Eng School	1	3.44%
More robots	1	3.44%
Other	5	17.24%

Table 4. Observations and comments from schools' survey

Nothing	**41%**	**47%**	**44%**	More activities	3%	5%	**4%**
Being offered a snack/drink	8%	4%	**6%**	Nearer facility	0%	0%	0%
Giving the robot	7%	8%	**8%**	Larger difficulty	4%	0%	2%
Longer duration	**16%**	**16%**	**16%**	Better robots	3%	0%	2%
Visit to University	1%	1%	1%	Have been recorded	0%	0%	0%
Bigger lab	2%	1%	1%	More free time	0%	2%	1%
Restrooms	0%	0%	0%	More black lines	1%	0%	0%
Groups of fewer people	6%	5%	**5%**	Shorter duration	0%	0%	0%
Able to freely program the robot	2%	0%	1%	Larger tables	0%	0%	0%
Not mounted base	0%	0%	0%	More monitors	0%	1%	0%
Groups of more people	0%	0%	0%	Different robots	2%	1%	2%
Larger robots	2%	1%	1%	Souvenir	1%	0%	0%
Monitors	1%	3%	2%	Competition	1%	0%	0%
Other			17%				

The figure of the volunteer monitor has beenidentified as worthy in terms of providing valuable feedback and information to complete the assessment, both in quantitative and qualitative forms.

In Fig. 6 we show a picture of a group of students working with the robot and some sensors.

Fig. 6. Results for students' survey Pictograms from promotional video

Conclusions

New demands have impelled the development of new teaching-learning methodologies and contents. Universities are introduced as agents that provide valuable contents to other educational levels. This contribution helps to open up the interaction between different levels as a way to avoid a deep educational gap.

The main advantages derived from this experience can be summed-up as follows:

- Multidisciplinary educational features involving part of the student's academic curriculum: mathematics, physics, computer, electricity …
- Enabling students' access to experimental work.
- Curricular reward for involved students.
- Introducing students to the methodology of robotics and open-source technology, with arising importance in the professional technological fields.
- Enabling the experience to be used in class as a teaching material with large and probed quality.
- Scalability: possibility of extension by incorporating or defining new experiments (new sensors, calculations, physics practices...).
- New teaching methodology possibilities based on problem solving, collaborative or project learning.

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At this moment, the importance of technology in all the areas of knowledge is undeniable. Students must acquire competencies in technology during their primary and secondary studies. In this chapter we present the ENXEÑO workshop developed by the University of Vigo and oriented to K-12 students from schools in the surrounding area. The experience pursued a two-fold target of providing an introductory scope of the Electrical and Computer Engineering degree as well as approaching technological knowledge by means of a through play experience. Pros and cons of this innovative learning methodology are analyzed in this chapter. The experiments done during the workshop are described in detail both in contents and organization. Ill. 6, bibl. 9, tabl. 4 (in English; abstracts in English and Lithuanian).

A. Vazquez Alejos, V. Santalla del Rio, M. Vera Isasa, E. de Lorenzo, I. Cuinas, M. Garcia Sanchez. ENXENO seminaro metu LEGO© robotų taikymas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2012. – Nr. 2(118). – P. 103–108.

Taikyti įvairias žinių gavimo technologijas yra neabejotinai svarbu. Studentai pirmame ir antrame kursuose turi įgyti reikiamų technologijų kompetencijų. Aukštesniuose kursuose jie gali taikyti įgytas žinias ir įgūdžius. Pateikiamas seminaro, pavadinto ENXENO, pavyzdys, kuris buvo sudarytas Vigo universitete ir skirtas studentams iš gretimų regionų. Siūloma metodika remiasi žaidimo principu. Gauta teigiamų seminaro dalyvių atsiliepimų. Il. 6, bibl. 9, lent. 4 (anglų kalba; santraukos anglų ir lietuvių k.).