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Exchanging Challenge Based Learning Experiences in the Context of RoboSTEAM Erasmus+ Project

Miguel Á. Conde[1](✉), Francisco Jesús Rodríguez-Sedano[2], Camino Fernández-Llamas[1], Manuel Jesus[3], María-João Ramos[4], Susana Celis-Tena[5], José Gonçalves[6], Ilkka Jormanainen[7], and Francisco J. García-Peñalvo[8]

[1] Department of Mechanics, Computer Science and Aerospace Engineering, Robotics Group, University of León, Campus de Vegazana S/N, 24071 León, Spain
{mcong, cferll}@unileon.es
[2] Department of Electric, Systems and Automatics Engineering, Robotics Group, Universidad de León, Campus de Vegazana S/N, 24071 León, Spain
francisco.sedano@unileon.es
[3] Departamento de Tecnologias, Colégio Internato dos Carvalhos, Rua do Moeiro s/n, 4415-284 Carvalhos, Portugal
manuel.jesus@cic.pts
[4] Department of Languages, Agrupamento de Escolas Emídio Garcia, Rua Eng. Adelino Amaro da Costa, 5300-146 Bragança, Portugal
f33laepq@gmail.com
[5] IES Eras de Renueva, Comandante Cortizo S/N, 24008 León, Spain
susanact@ieserasderenueva.org
[6] Department of Electrical Engineering, Instituto Politécnico Bragança, Campus de Santa Apolonia, 5301-253 Bragança, Portugal
goncalves@ipb.pt
[7] School of Computing/Joensuu Campus, University of Eastern Finland, Länsikatu 15, Joensuu 80101, Finland
ilkka.jormanainen@uef.fi
[8] GRIAL Research Group, Computer Science Department, Research Institute for Educational Sciences, University of Salamanca, 37008 Salamanca, Spain
fgarcia@usal.es

Abstract. In the context of the digital society, educational systems should prepare the students to succeed in a really volatile environment. In order to do so they require to acquire some specific competences that use to be related to STEAM Education. However, integrating STEAM is hard and requires of new methodologies and tools. RoboSTEAM is an Erasmus+ project that aims to facilitate this by using Challenge Based Learning and applying Physical Devices and Robotics. In order to know if what RoboSTEAM proposes work properly it must be tested in different contexts with different educational systems. The results of these tests should be compared, which requires of a common knowledge background. In order to achieve it RoboSTEAM proposes students and teachers exchanges between similar and different sociocultural environments, so they can learn how other people work in the project challenges and if what they do can be addressed by them in a similar way. The present work describes these exchanges, how they were planned and carried out and the main results obtained. From the exchanges carried out until now it is possible to say that they facilitate sharing knowledge that later can lead to better results in the project challenges and that they are enriching experiences both for students and for teachers.

Keywords: STEAM · Exchange · Competence · Challenge Based Learning · Robotics · Physical Devices

1 Introduction

Educational systems should adapt themselves to their ecosystem. Nowadays we are involved in what is known as digital society. A changing context that requires of flexible and well-prepared professionals, that know the tools and methodologies to succeed in so heterogeneous landscape. In order to do this the students need to develop what are known as 21st century competences such as: computational thinking, problem solving, teamwork, critical thinking. These competences are linked to what is known as STEAM Education [1].

STEAM (Science, Technology, Engineering. Arts & Mathematics) Education is critical to improve countries innovation capacity and students employability [2, 3]. Given this fact it must be integrated in current educational systems. However, this is not an easy task, because STEAM Education is not only a set of subjects, they should be integrated along educational institutions curricula by applying new methodological approaches [4, 5]. A sample of these approaches can be active methodologies such as Problem based Learning (PBL) [6], Project based Learning (PrBL) [7] or in the last years Challenge Based Learning (CBL) [8].

RoboSTEAM project is a proposal granted by Erasmus+ Strategic Partnership call in 2018. It aims to experiment with STEAM integration projects that help learners to develop 21st century skills by using a Challenge Based Learning methodology and applying Robotics and Mechatronics. In order to do so the project proposes the exchange in the European Context of experiences related to this topic [9, 10].

The project is coordinated by the University of León and beyond this institutions it includes in the partnership another 4 universities (Instituto Politécnico de Bragança - IPB, Karlsruher Institut Fuer Technologie - KIT, University of Eastern Findland - UEF and University of Salamanca - USAL) and 4 schools (Colégio Internato dos Carvalhos - CIC, Agrupamento de Escolas Emídio Garcia - AEEG, IES Eras de Renueva - IER and the Secondary School of the University of Eastern Finland UEF-SS). As associate partners are also involved an additional school (Karl Benz School) and a company (Arduino). This means that institutions of five different countries and different socioeconomic contexts will collaborate in the project.

RoboSTEAM project is described as a set of activities, outcomes, multiplier events and learning teaching and training actions, following the schema defined by the Erasmus+ call. The activities are related to project progress including tasks such as management, quality assurance, dissemination and two pilot phases employed to test the results of the project. The outcomes of the project define a set of challenges and tools to address them, and a digital environment to facilitate accessing to all those materials and managing the experiences and knowledge exchanges. The multiplier events are devoted to disseminate the project results and the project has scheduled one of them in each of the partners countries. Last but not least, RoboSTEAM teaching and training actions that facilitates knowledge exchange. The project includes one staff training exchange for teachers and four students exchanges.

This paper is focused on the latter of the exchanges, that is the students exchange. Why are they necessary? As we commented above, during the project students from the partnership schools will be addressing challenges, following a CBL approach and applying Robotics and Mechatronics kits. To do so they will define their own challenges and described the kits to address them. As part of the pilot phase 2 the schools will exchange challenges between them and will address such challenges with their own kits. These exchanges can be between similar or different sociocultural contexts, so for the project is interesting carrying out students exchanges in order to compare how they work and share good practices and knowledge when addressing the challenges. This work describes the students' exchanges and their results.

The rest of the paper is structured as follows. Section 2 describes the students exchanges planned in the proposal and the way in which they are evaluated. Section 3 details two exchanges already carried out. Section 4 presents and discusses the results of such exchanges and finally in Sect. 5 some conclusions are posed.

2 The Students' Exchanges

As commented above, students' exchanges are carried out during the project piloting in order to facilitate sharing knowledge and good practices about specific challenges or kits. The first pilot phase requires that students develop their own challenges with their kits, but for the second phase challenges are exchanged between schools. It is desirable to have knowledge about how students from a different socioeconomic context can deal with them, so during the first pilot phase students travel to other institutions in order to know how students from a different country work in the project. In this section the challenge schedule and the assessment methodology are described.

2.1 Description

The exchanges included in RoboSTEAM have a duration of 5 days each, including travelling time. They involve students and teachers from the partnership schools although the people travelling from each institution is not the same in all the exchanges.

The exchanges proposed are (we use the same actions ids employed in the proposal for the exchanges):

- C2. First exchange between Portuguese and Spanish school students. It aims that students from two similar sociocultural contexts can see how the others work. It is a short-term exchange of groups of pupils. It involves 5 students from AEEG and 5 from CIC and 2 teachers per institution. The hosting institution is IER and the exchange was developed in October 2019. During this action Portuguese students participated in challenges of the Spanish institution, so they saw how the latter address the challenges and the type of PD&R solutions they used.

- C3. Second exchange between Spanish and Portuguese school students. It is similar to C2 but in this case 5 Spanish students and 2 teachers from IER travelled to Bragança. The hosting institution was AEEG and the exchange was carried out in November 2019. In this case the Spanish students participated in Portuguese challenges.
- C4. Exchange between Finnish and Spanish students. In this case 5 Finnish students and 2 teachers travelled to Spain in order to know how students from a different sociocultural contexts addressed the challenges. The hosting institution was IER and the action was developed in February 2020.
- C5. Exchange between Finnish and Portuguese students. Similar to C4 but in this case Finnish students travelled to Portugal and the hosting institution was AEEG. It was carried out in February 2020.
- C6. Exchange between Spanish, Portuguese and Finnish students. This exchange involves 5 students from IER, 5 from CIC and 5 from IER. The hosting institution is UEF and the exchange will be developed in March 2020. During this action Spanish and Portuguese students will participate in challenges of the Finish institution.

A schema of the exchanges can be seen in Fig. 1. It is necessary to point out that C4 and C5 were carried out in the same week with different students and teachers and that C6 has not yet developed when writing this work.

2.2 Working and Assessment Methodology

To better understand how the exchanges were carried it is necessary first briefly describe CBL.

CBL is a flexible methodology that encourages students to leverage the technology they use in their daily lives to solve real-world problems [11]. CBL is a collaborative methodology. It is going to involve the students' groups, but also other peers, teachers, experts, parents, etc. in order to solve a real problem. A CBL approach requires to propone to the students a big idea, this idea will be discussed in order to find some main questions. The students analyze the questions and define a challenge. The challenge is addressed by the students in a collaborative way and involving people from their educational contexts and from the outside [8].

The main problem we found out regarding the methodology is the time each institution can devote to a challenge. Some of them can employ the whole term while others only a concrete number of hours and always orienting the challenges to fulfil their learning pathways. Given this context it was necessary to look for a challenge description that fits with all the involved partners requirements, so the challenge granularity was explored. In [12] we described how this issue is addressed during the project, that basically consist of the definition of challenges, mini-challenges and nano-challenges. This was based in Nichols, Caters and Torres work [13], that understands the challenge as the higher granularity level element, composed by mini-challenges with a lower level of granularity, up to the nano-challenge that is the lowest one. Thus, nano-challenges have a higher level of detail and requires less hours to be addressed.

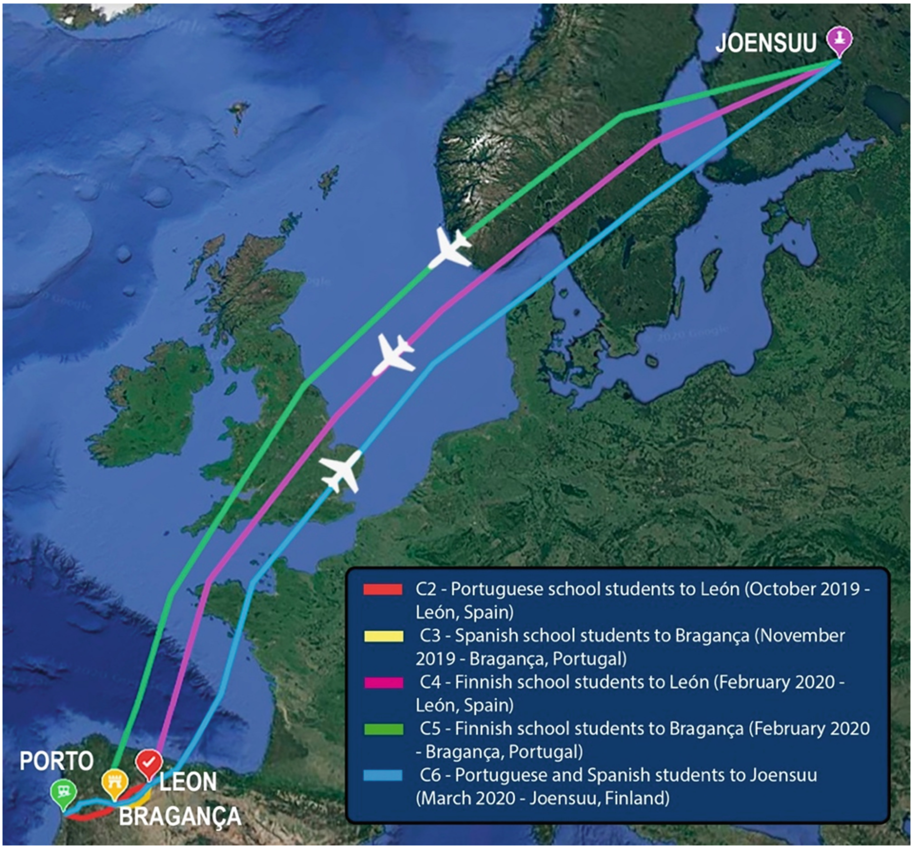

Fig. 1. Schema of the different exchanges carried out in RoboSTEAM project.

As the exchanges last only 5 days and they include also travel time, the decision was that the students that travel address a nano-challenge proposed by the hosting institution with the hosting institution kits. In addition, in order to share knowledge and to foster the interaction between the students, the teams includes members from both the hosting and the visiting institution.

For the evaluation of the exchanges we have applied a mixed methodology [14] taking into account quantitative and qualitative information.

As quantitative indicators we have:

- The grade for the outcome. After addressing a nano-challenges each team should present their results which will be graded by the teachers.
- In addition, we have used a co-measure rubric. “Co-Measure is a rubric focused on evaluating student collaborative problem solving when participating in STEAM activities, tasks, or units of study” [15]. We use this rubric during the pilots to measure the collaboration of students when addressing the challenges. However, in this case they are working together just a few days, so instead of rating each of the group members they have rated themselves as kind of peer review assessment.

- Time devoted to the challenges. That is how many hours the students have employed to address the challenges. Although we have measure it, this indicator is not so interesting in the exchanges, because it depends not only in the difficulty of the challenge but in the number of working days and working hours that the students employ, which is constrained by the duration and agenda of the exchange.
- Number of persons involved in the challenge. Both team members and external people that participate solving the work.

As qualitative indicators we have:

- Students perception about the exchanges. Gathered through the open questions of an anonymous questionnaire. The students describe their opinion about the exchange and the collaboration with students from other countries to solve the challenges.
- Teachers perception about the exchanges. The teachers were asked in semi-structured interviews about their perception regarding challenges. This information is analyzed to know the positive issues and the drawbacks of the activities and how they can be improved in the future.

In next sections two exchanges and the results about teachers perception are presented.

3 C2 and C3 Exchanges

In this section we described some details of the exchanges specially the persons involved and the challenge addressed.

3.1 C2. First Exchange Between Portuguese and Spanish School Students

This challenge took place from the 21th to the 25th of October of 2019. On it the educational institutions that participate were CIC with 2 teachers and 6 students, AEEG with 2 teachers and 5 students and IER, as the hosting institution, with 13 students and 2 teachers (although the initial proposal includes fewer visiting students the CIC involved more with their own funds).

The visit included working activities and also social and cultural activities to foster students' interaction. We focused our research in the former. In this case the students deal with a mini-challenge divide in several nano-challenges. Teams of four students were defined by the teachers. The teams mixed students from the different schools. It should be noted that although CIC and IER students had a technological background AEEG students come from the arts field which enriches students work.

The mini-challenge selected for the exchange consisted of improving school festival and it was especially focused on guiding students to the auditorium. Table 1. Summarizes the challenge. It was split in several nano-challenges with the same difficulty level as the described in Table 2. In order to address the nano-challenges students should use a kit, in this case Arduino: ELEGOO UNO Project Basic Starter Kit with Tutorial and UNO R3 Board Compatible with Arduino IDE for Beginner [16]. The results of these challenges are shown in Fig. 2.

Table 1. Mini - challenge description for C2

Title	Illuminated sign
Description	
The school festival will be held in the auditorium. Students' relatives and friends will be welcome to the event. We want to signal how to get to the auditorium from the main entrance. To do this you will have to design the light signaling Design a program to get 8 different color LEDs to turn on and turn off in a simple sequence. Insert them in a board to get the route correctly marked It is required to use a simulator program before making the model	
Goal/S	
General Objectives • Know the basics of computational thinking and acquire the skills to use it when solving simple problems • Understand and practice basic programming concepts acquiring the ability to create simple programs using them • Address diversity in the classroom: use methodologies and resources that have been specifically selected for STEAM teaching with students with different cultural, academic and competence levels • Identify and use relevant everyday real-life contexts and scientist reasoning to promote the essential values of our society • Foster inclusive education and intercultural learning through the use of STEAM contexts **Specific Objectives** • Know how a LED diode works • Calculate the current limiting resistors you should place in a circuit with LED diodes • Send different values to an Arduino digital pin • Work with loops to send different values with different delays	
Evaluation	
An active methodology, based on learning making, will be used. Special emphasis is placed on the social and connected nature of learning when designing the activities, by encouraging communication among participants Teachers will act as facilitators, monitoring the activities and providing the necessary support for a fruitful experience. Teachers will be also in charge of proposing the challenges students will rise to and provide them with web sources where to obtain the necessary information to carry out these challenges In addition, every participant will be able to help and collaborate with other participants to solve difficulties and challenges that could arise Every participating group of students will generate a solution to solve the challenge The realization of the activity plan will contribute to the development and improvement of digital competence, particularly in the Digital contents generation and Solving problems areas	

Fig. 2. Results of C2 exchange.

Table 2. C2 nano-challenge sample

Title	Make an LED turn on and off
What is an LED?	
What type of component is an LED? How is it connected? What resistor is required?	
Description	
• Research into the necessary components for the circuit to work correctly • Calculate the resistor needed to prevent LED from blowing • Create a program to turn on an LED • Simulate the circuit using, for example, Tinkercad and send different values to an Arduino digital pin • Connect the components to the breadboard • Power on the Arduino board by connecting it to a computer using an USB cable • Check that the real circuit works	
Goal/s	
Know how to connect an LED to turn it on and off	
Kits to use	
Simulator program, Arduino Uno or similar Arduino board, a breadboard (preferably with a positive and negative rail), an LED, a resistor, jumper wires, USB cable, a computer, IDE Arduino	
Evaluation	
The students should connect correctly all the components and calculate the value for the resistor	

3.2 C3. Second Exchange Between Portuguese and Spanish School Students

This exchange was carried out during from the 18th to the 22nd of November 2019. The institutions involved were IER and AEEG as the hosting institution. 8 students per institution take part in the experience (IER funded 3 more visiting students than the described on the proposal). The challenge was carried out by Art students (Portuguese) and the Spanish ones with an educational background related to technologies. There were four groups of four students in each. All groups were made up of Portuguese and Spanish students; all of them with mixed abilities concerning STEAM related competences. Therefore, the groups were heterogeneous.

As in previous exchange there was a cultural agenda and a working plan. Regarding the latter we have again a mini-challenge (Table 3) and some nano-challenges (Table 4).

In this case students programmed mBots [17] to follow straight lines with some turnings by the use of infrared sensors. The students created a fire detector which emits a sound whenever detects heat. Afterwards, students programmed ultrasonic sensors to create alternative ways so that mBots could avoid obstacles. All students achieved a good level at this skill. Results are shown in Fig. 3.

4 Results and Discussion

Regarding the results, the presentation of all the indicators gathered have not sense specially when not all the exchanges have finished, so we show the qualitative analysis of teachers' perspectives about each of the challenges and the time that students devoted to complete the nano-challenges.

Regarding C2, we should point out that students have devoted 7,5 h per day to work, which means 35 h during the exchange. They were distributed between: challenges work, visits to different ICT companies and cultural acts. In this first exchange students have worked a total of 15 h. That is around a 42% of the time.

In this exchange have participated 6 teachers, 4 from Portugal and 2 of the hosting institutions. We have asked them about the experience and the positive and negatives issues that they found. Their answers have been explored qualitatively. In order to do this, we grouped teachers' answers following a proximity criterion to the positive of the exchanges, the drawbacks found and other relevant issues. The results are combined and shown in a matrix (Table 5) as suggested by authors such as [18].

From the table it is possible to see that most of the upsides are referred to collaboration, interaction and knowledge exchange, which was very profitable both for visiting and hosting teachers and students. The main drawbacks were related to the fact that this was the first RoboSTEAM exchange, which requires to adapt some of the initially planned strategies, only half of the teachers described drawbacks. In addition, the teachers pointed out that cultural activities were very positive to break the ice between students and visits to know some of the hosting country ICT companies.

Fig. 3. Results of Exchange C3.

Table 3. Mini – challenge description for C3

Title	Use mobile robots to detect and avoid the cause(s) of wildfires and reduce the impact of global warming on this issue
Description	
Can mobile robots prevent fire(s)? (acts of arson, lack of cleanliness, global warming – drought and severe heat- etc.) Human activities such as lighting campfires, discarding lit cigarettes, acts of arson, bushfires etc. are mainly responsible for starting a fire. However, hotter weather makes forests drier and more prone to burn Rising temperatures, a key indicator of climate change, evaporate more moisture from the ground, drying out the soil and making vegetation more flammable. Think about how to employ mobile robots to reduce the impact of global warming on environment and avoid other causes of wildfires	
Goal/s	
• Study mobile robots • Develop computational thinking • Study possible ways to apply mobile robots to improve environment • Develop soft skills • Implement collaborative solution/strategy that involves students, parents, teachers and experts in this field • Design and explore the scenarios where mobile robots can be applied • Develop creativity	
Evaluation	
• Time employed to solve the challenge (stds will fill in a grid) • Degree of success producing a solution (stds will fill in a self and hetero evaluation report) • Number of people involved in the challenge (information sheet including age, role/status and Education level) • Perception about STEAM (stds will be asked to talk about their experience throughout the whole process of this challenge – they can make a video, around two minutes) • Assessment of STEM skills and CT skills before and after the challenge (online questionnaires)	

Table 4. C3. Nano – challenge sample

Title	Follow lines with a mobile robot to patrol the forest
Specific Issue to deal with	
Use or built a robot that was able to follow a line	
Description	
Human activities in the countryside namely forests have a great impact on the environment A possible solution to address this issue can be the use of mobile robots We want to find out how to use a robot to follow a line in order to patrol the forest	
Goal/s	
• Study navigation issues in mobile robots • Study possible ways to make a mobile robot follow a line • Explore scenarios where mobile robots can be applied • Implement collaborative solution/strategy that involves students, parents, teachers and experts in this field • Develop soft skills • Develop CT skills and Enhance creativity	
Kits to use	
mBot, a STEAM educational robot for beginners	
Evaluation	
Checking if the mobile robots are following properly the line and number of possible errors. Assessing students' collaboration and the acquisition of knowledge about mobile robots	

C3 followed the same schema defined in C2. Students worked 7,5 h per day (for a total of 35 h during the exchange), from them 16,5 were applied to address the challenges, which means a 47% of the total working time. As in C2 rest of the time was divided in visits and cultural activities. In this case 5 teachers were involved, 3 from the hosting institution and 2 from IER. Table 6 shows their opinions by the topics also explored in C2.

In this case the upsides were similar to C2, teachers pointed out issues such as collaboration and knowledge exchange. They are especially happy with the fact that their students, with a background of arts, could complete challenges that are more related to use of robots and programming, thanks to the collaboration with the visiting students. Regarding drawbacks in this case the problem is that the school has not previous experience with Erasmus+ projects so the exchange required new dynamics that are not always easy to implement. In addition, during the exchange students from the hosting institution had exams so their participation in solving the nano-challenges was not easy. Some teachers point out that the experience carried out C2 helped them to develop this exchange.

Table 5. Matrix with teachers' opinions about C2 upsides, drawbacks and other issues.

	Positive issues	Drawbacks	Other
T1	Very good collaboration and interaction. Really enriching experience	Improve resources and planning	Visits were very interesting
T2	Quality of results and Collaboration	Clarify the process	Visits
T3	The was very enriching and profitable	–	Cultural activities
T4	Knowledge Exchange and the quality of products	–	–
T5	Getting to know the methodology and educational context of a foreign school. Materials and human resources	Language barriers in some cases	–
T6	Know a different educational system and the performance of my students there	–	–

Table 6. Matrix with teachers' opinions about C3 upsides, drawbacks and other issues.

	Positive issues	Drawbacks	Other
T1	Very interesting challenges and very good collaboration	–	Excellent facilities for the challenges and good visits
T2	Knowledge Exchange, lessons learned	It is necessary to motivate students to work together	Previous work done to complete the challenges
T3	The chance to share knowledge and educational ideas was enriching	Different dynamic	–
T4	Students and teachers can learn from the exchange experience and broaden their mindset	Logistic constraints	–
T5	The intercultural exchange among students and teachers	Few students for artwork	–

5 Conclusions

The present work has described a key element in RoboSTEAM project, the students and teachers exchange. These activities facilitate sharing knowledge with peers from other countries or even from different socioeconomical contexts. This means with people that have different educational systems, customs, languages, etc. Why is this so relevant for RoboSTEAM? Because one the main aims of the project is the application of CBL in STEAM Education by using Robotics and Mechatronics, but it is not enough to test this in one country, we should check how it works and how to adapt it in different environments. That is why two different pilot phases are carried out, with the idea of checking it what is used in a context is also applicable in a different one. In order to do so it is necessary to build a common knowledge base to address challenges and the exchanges make this possible.

RoboSTEAM exchanges plan has included institutions with similar and different sociocultural context and with similar and different educational background, so a wide choice of possibilities is being considered.

From the exchanges that have already taken place the perception both of students and teachers were really positive and has help addressing the challenges from a different perspective. This can be seen as a success but it is necessary to evaluate it once all the exchanges and pilots phases have finished.

In order to conclude the work it is important to say that exchanges are really helpful to know how other students live and work, so it is a desirable activity even beyond the Erasmus+ initiatives.

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